EVALUATION OF RECLAMATION PRACTICES ON UPLAND AND PEATLAND WELLSITES

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EXECUTIVE SUMMARY

In general, regulators expect that disturbed sites in the boreal forest will undergo complete reclamation (recontouring, soil replacement and revegetation) with the goal of returning the site to pre-disturbance condition and land use (equivalent land capability). Legislation and policies provide opportunities to vary from these expectations with written approval from a specified decision maker (Director, Regulator, or Land Manager). Alberta’s Wetland Policy requires replacement of wetlands lost due to industrial development, but recognizes that the relative value of a wetland (used to calculate replacement ratios) is based, in part, on the relative abundance of wetlands in the region. In areas of high abundance (such as northeast Alberta) and low historical loss, the concept of *relative abundance* will facilitate a considered approach to wetland management, balancing environmental, social, and economic priorities in the execution of management decisions.

The two specific instances of relevance to this project where a regulatory decision is needed are: (1) a request for a variance based on a site having natural vegetation encroachment rather than complete reclamation; and, (2) a request to leave well pads in peatlands in place.

The following key observations were made from this phase of the project:

- It is clear in the wellsite criteria and SED 002 that the Land Manager (AEP) must approve a change in land use from peatland to upland; it is less clear if the Land Manager or the AER must approve the variance for a vegetation override where a site has natural vegetation encroachment. Furthermore, when a pad in a peatland is partially removed it is unclear if a change in land use approval is required for the remaining upland portion (and if so, if there is a size of remaining upland below which an approval is not required). **Clarity of roles must be provided.**
- There is limited guidance on how decisions are being made to accept or reject requests for change in land use and variances. There are perceptions within the government/regulator and industry/consultant worlds about the “real” reason for applications and the willingness to make the decisions in a timely manner. **These perceptions must be addressed before meaningful change can occur.**
- There is limited scientific information available to support applications and decisions related to requests for variances and changes in land use. Some information is coming to light from various field-based research and demonstration trials but awareness of, access to, the information is not widespread. **A compilation of existing experience in an easily accessible and continuously updated location would be very helpful for practitioners and regulators.**
- Several interview respondents defaulted to the criteria when asked about reclamation expectations; however, **the issues at hand (request for variance and change in land use) are, by definition, exceptions to the criteria therefore a new way of thinking is required to address these requests**.
- During the reclamation certification process, professional justification is required for sites requiring a change in land use and/or a variance to criteria for one or more reclamation

deficiencies according to the applicable wellsite criteria. It is clear from the interviews that **there is a need for clear direction on what information is required to support professional justification** which describes why the specific deficiencies will not have long term adverse environmental impacts and/or ultimately influence equivalent land capability.

- **Clarity is required on the relative priority that should be placed on the core components of the reclamation criteria (soils, landscape and vegetation) when evaluating a request for a variance to the criteria** (i.e., what are the minimum parameters that must be met). There was considerable variability in the interview responses regarding which parameters were most important, especially when it came to vegetation; the variability appeared to be correlated to the specific area of expertise and interest of the respondent.
- **Clarity is required on the application of the Wetland Policy to requests for a change in land use, as well as the extent to which local and regional implications of site-specific land use changes will be considered**.
- The concept of net environmental benefit (environmental and economic) arising from regulatory decisions was often raised in the context of removing pads in peatlands. **Clear guidance on the environmental and economic factors to be considered when making the decision to grant or refuse a request for change in land use is required.**
- **Care is required in discussing policy and practice approaches using generic terms like *peatland*** – there is information to suggest that different peatland types may respond to reclamation differently. More research, and documentation of existing practices and results, is required to ensure the appropriate policies and practices are developed.
- Similarly, while some general policy guidance may be provided, **site-specific factors (e.g., caribou habitat, location, access, etc.) will still need to be incorporated into final decisions to grant a variance or request for change in land use**.
- **One or more decision support tools are required to guide practitioners and regulators through the application, review and decision process**; these tools should be designed to remove subjectivity from the decision process.
- This document has focused primarily on well pads; however, access roads, particularly in peatland sites, will also face similar concerns and be subject to request for variances and/or changes in land use. **Once a final set of recommendations is made for well pads the rules for access roads can be addressed.**

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LIST OF ACRONYMS

AEP	Alberta Environment and Parks
AER	Alberta Energy Regulator
ASRD	Alberta Sustainable Resource Development

ATV	All-terrain Vehicle
AUPRF	Alberta Upstream Petroleum Research Fund
C&R	Conservation and Reclamation
CNT	Consultative Notation
CRBP	Conservation and Reclamation Business Plan
CRR	*Conservation and Reclamation Regulation*
DBH	Diameter at Breast Height
DOC	Dissolved Organic Carbon
DSA	Detailed Site Assessment
EFR	Environmental Field Report
ELC	Equivalent Land Capability
EPEA	*Environmental Protection and Enhancement Act*
ERA	(University of Alberta) Education and Research Archives
FMA	Forest Management Agreement
GHG	Greenhouse Gases
iFROG	Industrial Footprint Reduction Options Group
LARP	Lower Athabasca Regional Plan
LAT	Landscape Analysis Tool
LFH	Litter, Fibric, Humic
NAIT CBR	Northern Alberta Institute of Technology Centre for Boreal Research
NPP	Net Primary Productivity
PDA	Pre-disturbance Assessment
PLCRCP	Project-Level Conservation, Reclamation, and Closure Plan
PNT	Protective Notation
PTAC	Petroleum Technology Alliance Canada
OSE	Oil Sands Exploration (operation)
RCAG	Reclamation Criteria Advisory Group
SAR	Sodium Adsorption Ratio
SED	Specified Enactment Direction
UTV	Utility Vehicle

Evaluation of Reclamation Practices on Upland and Peatland Sites

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1.0 INTRODUCTION

1.1 BACKGROUND

In 2018, the Petroleum Technology Alliance Canada (PTAC)[1] put out a request for proposals entitled *Reclamation Practices on Upland and Peatland Well Sites* (PTAC AUPRF RRRC 1801). The project was established in response to challenges experienced by practitioners, regulators and industry stakeholders related to reclamation certification of legacy sites. In the context of this project, the term **site**[2] is defined as an upstream oil and gas wellsite and the associated facilities requiring reclamation to meet Alberta's reclamation criteria for peatland and/or forested sites, and a **legacy site** is defined as sites constructed and abandoned and/or reclaimed prior to establishment of the current relevant upland reclamation criteria. The specific sites in question are legacy sites that were constructed using imported mineral soil pads in peatlands, and upland sites that that have had natural vegetation encroachment. These sites present one or more reclamation deficiencies according to the applicable wellsite criteria, and cannot receive a reclamation certificate without additional scrutiny and justification under current regulatory criteria and policies.

When dealing with these sites, the question arises of whether to remove mineral soil pads in peatlands or whether to disturb existing vegetation to modify soil and landscape features to meet reclamation criteria. There has been inconsistency in how decisions about these sites are being made (i.e., different levels of reclamation effort have been applied) and in how reclamation criteria is interpreted and applied in terms of defining what are acceptable conditions for certification.

Historically, industry and regulators have agreed that in certain site-specific circumstances, forested sites that have natural vegetation encroachment can be certified without removing existing vegetation and re-starting the traditional reclamation process. Similarly, sites with mineral pads in peatlands have been certified without the removal of the pad or with partial removal of the pad. There has been a recognition that sites can be deemed to be on a trajectory towards developing a sustainable plant community from an ecological perspective (keeping in mind some grandfathering of what is acceptable with regards to

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[1] Acronyms used in this report are provided in the List of Acronyms at the front of the report.
[2] Definitions for terms used in this report are provided in section 1.4.

species such as seeded grasses), without further disturbance/reclamation. A consistent and standard method to define and address these circumstances has been difficult to discern within the current regulatory and policy framework.

The purpose of this project is to document the basis for current industry practices and regulatory decisions for legacy sites, assess measurement criteria for evaluating whether equivalent ecosystems have been established on naturally revegetated and padded peatland sites, and provide regulators, practitioners and industry stakeholders with management options supported by literature review, practitioner interviews, and case studies. Subsequently, recommendations for an acceptable policy framework/decision support tool to assist in making decisions around appropriate management and certification of these sites will be developed. The goal is to ensure that functioning ecosystems are developed with an appropriate level of activity, and that there is a process that outlines eligibility for reclamation certification.

InnoTech Alberta, NAIT and Vertex will be carrying out the project in three stages from 2018 to 2020. The first stage of the project, which is summarized in this document, focused on desktop review (current guidelines and literature), assembly of case studies and an outreach program to identify the site characteristics (i.e., site categories or classes) that have led industry and regulators to agree that no or minimal further disturbance was required. To establish case studies and document practitioners' perspectives, select representatives identified by project champions were interviewed. Stage 2 will include field visits to select sites with relevant stakeholders, and Stage 3 will provide recommendations and conclusions based on learnings from previous stages.

1.2 SCOPE AND OBJECTIVES

1.2.1 *Scope*

As previously stated, in the context of this project, the term 'site' is defined as a legacy[3] upstream oil and gas wellsite and the associated facilities requiring reclamation per Alberta's reclamation criteria for peatlands and/or forested lands. Sites included in this project are restricted to those on public land at which the well has been properly and fully abandoned, and where contamination is absent or has been remediated.

The discussion, analysis and conclusions drawn by this report and the recommendations provided apply only to the legacy sites that have been defined. This document is not intended to inform reclamation

[3] In the context of this project, "legacy" refers to sites constructed and abandoned and/or reclaimed prior to establishment of the current relevant reclamation criteria.

practices on newer sites, although it will consider newer reclamation practices in the discussion of leaving certain parameters in place that do not meet specific guidelines. This document is not intended to eliminate the need for reclamation for newer sites. This document is also not intended to prescribe reclamation practices for legacy sites, it will still be up to the individual's, company's and regulator's professional judgement what should be done at a particular site.

1.2.2 *Objectives*

The goal of the project is to ensure that legacy sites that developed functioning ecosystems can proceed through the reclamation certification process with an appropriate level of reclamation activity. The specific objectives of the project are as follows:

- Evaluate the benefits and drawbacks of removing mineral soil pads in peatlands and disturbing established upland vegetation to modify soil and landscape features required to meet reclamation criteria.
- Identify and validate considerations required to make the decision that no further disturbance on legacy sites is required.
- Provide regulators, practitioners and industry stakeholders with support tools to assist in making decisions around the appropriate level of reclamation to achieve certification on legacy sites.

1.3 METHODOLOGY

For this review, relevant regulatory and policy documents were reviewed and summarized to provide context for the project. Detailed searches through multiple resources including conference proceedings; electronic journals; industry, government and public reports; and, the Internet were completed to find literature related ecological function on reclaimed upland forested and peatland wellsites. A significant body of knowledge exists regarding ecological function and reclamation of upland and peatlands [to a lesser extent] therefore emphasis was placed on the collection of recent literature from peer-reviewed journal articles and industry publications where the research/case studies were conducted in forests and peatlands of western Canada and from disturbances other than conventional oil and gas to leverage learnings from other industries. Searches on the Internet included the use of general search terms encompassing Boolean and iterative search strategies to capture a broad swath of literature. Once collected, resources and abstracts were reviewed to determine whether documents met the inclusion criteria.

Inclusion criteria: Due to the range of topics considered within this report, no specific key words were required as inclusion criteria. Documents discussing topics including, but not limited to, wellsite reclamation, forest reclamation, forest ecology, boreal ecosystems, natural regeneration, forestry practices, noxious weeds, peatland initiation and succession, wetland classification, disturbance ecology, bryophyte biology were included within the review.

Exclusion criteria: Documents that were not in English; patents and conference abstracts were excluded from all searches. No documents were excluded based on the date of publication; however, where literature was abundant, an emphasis was placed on the collection of literature from the most recent years (2015 to 2019).

The Internet and the Google scholar search engine were used to conduct general searches of peer-reviewed publications, reports, and industry-related publications. More specific searches were conducted using the University of Alberta's Education and Research Archives (ERA).

A list of interview questions was developed and circulated amongst the project team, industry champions, Alberta Energy Regulator and Alberta Environment and Parks for comments and suggestions (Appendix A). A project statement which articulated the scope and objective for the project was included with the interview questions to provide context for respondents (Appendix A). A list of potential interviewees was developed by the project team and industry champions and expanded through initial consultations. Initially, interview questions were emailed to all potential participants, who were then given the option to either provide feedback in writing or to schedule a one hour phone interview. The majority of respondents (80%) selected the phone interview option, which allowed for additional follow-up questions and for additional context and clarity to be provided when requested. Feedback from individuals was recorded and compiled into a single document and responses for individual questions were then categorized based on common themes (Appendix A). A summary of the interview responses is provided in Appendix A and individual comments are used to support technical statements in the body of the report. Interviewees were asked to provide case studies applicable to the project which were integrated into a database detailing site specific information regarding site history, characteristics, and certification status. Case studies will be used in subsequent project stages.

1.4 DEFINITIONS

Borrow Site (Pit)
An excavation created to provide construction material for well pads, access roads and other infrastructure.

Change in Land Use
For the purposes of this report it is a change from a peatland site (peatland criteria apply) to an upland site (forested land criteria apply).

Ecosite

Ecological units that develop under similar environmental influences (climate, moisture and nutrient regime). […] It is not tied to specific landforms or plant communities […], but is based on the combined interaction of biophysical factors that dictate the availability of moisture and nutrients for plant growth. Thus, ecosites are different in their moisture regime and/or nutrient regime (Beckingham and Archibald, 1996).

Forested Land Criteria

The *2010 Reclamation Criteria for Wellsites and Associated Facilities for Forested Lands (Updated July 2013)* (Alberta Environment and Sustainable Resource Development, 2013a).

Land Manager

The Forest Officer, Lands Officer, Land Management Specialist, and/or Lands Approval Team Lead in Alberta Environment and Parks for a specific Region. For Provincial Parks and Protected Areas, it is an Alberta Environment and Parks staff member from the Parks Division.

Legacy Site

Refers to sites constructed and abandoned and/or reclaimed prior to establishment of the current relevant upland reclamation criteria.

Site with Natural Vegetation Encroachment

Legacy site where vegetation naturally established (i.e., no tree planting occurred though some may have been seeded to grass mixes). The site may have had some landscape and soils replacement work done, but often have had no traditional reclamation work done.

Mineral Soil Pad in Place

A well pad or access road that is constructed in a peatland, consisting of mineral soils, usually clay-based, that is left in place after decommissioning of the well rather than being removed. Geotextile or corduroy (logs) are typically placed on the surface of the wetland prior to the addition of the mineral soil fill; these are also left in place below the fill.

Mineral Soil Pad Removal (Full)

Excavation and removal of a well pad constructed in a peatland.

Mineral Soil Pad Removal (Partial)

Excavation and removal of a portion of a well pad constructed in a peatland. The portion removed may be vertical (e.g., shave a layer off the top of the pad, usually to get the surface at or below the surrounding water level), or it may be horizontal (e.g., the overall pad size is reduced by excavating a portion, usually from the edge).

Peatland Criteria

The *Reclamation Criteria for Wellsites and Associated Facilities for Peatlands* (Alberta Environment and Parks, 2017).

Peatland Site

A site located in a peatland. A peatland is defined as lands covered by peat to a minimal depth of 40 cm, as in the *Reclamation Criteria for Wellsites and Associated Facilities for Peatlands* (Alberta Environment and Parks, 2017).

Reclamation (Modified)

Any reduction in all or part of the reclamation steps required to meet the forested land or peatland criteria without applying for a variance to criteria or a change in land use. In the case of upland sites modified reclamation is practiced due to the presence of naturally encroached vegetation. In the case of pads in peatlands, modified reclamation is practiced (de-compaction, partial re-contouring, etc.) due to a decision to leave all or part of the pad in place.

Reclamation (Traditional)

The recontouring of a wellsite to meet the Landscape Criteria, the replacement of salvaged soils to meet the Soil Criteria and the revegetation of the site to meet the Vegetation Criteria, predominantly in reference to upland sites.

Site

An upstream oil and gas wellsite and the associated facilities requiring reclamation to meet Alberta's reclamation criteria for peatland and/or forested sites.

Upland Forested Site

Any treed land, whether or not the forest vegetation is utilized for commercial purposes.

Topsoil

In the context of forests, the topsoil includes all of the organic horizons (L, F, H and O) *and* the Ae, Ahe or Ah horizons, as defined in the *Canadian System of Soil Classification – Third Edition* (Soil Classification Working Group, 1998). On reclaimed sites, the topsoil is the replaced surface soil layer created by the mixture of these horizons during salvage, stockpiling and replacement. Topsoil is not limited to solely the organic L, F, H and O horizons.

Variance to Criteria

A request to change the criteria or the assessment process described in the relevant wellsite criteria document.

Vegetation Override

A specific type of variance to the wellsite certification criteria, where reasonable forest cover (i.e., amount, species and distribution) is present, and where additional activities required to meet the conditions described in the criteria pose a risk to existing ecosystem function.

Well Pad

The surface area upon which the well and associated facilities are located. The well pad is generally constructed by removing upper soil materials to expose a level mineral soil surface and/or by importing fill to create a level surface. NOTE: this report focuses on the reclamation requirements for well pads, but similar issues arise for the access roads to these well pads. Rather than repeat the phrase "well pad and access road" throughout the document we have used well pad unless there are specific issues related to access roads.

1.5 STRUCTURE OF THIS REPORT

Section 2 of the report provides a review of the relevant legislation and policies related to the project. Section 3 summarizes the key factors that control functional ecosystems and the components used to evaluate functionality. Section 4 provides detailed discussions about sites with natural vegetation encroachment, including key challenges, common site conditions, traditional reclamation approaches, processes and factors affecting the decision to apply for and grant a variance, justification rationale for a variance and reclamation options for sites granted a variance. Section 5 provides detailed discussions about sites with mineral soil pads in peatlands, including key challenges, reclamation approaches, processes and factors affecting the decision to apply for and grant approval to leave a mineral soil pad in place and to obtain a change in land use, justification rationale leaving a pad in place and for a change in land use, and reclamation options for sites where the pad is fully or partially removed. Section 6 lists current knowledge gaps and recommendations.

Section 7 provides the references cited in the report. Appendix A summarizers the stakeholder interviews and Appendix B summarizes some case studies from the literature. Appendices C and D provide detailed versions of the material summarized in Section 3.

Throughout the document the **blue highlighted text** identifies key findings from the literature review and outreach interviews.

2.0 REGULATORY REQUIREMENTS FOR RECLAMATION AND CHANGE IN END LAND USE

This section provides an overview of the regulatory and policy requirements related to reclamation of industrial disturbances in Alberta, with emphasis on wellsites and associated facilities (wellsites). Rather than a complete review, the following sections highlight regulations and policies that relate specifically to those circumstances where forested sites with natural vegetation encroachment and padded sites in peatlands can be certified without further disturbance (as defined in Section 1.4).

2.1 BACKGROUND

Three documents in particular are key in this review: the *2010 Reclamation Criteria for Wellsites and Associated Facilities for Forested Lands (Updated July 2013)* (forested land criteria; Alberta Environment and Sustainable Resource Development, 2013); the *Reclamation Criteria for Wellsites and Associated Facilities for Peatlands* (peatland criteria; Alberta Environment and Parks, 2017); and, the *Specified Enactment Direction 002: Application Submission Requirements and Guidance for Reclamation Certificates for Well Sites and Associated Facilities* (SED 002[4]; Alberta Energy Regulator, 2018). There are some terminology differences between the documents that create potential for confusion – the terms used in the source documents are used here with notes about the differences provided for clarity. In particular, **SED 002 uses the term variance to refer to formal requests for deviations from applicable criteria – this term is not used in either the forested land criteria or the peatland criteria. In addition, SED 002 doesn't use the forested land criteria term vegetation override; it is presumed to be a specific type of a variance.** All variances require justification (Alberta Energy Regulator, 2018):

> *An operator may provide justification as to why a site should be permitted to vary from the criteria and still receive certification*. Operators should first discuss options with the AER prior to conducting the detailed site assessment. If a variance is being requested, the operator must provide the *rationale for its decision*, supported by acceptable references.

Both the peatland criteria (Alberta Environment and Parks, 2017) and SED 002 reference *change in land use* when discussing requests for a change from peatlands to forested lands (i.e., leaving a pad in place); rather than being called a variance, SED 002 refers to this as a request for a "change to the assessment

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[4] SED 002 (Alberta Energy Regulator, 2018) came into effect June 21, 2016, replacing Government of Alberta 2010 Reclamation Criteria for Wellsites and Associated Facilities: Application Guidelines (Alberta Environment, 2011). SED 002 did not change the wellsite criteria but did align some of the application submission process requirements with the online submission tool (OneStop).

criteria". Such changes must be approved by the AEP Land Manager. This is discussed in further detail in later sections.

Under the *Environmental Protection and Enhancement Act* (EPEA; Government of Alberta, 2000):

> 137(1) An operator must
>
> > (a) conserve specified land,
> >
> > (b) reclaim specified land, and
> >
> > (c) unless exempted by the regulations, obtain a reclamation certificate in respect of the conservation and reclamation.

EPEA Section 1(l) defines "conservation" as:

> ... planning, management and implementation of an activity with the objective of protecting the essential physical, chemical and biological characteristics of the environment against degradation;

While **conservation generally applies to the construction phase (e.g., soil salvage, minimum disturbance) it can equally apply to the operation and reclamation phases. Thus, when planning reclamation strategies for sites with natural vegetation encroachment, conservation of the existing vegetation (biological characteristics) should factor into decisions on the best reclamation strategy. Similarly, where pads have been in place in wetlands for many years and have become an integral part of the "new" wetland system, conservation of the pad (physical characteristics) should also be factored into reclamation decisions.**

The objective of reclamation for wellsites is the return of equivalent land capability (*Conservation and Reclamation Regulation*, section 2; CRR; Government of Alberta, 1993). The Regulation (s. 1(e)) defines equivalent land capability 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[5];

This definition is intentionally broad to allow for a variety of landforms and land uses following reclamation. For example, the Lower Athabasca Regional Plan (LARP; Government of Alberta, 2012) notes that reclamation can "help achieve regional objectives relating to biodiversity, recreation and forestry."

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[5] Note that the *Public Lands Administration Regulation* (s. 1(1)(l); Government of Alberta, 2011) defines equivalent land capability differently: … in respect of land that is the subject of a disposition, a condition in which the ecosystem processes on the land are capable of producing goods and services of a quality and in a quantity that is at least equivalent to that which existed before the disposition was issued to the holder;

More specifically, LARP notes (emphasis added) that “Implement[ing] the progressive reclamation strategy … will provide mechanisms to define, measure and report on the return of equivalent capability – the objective for reclamation – *including the return of a suite of acceptable land uses, such as commercial forestry, wetlands, wildlife and biodiversity, traditional use, and recreation*”. Similarly, the Fort McMurray-Athabasca Oil Sands Subregional Integrated Resource Plan (emphasis added; Alberta Sustainable Resource Development, 2002) notes that “Sites will be reclaimed to a level of capability equivalent to the pre-disturbance level, *optimizing the values of watershed, timber, wildlife, fish, recreation or other resources*.”

While in most cases the return of landforms and vegetation similar to the pre-disturbance conditions is desired, the government has recognized that land use may need to change following reclamation of a wellsite (Alberta Energy Regulator, 2018; emphasis added):

> In some cases, a change of land use at a site from the original use may require the applicant to apply using different assessment criteria from the original pre-existing conditions to the current surrounding or adjacent end land use (e.g., from forested lands to cultivated lands).
>
> *Requests for changes to the assessment criteria must be approved in advance by the AER*. A copy of the written acceptance must be submitted with the application. Documentation demonstrating discussions with the landowner, land manager, or occupant about the implications of this assessment criteria change must be included, along with signed acceptance of the criteria changes by the landowner, land manager, or occupant.
>
> **On public land, AEP is the land manager following reclamation certification and thus must be in agreement with any criteria use change.** Approval by AEP is required. Additionally, where there is an occupant on public land, their consent must be received as well. A copy of the approval from AEP and the occupant must be submitted with the application.

For example, Public Land Management Policy No. 7 regarding borrow activities[6] on public land (Alberta Environment and Parks, 2018) notes (emphasis added):

> Approval must be received for any reclamation outcomes that are not the pre-disturbance land use on public lands. This approval is typically referred to as a “change in land use” or “alternate end land use”. A request for a change in end land use should reflect an ecological community

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[6] One of the common changes in larger-scale disturbances is the creation of pit lakes, ponds or dugouts (see Alberta Environment, 2004; Alberta Sustainable Resource Development, 2002; Alberta Sustainable Resource Development, 2010; Alberta Transportation, 2013; Hrynyshyn, 2012).

> found in the natural sub region of the site ... The rationale for changes in land use or an alternate end land use must be provided with the request for regulatory approval. The request should occur prior to commencing the activity, recognizing that the land use may later change.

For peat operations, “The preferred outcome ... is to return land to its pre-disturbance condition, including replacement of salvaged mineral soils, presence of pre-disturbance moisture regimes and establishment of the pre-disturbance vegetation community (eco-site phase or wetland type).” (Alberta Environment and Parks, 2016). Alternate land uses are an option (emphasis added):

> Site characteristics, historical practices, and/ or subsequent land uses may result in requests for a change in end land use. This change is referring to cultivated, forested, and wetland types ... A *request for a change in end land use should reflect an ecological community found in the natural subregion of the site*. For example, if a peatland was approved to be reclaimed to an upland, the preferred upland eco-site phase would be present within the natural subregion for the area.
>
> The selection of an end land use should consider adjacent land uses and the needs of the community and landowner or land manager. The end land use must be discussed and approved with AEP on public land, and with the municipality on private land.

Alberta Environment and Parks (2016) provides a hierarchy of preferred outcomes to aid in decisions related to change in land use for peat operations (Figure 1).

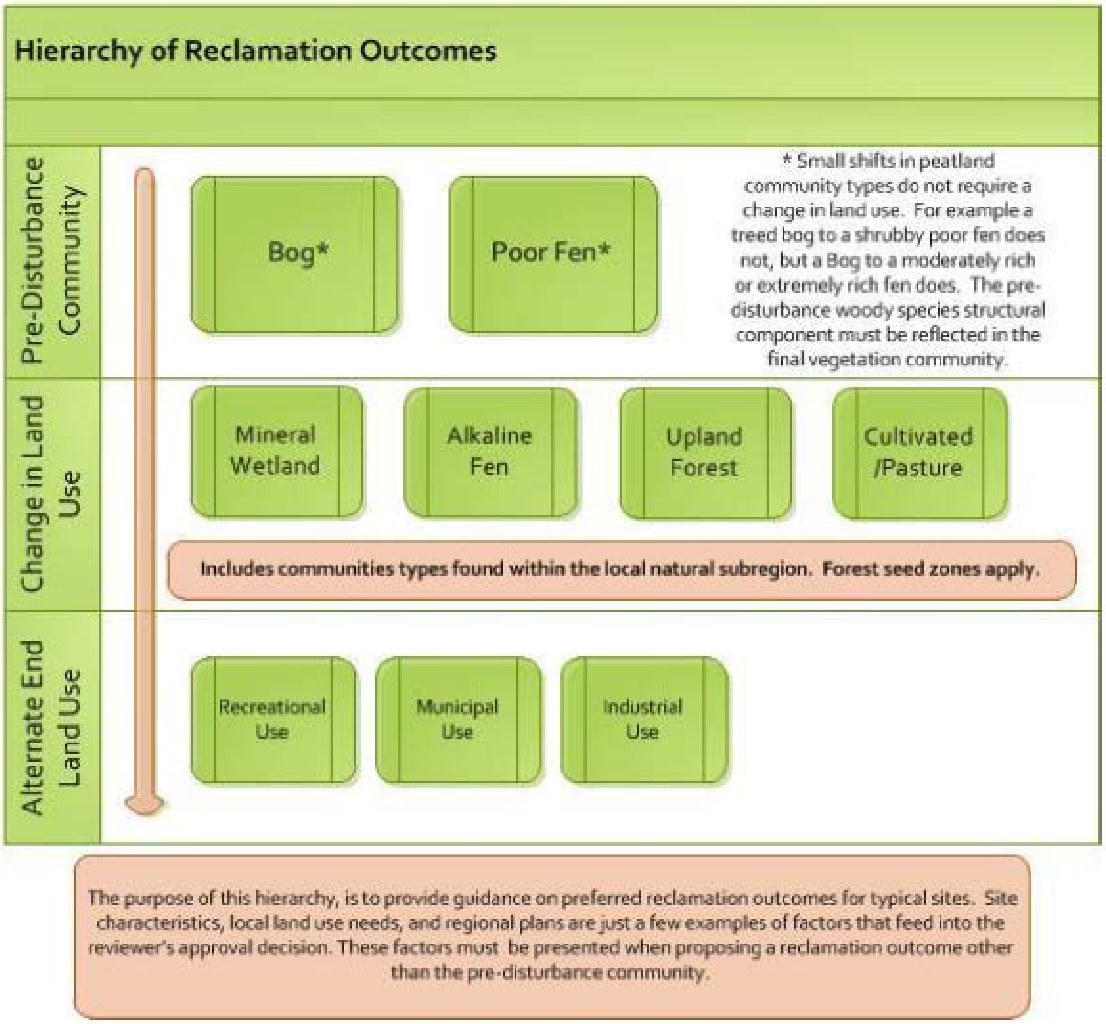

Figure 1. Hierarchy of reclamation outcomes for peat operations.
From Alberta Environment and Parks (2016).

Alberta Sustainable Resource Development (ASRD; Alberta Sustainable Resource Development, 2010) provides additional guidance on land use changes relative to aggregate operations (emphasis added) and a table showing possible end land-uses by natural region (Table 1):

> **End land-uses are site specific and will depend primarily on the pre-disturbance condition. The choice of an end land-use will depend on the following factors:**
>
> • **Regional Limitations – The natural environment surrounding a site will strongly influence the types of end land-uses that are attainable.** Climate, soil type, and landforms available in the region will influence the plant types that can grow in the region. Vegetation on reclaimed land must be self-sustaining under normal management, which means plant communities becoming

established and mature without an ongoing, external source of nutrients, water, seeds or seedlings.

• **Surrounding Land Uses** – The end land-use should be compatible with adjacent lands.

• **Costs – The overall cost may dictate the type of landuse.** Applicants must work with ASRD prior to obtaining a licence or lease to determine the final end land-use. Costs for conservation and reclamation should be identified in the [Conservation and Reclamation Business Plan] (CRBP). It is not appropriate to re-evaluate costs at the end of a pit life and determine that conservation and reclamation plans are cost prohibitive. Pit end land-uses must be identified in the CRBP and adhered to at the end of a pit life.

Table 1. Possible end land uses based on natural region.
From Alberta Sustainable Resource Development (2010) (adapted from Green et al. (1992)).

	Native Grassland	Forestry	Wildlife Habitat	Waterbody	Wetland
Grassland	✓		✓		✓
Aspen Parkland	✓		✓	✓	✓
Boreal Forest		✓	✓	✓	✓
Foothills		✓	✓		

Reclamation certification is based on published reclamation criteria where available (e.g., the forested land criteria (Alberta Environment and Sustainable Resource Development, 2013a) and peatland criteria (Alberta Environment and Parks, 2017)). These documents generally require comparison with adjacent land or pre-disturbance assessment information, but do provide the option for using alternate controls (e.g., an upland site for a pad left in place) if the application provides acceptable justification (Alberta Environment and Sustainable Resource Development, 2013; emphasis added):

> Given the complexity of the different land use types, soil zones and landscapes, it is acknowledged the 2010 Criteria may not be applicable to all sites under all circumstances. *The assessor, operator, inspector, Land Manager or reviewer is not limited to the methods identified in the criteria to draw his/her conclusion on 'equivalent capability'. Where such circumstances occur and the operator is satisfied that the site is ready to certify, an application can be submitted but must be accompanied*

with a detailed justification as to why the methodologies in the criteria do not support certification yet the site does meet 'equivalent capability'.

Where published criteria are not available but an activity has an EPEA approval issued[7], the terms and conditions of the approval will govern (e.g., Alberta Energy Regulator, 2015a; b). In both cases, the conditions of a public land disposition will also be considered.

Reclamation planning (both conceptual at the Environmental Impact Assessment (EIA) or pre-development stage, and with greater detail as the project is built, operated and prepared for decommissioning) is required for larger disturbances[8] (e.g., Alberta Energy Regulator (2016) for in-situ projects; emphasis added):

> A Project-Level Conservation, Reclamation, and Closure Plan (PLCRCP) is required under EPEA approval terms and conditions for commercial in situ facilities. It depicts the approval holder's conservation and reclamation plans following project approval. The PLCRCP is updated through the life of the project and is to incorporate research findings, monitoring results and best practices, which reflect an adaptive management approach to conservation and reclamation. The *PLCRCP is a project-level plan for achieving equivalent land capability* and long-term sustainable reclamation outcomes after closure. The *PLCRCP is a tool for evaluating the alignment of site-specific conservation and reclamation activities with project-level goals and objectives*. It acts as an update to the conceptual conservation and reclamation plan submitted with the EIA and the EPEA application for the project.
>
> The PLCRCP must be implemented as authorized in writing by the AER. Once the plan has been authorized, the approval holder is expected to conduct all conservation and reclamation activities in accordance with the authorized plan.

2.2 UPLAND SITES WITH NATURAL VEGETATION ENCROACHMENT

The term *natural recovery* is generally applied to a planned revegetation strategy that relies on a site being minimally disturbed and the presence of an adequate vegetation propagule source (in minimally disturbed soil, or in lands adjacent to the site, or both) to allow for revegetation of desired plant species. The term applies to both forested and grassland sites, but has historically been a more common revegetation

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[7] Note, regulators have also specifically identified the wellsite criteria as the relevant criteria for use with other disturbance types (e.g., for coal and oil sands exploration sites – (Alberta Environment and Parks, 2015).
[8] Other information is required for activities such as wellsites on public land that do not require EPEA approvals (Alberta Environment and Parks, 2018b).

strategy in the latter. **In this document we refer to sites with natural vegetation encroachment to distinguish a planned strategy from sites with minimal reclamation action taken (i.e., site not recontoured or soils not replaced in accordance with the criteria) that have developed a vegetative cover that includes the desired plant species. Sites with natural vegetation encroachment may occur in upland forest areas or in padded sites in peatlands.**

The forested land criteria (Alberta Environment and Sustainable Resource Development, 2013a) describes the basic requirements for assessing the landscape, soil and vegetation characteristics of a site for certification and provides the pass/fail criteria to be used. However, there are specific provisions for natural recovery sites[9]. Of particular relevance for this project, natural recovery sites have different vegetation requirements than planted sites (s. 8.1; Alberta Environment and Sustainable Resource Development, 2013):

(a) Sites Reclaimed Prior to June 1, 2007 must meet the following:

(i) If a site seeded with grasses: Minimum 80% compatible vegetation cover based on seed mix.

(ii) If a Natural Recovery Site: A minimum of 25% canopy cover of herbaceous species; and, a minimum 25% canopy cover of woody species or a minimum stem/plant count of 5.

(iii) If a Planted Site: A minimum of 25% canopy cover of herbaceous species; and, a minimum 25% canopy cover of woody species or a minimum stem/plant count of 2.

(b) Sites Reclaimed On or After June 1, 2007, sites must meet the following:

(i) If a Natural Recovery Site: A minimum of 25% canopy cover of herbaceous species; and a minimum of 25% canopy cover of woody species or a minimum stem/plant count of 5 stems per assessment point area (1.78 m radius assessment area; 10 m^2).

(ii) If a Planted Site: A minimum of 25% canopy cover of herbaceous species; and a minimum of 25% canopy cover of woody species or a minimum stem/plant count of 2 stems per assessment point area (1.78 m radius assessment area; 10 m^2).

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[9] Note that the criteria document defines the term "natural recovery" as: Long term re-establishment of diverse native ecosystems (e.g., prairie, forest) by establishment in the short-term of early successional species. This involves revegetation from soil seedbank and/or natural encroachment and no seeding of non-native agronomic species.

Section 8.2 of the forested land criteria provides for a vegetation override "where reasonable forest cover (i.e., amount, species and distribution) is present" (emphasis added):

> **Where reasonable forest cover (i.e., amount, species and distribution) is present, and where additional activities required to meet the conditions described in this criteria pose a risk to existing ecosystem function, a vegetation override may be appropriate. Equivalent capability for forested landscapes must be demonstrated.** The use of a vegetation override will result in a Non-Routine Application and will result in greater scrutiny by the Regulator.

Section 12.2 of the forested land criteria also provides guidance for sites where desirable vegetation is present (emphasis added):

> *Although not recommended, at times where additional topsoil is desirable (e.g., to avoid re-stripping a site where desirable vegetation is already established)*, it shall be described (e.g., source, texture, volume, weed count) and shall have similar or as close as possible chemical and physical properties as the control topsoil (e.g., addition of Orthic Black Chernozem to Orthic Black Chernozem). The date and method of application and incorporation, and documentation showing Land Manager acceptance are required.

EPEA approvals for large facilities such as mines and in-situ oil sands operations generally require replacement of subsoil and topsoil unless otherwise authorized in writing by the Director (Alberta Energy Regulator, 2015a).

Section 7.1.1 of the forested land criteria describes the requirements for peatland sites that have been reclaimed to forested land (emphasis added):

> On former peatland sites that have been reclaimed to a forested ecosystem, the soils quantity criteria does not apply, however the site must be assessed for soil stability, vertical processes and vegetation. The area must not cause off-site impacts. *Vegetation may not be representative of the adjacent off-site (wetland) but must be on the same trajectory as a corresponding off-site upland eco-site based on the eco-site guide for the region*.

There is no clear guidance provided in the forested land criteria as to the type of information/justification required by the Regulator or Land Manager to accept a change in reclamation practice and certification requirements. Furthermore, there is no clear indication in either the forested land criteria or SED 002 (Alberta Energy Regulator, 2018) if the Land Manager must approve the variance request for a vegetation override, or if the AER can make that determination on its own – stakeholder interviews noted this as well.

2.3 MINERAL SOIL PAD REMOVAL

General reclamation requirements focus on removing pads and access roads to ensure a return of pre-pad hydrology: contouring the site to conform to, or blend into, the surrounding topography unless otherwise approved; restoring surface and subsurface drainage to conform to the adjacent drainage system; and, employing procedures that do not divert, block or impound natural surface or subsurface drainage (Alberta Environment and Parks, 2018b; Alberta Environmental Protection, 1994). Access roads are expected to have water crossings and culverts removed unless otherwise authorized by the Director (Alberta Energy Regulator, 2015a; Alberta Environment and Parks, 2015).

Alberta's Wetland Policy (Alberta Environment and Sustainable Resource Development, 2013b) manages impacts to wetlands based on the concept of "relative wetland value, which acknowledges the relative contribution of an individual wetland to water quality improvement, hydrology, biodiversity, and various human uses." The Policy assesses wetland value based on five functional groups, including *relative abundance* (The relative abundance of wetlands in an area strongly affects the sensitivity of an area to the effects of further wetland loss). The Policy notes (emphasis added):

> In keeping with a comprehensive and informed approach to wetland management, the 'relative abundance' component of the system incorporates aspects of current abundance/density and historical loss into the value assessment. In areas of low current abundance and high historical loss, the approach will place additional value on existing wetlands and promote both conservation and restoration as wetland management priorities. **In areas of high abundance and low historical loss, the system will continue to acknowledge and promote the importance of wetlands and wetland values on the landscape. At the same time, it will facilitate a considered approach to wetland management, balancing environmental, social, and economic priorities in the execution of management decisions.**

The Wetland Policy incorporates a "*Wetland Mitigation Hierarchy*, which refers to a three stage approach toward achievement of wetland management objectives and/or goals. The three stages, listed in order of descending priority, are: (1) avoidance of negative wetland impacts, (2) minimization of negative wetland impacts, and (3) wetland replacement to account for negative wetland impacts that could not be avoided or minimized[10]." The Policy notes (emphasis added):

[10] Other regulatory documents support the three-tier approach (e.g., Alberta Environment and Parks, 2018c)

Where avoidance and minimization efforts are not feasible or prove ineffective, *wetland replacement is acknowledged as the last resort in the mitigation process*. It will only be considered for residual impacts that were impractical to minimize or avoid and will not apply to temporary wetland impacts. If, after all practicable avoidance and minimization measures have been exercised, permanent loss of a wetland, or portion thereof, is incurred, wetland replacement will be required for the portion that is lost. *Replacement requirements will be established on the basis of* a) wetland area lost and b) *the relative value of that area*.

In cases where development that results in wetland loss is subject to a reclamation plan, replacement requirements will be adjusted accordingly, taking into account the area and value of both wetlands lost and wetlands constructed under the reclamation plan.

Replacement requirements will be established on the basis of replacement ratios. A replacement ratio determines how many hectares of replacement wetland are required per hectare of permanently lost wetland. The *ratio system has been developed on the basis of relative wetland value, taking into account both the relative value of the impacted wetland and that of the replacement wetland*. [The replacement ratio] is based on three key considerations:

1. *A restored wetland is unlikely to achieve the same level of function as the natural wetland it replaces*.
2. A significant time lag is expected to occur, between the moment a wetland is lost and the point a restored wetland achieves a reasonable level of function.
3. Some proportion of restored wetlands is expected to fail over time.

In 2017, AER Bulletin 2017-19 noted that "Effective January 2, 2018, authorizations under the Water Act, Public Lands Act, and *Environmental Protection and Enhancement Act* (EPEA) for projects that will have permanent or temporary impacts on wetlands will contain approval conditions related to policy. These conditions may capture commitments by the applicant on minimizing wetland loss and reclaiming or replacing wetlands." (Alberta Energy Regulator, 2017).

The peatland criteria (Alberta Environment and Parks, 2017) " ... 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." The document further notes that "While not all function will be restored in a disturbed site for decades or millennia, pre-disturbance function such as peat accumulation, carbon sequestration, water storage/filtration and wildlife habitat are the desired reclamation outcomes in the long-term" and "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."

Section 2.3 and Figure 1 of the peatland criteria (Alberta Environment and Parks, 2017) acknowledges the potential for leaving pads and access roads in place by providing guidance on the assessment criteria to use when a land use changes (emphasis added):

> **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 2).

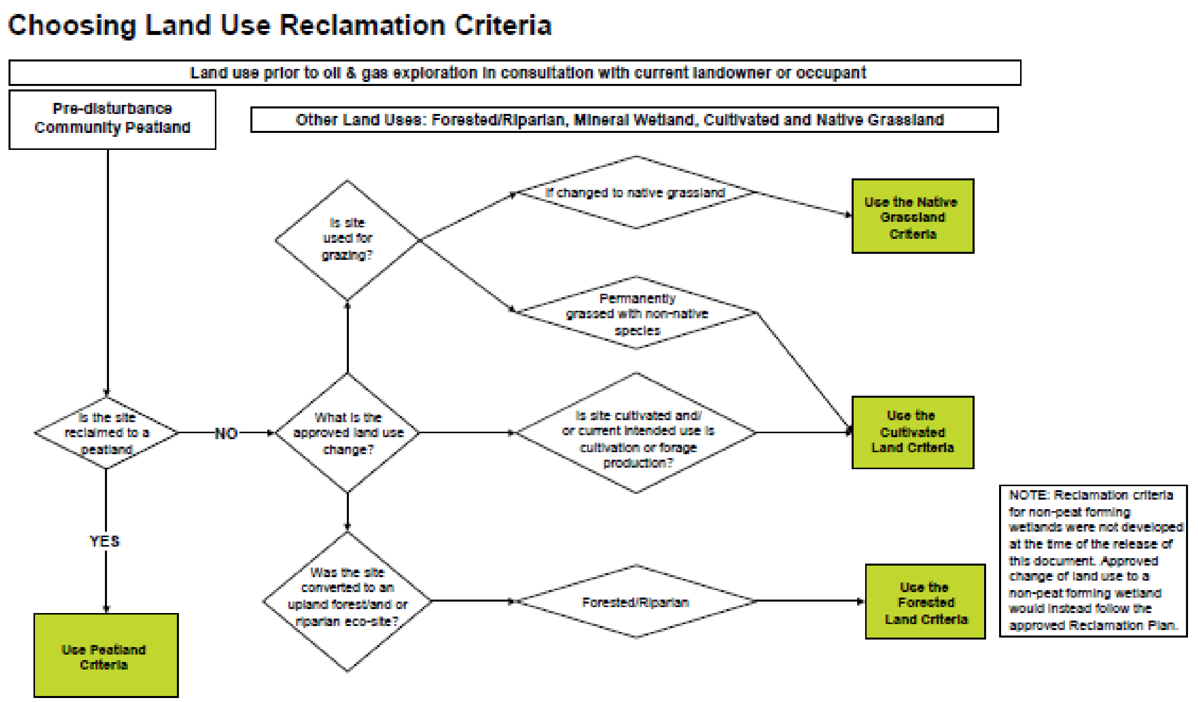

Figure 2. Choosing land use reclamation criteria for peatland sites.
From Alberta Environment and Parks, 2017.

The peatland criteria (Alberta Environment and Parks, 2017) also states that:

> 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, nonhazardous and have no impact to off-lease lands.

The AER requires submission of specific information when requesting a change in land use for pads in peatlands (Alberta Energy Regulator, 2018):

- Peatland type
- Presence/absence of subsurface or surface water impacts to vegetation
- Absence/presence of locally common upland communities and type

As noted above for the forested land sites, there is no guidance on how the Land Manager will make the decision to approve the land use change.

In-situ Project-Level Conservation, Reclamation, and Closure Plans (PLCRCP), under an EPEA approval, require an operator to (Alberta Energy Regulator, 2016; emphasis added):

> Include a description of proposed strategies or results, or both, for the following topics:
>
> > Infrastructure management – Provide a description of the infrastructure management strategies for ... *pads to be removed or left in place and recontoured*; geotextile management, and *any proposal for roads that may be left in place* for stakeholder or Crown use, and say whether formal agreements or authorizations are pending.
> >
> > Permanent reclamation – Any constraints (e.g., salinity, sodicity, pH) of pad fill materials and how such constraints will be managed during construction operations and final reclamation. Explain how site drainage and surface water hydrology will be restored or maintained at closure and how topography will be integrated with adjacent undisturbed lands (e.g., *recontouring pads left in place to match surrounding topography*; reclaiming pads in peatland in a manner that restores wetland function; removing water management structures). *Describe any permanent changes in site conditions (e.g., conversion of wetland to upland, or fen to marsh)*.

In the guide for PDA/C&R plans (Alberta Environment, 2009), the following guidance is provided on creation of post-reclamation topography:

> The development of the post reclamation topography is important to the success of the reclaimed development. This section should include a discussion on site preparation methodology as well as *how the pad fill materials and geotextile materials will be handled*.
>
> Information regarding the reclaimed topography should include ... post-reclamation goals regarding drainage including *discussion about wetland restoration (if applicable)*.

EPEA approvals require operators to conduct research relative to pad removal and to monitor the potential effects on wetlands ((Alberta Energy Regulator, 2015a); emphasis added):

> 41. The Wetland Reclamation Trial Program proposal shall include, at a minimum, all of the following:
>
> > (a) trial plans for the *removal or partial removal of pad materials* from well pads and roads located in wetland ecosystems with emphasis on dominant wetland ecosystems that have been disturbed;
> >
> > (c) the possible reuse of the bed and fill material removed from the areas specified in (a) as construction or backfill material;
>
> 2. The updated Wetland and Water Body Monitoring Program proposal shall include, at a minimum, all of the following:
>
> > (e) an updated plan to determine and monitor the potential effects on wetlands from:
> >
> > (ii) roads, well pads or other infrastructure constructed within wetland and water bodies.

Historically, the wellsite criteria for peatland sites specifically addressed pads and roads left in place (Figure 3; Alberta Environmental Protection, 1995), though the general expectation again was that "Site drainage should be consistent with the original patterns, directions and capacity or compatible with the surrounding landscape" and that "*Facilities or features left in place (e.g., clay pads, roads) may not negatively impact drainage or adjacent forest growth*".

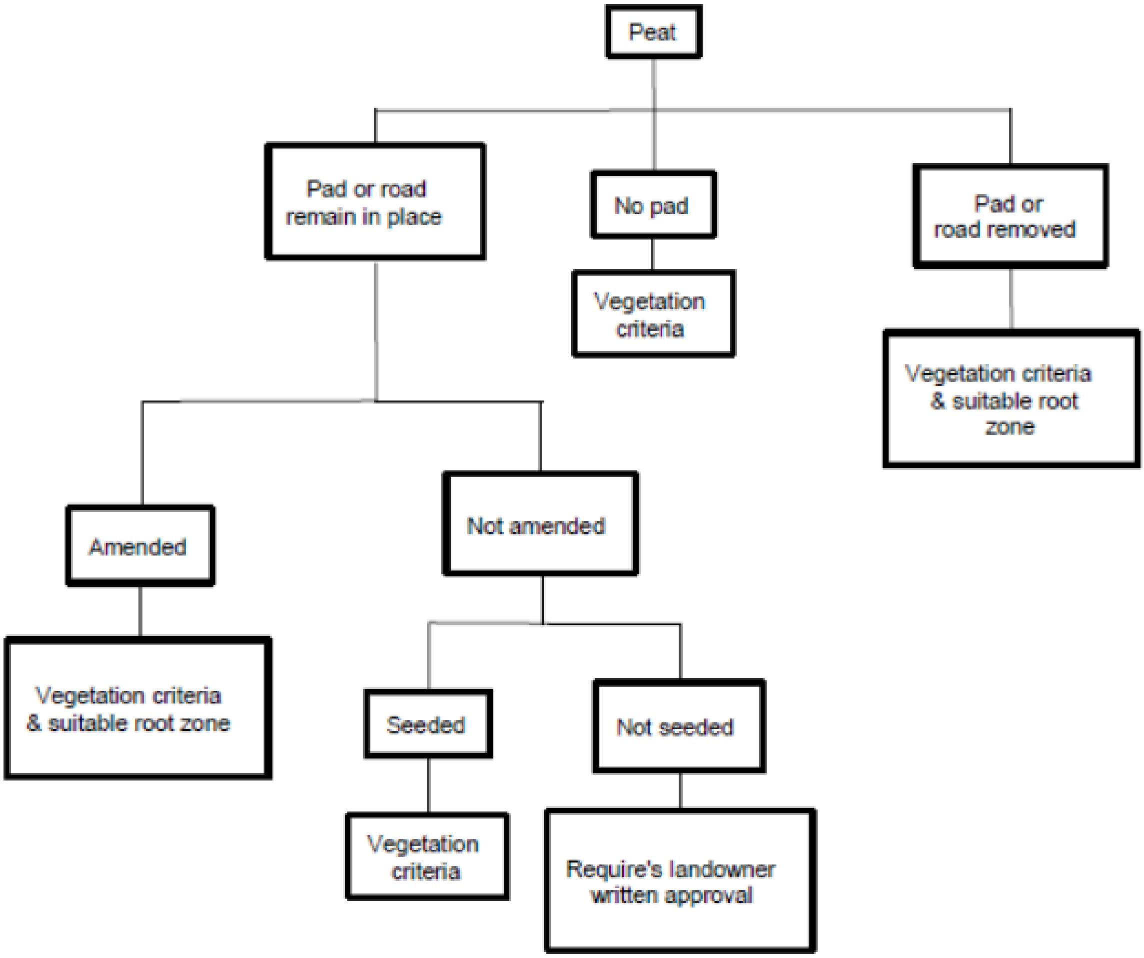

Figure 3. Relationship between pad construction / removal and criteria.
From Alberta Environmental Protection (1995).

2.4 Summary

In general, regulators expect that disturbed sites in the boreal forest will undergo complete reclamation (recontouring, soil replacement and revegetation) with the goal of returning the site to pre-disturbance condition and land use. Legislation and policies provide opportunities to vary from these expectations with written approval from a specified decision maker (Director, Regulator, Land Manager). Alberta's Wetland Policy requires replacement of wetlands lost due to industrial development, but recognizes that the relative value of a wetland (used to calculate replacement ratios) is based, in part, on the relative abundance of wetlands in the region. In areas of high abundance (such as northeast Alberta) and low historical loss, the concept of *relative abundance* will facilitate a considered approach to wetland management, balancing environmental, social, and economic priorities in the execution of management decisions.

The two specific instances of relevance to this project where a regulatory decision is needed are: a request for a variance based on a site having natural vegetation encroachment rather than complete reclamation; and, a request to leave well pads in peatlands in place. It is clear in the wellsite criteria and SED 002 that the Land Manager (AEP) must approve a change in land use from peatland to upland; it is less clear if the Land Manager or the AER must approve the variance for a vegetation override where a site has natural vegetation encroachment. Furthermore, when a pad in a peatland is partially removed it is unclear if a change in land use approval is required for the remaining upland portion (and if so, if there is a size of remaining upland below which an approval is not required).

While there is limited guidance as to what kinds of information would be required to assist the decision maker, the documents reviewed here indicate some potentially influential factors:

- **For sites with natural vegetation encroachment**:
  - **Reasonable forest cover (i.e., amount, species and distribution) is present**
  - **Additional activities required to meet the conditions described in the certification criteria pose a risk to existing ecosystem function**
  - **The area must not cause off-site impacts**
  - **Vegetation must be on the same trajectory as a corresponding off-site upland eco-site based on the eco-site guide for the region**
  - **Soil additions, while not recommended, shall be described (e.g., source, texture, volume, weed count) and shall have similar or as close as possible chemical and physical properties as the control topsoil**
- **For pads left in place**:
  - **Confirm that the end land use will reflect an ecological community found in the natural subregion of the site and considers adjacent land uses and the needs of the community and landowner or Land Manager**
  - **The overall cost may dictate the type of land use; determine costs for conservation and reclamation [for different options] and work with the Land Manager to determine the final end land-use**
  - **Obtain approval from Land Manager for a change in land use**
  - **Provide information showing that the pads do not negatively impact drainage or adjacent forest growth (at a minimum remove culverts and crossings)**
  - **Describe any recontouring of pads to match surrounding topography**
  - **Provide the AER information on peatland type, presence/absence of subsurface or surface water impacts to vegetation, and absence/presence of locally common upland communities and type**
  - **Provide information on constraints (e.g., salinity, sodicity, pH) of pad fill materials and how such constraints will be managed during construction operations and final reclamation**

Figure 4 presents a preliminary decision tree for selecting reclamation options and criteria for reclamation evaluation based on the regulatory requirements described above. This figure, and the modified forested criteria referenced within it, will be further developed through the various stages of the project.

It is important to note that change in land use decisions are made as a result of a site-specific application and consultations with the Land Manager. At the site level, the impact of such a change may appear to be significant but when considered at the local or regional scale the impact may become innocuous. At the same time, the cumulative effects of multiple applications for change in land use could become significant at the local or regional scale, even if individually the changes are innocuous. Thus, if cumulative impacts are to be considered in change of land use decisions there will need to be an agreement on the appropriate scale and threshold for impacts.

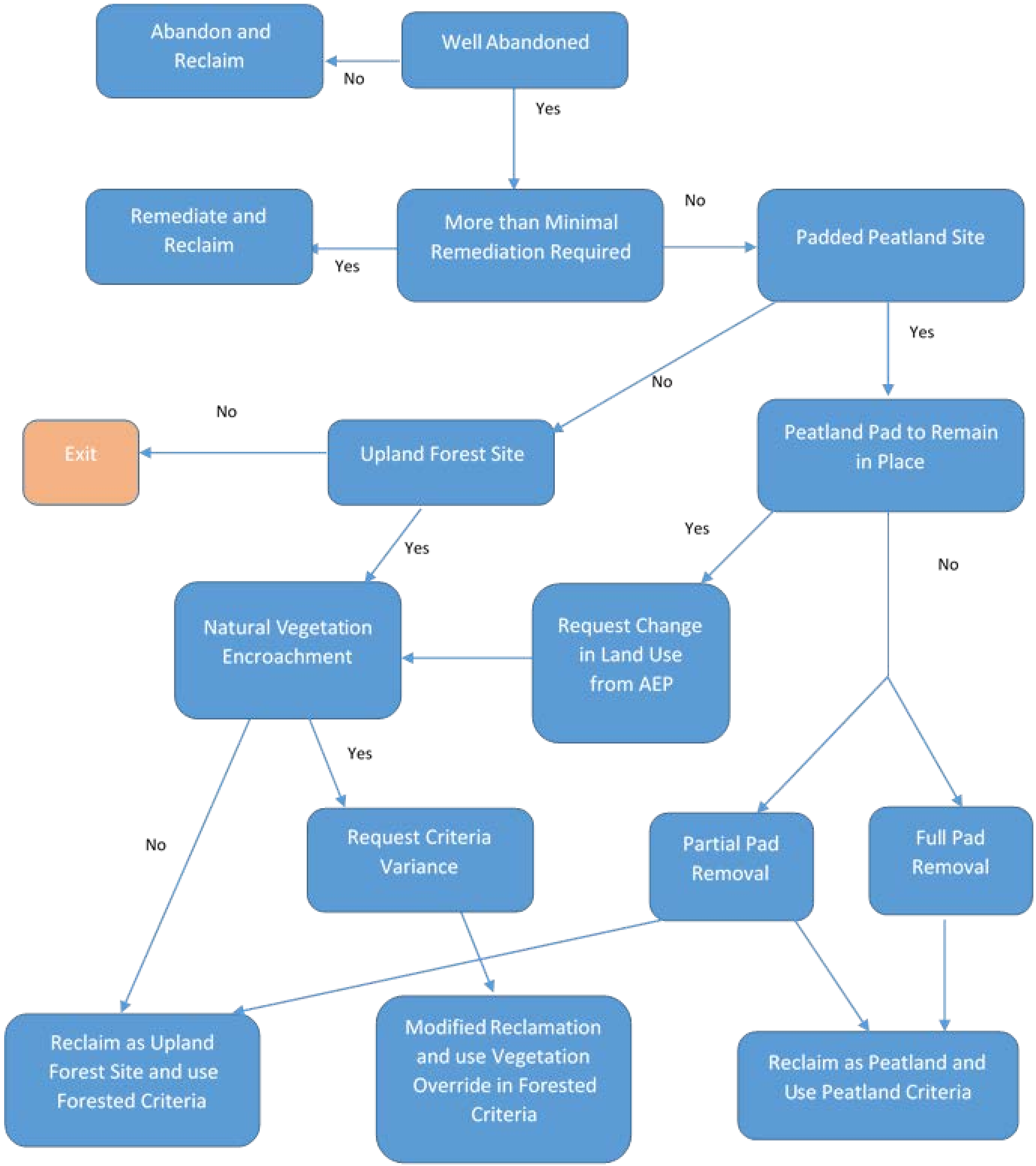

Figure 4. Preliminary decision tree for selecting reclamation and criteria options. Based on the regulatory requirements reviewed in this section.

3.0 ECOLOGICAL FUNCTIONALITY OF RECLAIMED WELLSITES

During the reclamation certification process, professional justification is required for sites requiring a change in land use and/or a variance to criteria for one or more reclamation deficiencies according to the applicable wellsite criteria. To prepare an appropriate professional justification which describes why the specific deficiencies will not have long term adverse environmental impacts and/or ultimately influence equivalent land capability, one must understand the factors influencing the ecological function of a site. Key drivers influencing ecological function of upland forested sites is summarized below in Section 3.1 and in more detail in Appendix C. Similarly, when considering the implications of a mineral soil pad and/or access road within a peatland and ultimately the factors affecting the decision to remove it or not, it is essential to understand the ecology and function of peatlands. The key factors that control functional peatland ecosystems are summarized in Section 3.2 and described further in Appendix D.

3.1 UPLAND FORESTS

3.1.1 *Peer-reviewed and Grey Literature Discussing Ecological Function of Upland Ecosystems*

Upland forest ecosystems in Alberta operate though a complex web of abiotic and biotic factors and are made up of three main components: forest soils, understory plant communities and overstory trees. Forest soils and vegetation layers interact internally and with each other and provide essential forest functions including nutrient and hydrologic cycling, carbon storage and sequestration and wildlife habitat (Frerichs, 2017; Lupardus et al., 2018; Nilsson and Wardle, 2005). **Functional forest ecosystems are self-sustaining and are resilient to stressors and disturbance** (Brandt et al., 2013; Welham, 2013).

Forest soils are characterized by a surface organic litter layer overlying two or three mineral soil horizons; development of mineral soil horizons varies with soil forming factors: climate, organisms, relief, parent material, and time (Jenny, 1941). The litter layer can be divided into three horizons (L, F, H) based on degree of decomposition of the litter material (and is often referred to collectively as the LFH horizon or as the forest floor). Forest floor and mineral soil horizons provide the physical medium for plant roots to grow. They also provide water and nutrients for plant uptake, and support microbial populations (including mycorrhizal fungi) important in ecosystem biogeochemical cycling which occurs in the forest floor where litter inputs are mineralized into plant available nutrients.

Typically a functional ecosystem in the boreal region of Alberta can be characterized by multiple structural layers; overstory (trees), shrub (woody vegetation), herbaceous (non-woody; also called the field layer) and ground cover (moss, lichen, small herbs and shrubs, seedlings etc.) (British Columbia Ministry of

Forests and Range and British Columbia Ministry of Environment, 2010). The species that make up these layers varies considerably across the landscape, based on climate, site and soil properties, biotic interactions between layers, and then how previous disturbance impacted how the community assembled during regeneration (the latter is discussed in more detail in Appendix C) (reviewed in Macdonald and Fenniak (2007) and Macdonald et al. (2012)). It is important to understand the patterns and processes that drive existing structure and composition of forest plant communities to understand the targets for reclamation and whether ecosystem function has been restored. Forest soil properties as well as abiotic site and climate conditions (precipitation, temperature, slope, aspect, topographic position, drainage) can be integrated into the concepts of soil moisture and nutrient regimes (Alberta Environment, 2010; Beckingham and Archibald, 1996). Site and soil characteristics vary across the landscape, creating gradients in nutrient and moisture regimes (the term ecosite is used to describe the position of a site along nutrient and moisture regime gradients). These site conditions then affect vegetation establishment as plant species respond to moisture and nutrient regimes differently, because different plant species have developed different strategies to respond to abiotic limitations (e.g., drought tolerance) (Alberta Environment, 2010). Although individual plant species may have a wide range of tolerances (Hart and Chen, 2006), each ecosite is characterized by a slightly different assemblages of species capable of establishment and co-existence.

Plant community development and trajectories are further influenced by interactions between structural layers and between vegetation and soils. These associations are key for ecosystems to be self-sustaining and maintain their function over time. In earlier stages of development (and in canopy gaps that form in late successional forests when trees senesce, or as a result of small scale disturbances such as windthrow) understory communities can modify microclimate conditions of the forest floor and impact recruitment of tree species (Lieffers et al., 1993; Nilsson and Wardle, 2005), while in later successional stages the canopy affects microclimate conditions which impacts growth of understory species and drives plant community composition and diversity (Chávez and Macdonald, 2010; Hart and Chen, 2006; Macdonald and Fenniak, 2007). For example, conifer forests have lower light transmission, soil temperature, soil nutrients, pH, litter depth and litter quality and thus lower herbaceous plant diversity than deciduous forests (Hart and Chen, 2006; Macdonald and Fenniak, 2007). Conifer forests do have higher bryophyte diversity than deciduous forests and more low nutrient demanding, shade tolerant species (Chávez and Macdonald, 2010; Hart and Chen, 2006). Deciduous forests on the other hand favour vascular plants and inhibit mosses and lichens and have more shrubs and shade intolerant forbs (Chávez and Macdonald, 2010; Macdonald and Fenniak, 2007). Mixedwood forests have both shade tolerant and shade intolerant, nutrient demanding species, but are more similar in composition to conifer forests (Macdonald and Fenniak, 2007). Many of these understory/overstory patterns are regulated by the forest floor. In addition to parent material and stand age, forest floor properties are dependent on the vegetation growing on site (Lamarche et al., 2004). Forest floors under aspen dominated stands have a distinct chemical composition and microbial community, compared to forest floors developing under spruce dominant stands; distinctions are influenced by differences in pH and litter inputs (reviewed in Macdonald et al., (2012)). Differences in litter properties from understory species can also impact forest floor processes, including soil microbial decomposition rates, and soil carbon and nitrogen, which can ultimately impact vegetation productivity and species composition (Nilsson and Wardle, 2005). **Biogeochemical cycling between soils and plant communities is considered critical in ensuring that the ecosystem is self-perpetuating and sustainable** (Macdonald et al., 2012).

On a practical level, forest ecosystem diversity created through these processes of interactions between soils, understory and overstory layers can be organized and understood through ecological classification systems. Ecological units like those described below are commonly used by practitioners to describe pre-disturbance plant communities and end land use targets. In Alberta, forested regions include the boreal forest, foothills and rocky mountain natural regions, which are subdivided into natural subregions (e.g., dry mixedwood and central mixedwood natural subregions) based on climate and landscape. Natural subregions are then subdivided into ecosites based on moisture and nutrient regimes. Ecosites are subdivided into ecosite phases based on overstory species composition. There are three main broadleaf tree species that dominate Alberta forests: trembling aspen, balsam poplar and white birch, and six main conifers: jack pine, lodgepole pine, balsam fir, white spruce, black spruce, and tamarack. Each species has different ecological properties, growth rates and tolerances for shade, moisture and nutrient regimes (reviewed Bergeron et al. (2014) and Macdonald et al. (2012). Overstory species composition are often used to define stand types across the landscape (e.g., pine vs. mixedwood aspen-spruce forests) and have traditionally been the focus of forest research (Nilsson and Wardle, 2005).

Ecosite phases are then subdivided into plant community types based on understory species composition. Understory plant communities typically have a much higher species richness and diversity than the overstory. The forest understory is an important but often underrated component of the forest ecosystem (Nilsson and Wardle, 2005). Forest function is enhanced by species diversity in the understory layer, which results in a range of functional types and traits that can support a wider variety of wildlife species at multiple trophic levels (Chávez and Macdonald, 2010; Melnik et al., 2018). Additionally, through competitive interactions, understories can discourage invasion by undesirable species, and can influence succession of desirable species (Osko and Glasgow, 2010).

Ecosites, ecosite phases and plant community types are described in the *Field Guide to Ecosites of Northern Alberta* (Beckingham and Archibald, 1996) and the *Field Guide to the Ecosites of West-Central Alberta* (Beckingham et al., 1996). The *Guide to Range Plant Community Types and Carrying Capacity for the Dry and Central Mixedwood Subregions in Alberta* uses a related but slightly different system that takes into account plant community response to disturbance (Moisey et al., 2016). The terms ecological sites and ecological site phases replace ecosite and ecosite phase; the term plant community type is used in both systems (Moisey et al., 2016). The *Guidelines for Reclamation to Forest Vegetation in the Athabasca Oil Sands Regions* uses site types as target end land uses instead of ecosites or ecosite phases (Alberta Environment, 2010). A site type is a broader vegetation unit that encompasses two or three ecosites based on similarity in soil moisture and nutrient regimes and overlap in dominant and subdominant species (e.g., moist rich site type encompasses the d and e ecosites). These guides and classifications provide references for the natural range of variability within and among ecosites in a region, which can be used for evaluating restoration of ecological function.

Sustainability of functional upland forests can be measured as resilience. Resilience refers to "the capacity of an ecosystem to resist and recover from a perturbation or disturbance, [and return to the pre-disturbance state and maintain] its essential characteristics, taxonomic composition, structures, ecosystem functions, and process rates" (Welham, 2013). Natural, undisturbed forests have resilience because they have a historical legacy (seed and propagule bank, litter, coarse dead organic matter and natural capital), which act as sources for ecological recovery and influences patterns of self-organization after a disturbance in a manner that regenerates the ecosystem's previous structure, composition and function (Welham, 2013).

Ecological restoration literature suggests that measurement of whether a restored site has recovered and is self-supporting should focus on three components: vegetation structure, species diversity and ecosystem processes; measures of vegetation alone are not sufficient (Ruiz-Jaén and Aide, 2005).

Ruiz-Jaén and Aide (2005) specify that (citations removed):

> "Measures of vegetation structure provide information on habitat suitability, ecosystem productivity, and help predict successional pathways […]. Measures of species diversity provide information on susceptibility to invasions (e.g., proportion of native and exotic species), and trophic structure necessary for ecosystem resilience […]. Measures of ecosystem processes

provide information on biogeochemical cycles and nutrient cycling necessary for the long-term stability of the ecosystems […].”

Some examples of vegetation structure measures include vegetation cover, tree height and diameter at breast height (DBH) while species diversity measures include vegetation species composition and also insect and wildlife composition, and ecosystem processes include litter production, litter turnover, nutrient content and nutrient cycling (Ruiz-Jaén and Aide, 2005).

Forest ecosystem recovery for reclaimed wellsites in Alberta is currently assessed using the forested lands criteria, in the context of determining whether a reclaimed wellsite meets equivalent land capability and can receive a reclamation certificate. A recent study on ecological recovery on previously certified forested wellsites suggests the addition of three additional components to the forested lands criteria: (a) desirable plant species diversity (particularly shrubs) or the conditions that promote this diversity (e.g., microtopography and bulk density), (b) growth and stocking of tree species on natural recovery sites and (c) coarse woody material (Dewey et al., 2017).

In the mineable oil sands industry, instead of the forested land criteria, a very detailed framework was developed to identify the appropriate criteria and indicators to evaluate the success of oil sands mining reclamation and readiness for certification (Alberta Environment and Sustainable Resource Development, 2013c). Oil sands reclamation occurs on a much larger scale than wellsites, which may warrant a more complex framework for evaluation.

This framework distinguishes three reclamation objectives:

- Reclaimed landscapes are established that support natural ecosystem functions
- Natural ecosystem functions are established on the reclaimed landscape
- Reclaimed landscapes support an equivalent land capability appropriate to the approved end land uses

Within each objective, several criteria and indicators were developed to assess whether objectives have been achieved. Indicators relevant to wellsite reclamation (and therefore excluding those related to geotechnical stability, end pit lakes, wetlands) include soil depth, soil pH, soil salinity, plant community composition, weed species richness, foliar nutrients, ecosystem net primary productivity (or site index as a proxy), ecosystem health (or leaf area index, foliar chlorophyll content or foliar nutrients as a proxy), resilience (or weed species richness as a proxy), species diversity, richness, evenness and abundance, species and community diversity, tree regeneration, tree health and vigour, tree height, as well as several indicators related to wildlife and wildlife habitat, and land use (wildlife habitat, traditional use, and recreational use).

3.1.2 *Outreach Responses Related to Ecological Function of Upland Ecosystems*

Outreach participants were asked two questions relevant to ecological function: (1) how do you define and evaluate ecosystem function and (2) how do you determine if a site is on an appropriate trajectory for natural revegetation to achieve equivalent land capability. Answers to both questions were related and are summarized here; discussions pertain to both upland sites and sites that have had mineral soil pads left in place in peatlands but have been reclaimed to upland forests.

There was a considerable difference in views of respondents relative to the key factors determining equivalent land capability. Outreach responses generally suggest that achieving equivalent land capability means re-creating a functioning ecosystem able to support, in this case, a forested land use that may include wildlife utilization, recreational users and/or merchantable timber. This acknowledges that ecosystem function and equivalent land capability go hand in hand, although equivalent land capability also incorporates current and future land use and trajectories, while ecosystem function is usually described in terms of current state (and does not include land use). End land use goals were noted as a key factor in determining what the expectations of the site should be.

Outreach respondents defined a functioning upland forest ecosystem as an assembly of the typical biotic components of a forest ecosystem (i.e., flora and fauna species) and suitable abiotic components that support those biotic components, and that provides wildlife habitat, carbon sequestration, nutrient and water cycling, pedogenesis, and temperature regulation.

Resilience to disturbance was also included in responses as a characteristic of a functional ecosystem. One respondent noted that sites with a history of grasses and weeds may respond differently to a disturbance. They may become dominated by grasses and weeds after disturbance and may not recover to a functioning forest. Evaluation of the propagule bank would be helpful in assessing the potential of this occurring. **Respondents also noted that another aspect of determining whether ecosystem function and equivalent land capability have been replaced was that a site should not be impacted by limitations imposed by site conditions, which can include (but are not limited to) soil rooting restrictions, erosion, slumping, drainage issues (ponding), or debris (noting that site limitations that are inherent qualities of the site and were not impacted by disturbance and reclamation would not be included in this, such as dry moisture regime or poor nutrient status).** One respondent suggested that the goal (over potentially a 100 to 200 year timeframe) is that the wellsite is indistinguishable from the surrounding area on an air photo. That being said, several respondents referred to situations where ecosystem function can be deemed to be re-established even if it does not match the pre-disturbance or off-site ecosystem function (e.g., pads left in place).

A few respondents commented on the relevance of larger regional implications in evaluating return of ecosystem function and equivalent land capability. Responses differed, with one respondent suggesting that function can be assessed on a site by site basis, with the exception of land use changes which must be considered in a regional context, while another respondent was of the opinion that we cannot simply think of the function of individual sites, we need to consider the ecosystem function of the region as a whole and the net environmental benefit. One respondent did note that they had doubts about whether meeting the criteria was truly an indication that pre-disturbance ecosystem function was returned. Several respondents had concerns about the effects of landscape, vegetation and soils requirements in the criteria potentially limiting (setting back) achievement of natural recovery and equivalent land capability and/or creating unnecessary work, which is discussed further below.

Vegetation composition was a focus for many respondents in defining ecosystem function and equivalent land capability. Some suggested that trees were the most important component, as the establishment of a tree canopy is believed to direct the development of all other species. Several others considered vegetation more broadly than solely trees, and suggested that if forest vegetation recovery occurs, the other components will "equilibrate." For example, woody vegetation was believed to drive the trajectory of the site through forest floor development, soil temperature and moisture regulation and attraction of wildlife which results in the spread of propagules and nutrient cycling. Others viewed soils as the foundation of the ecosystem, and vegetation merely the response. Respondents had several specific comments about vegetation, soils, landscape, and wildlife components of ecosystem function and equivalent land capability which are discussed below.

Several were of the opinion that functional upland ecosystems have several structural layers (ground cover of mosses, lichens, ericaceous shrubs; herbaceous plants; tall shrubs; trees), and that each structural layer should have a variety of species (species richness and diversity; one respondent suggested that there should be 2 to 3 tree species, 2 to 3 shrub species, 3 to 5 herbaceous species and 3 to 5 non-vascular species, depending on the ecosite) that are comparable to the species found off site (or at least in stands with similar moisture/nutrient regimes), noting that vegetation composition must be considered in the context of the stage of succession of the site. As noted above, there were different views on the importance of trees, woody vegetation or vegetation as a whole in the return of function and equivalent land capability. One respondent suggested that, beyond the structural layers, the presence of leaf-litter forming species was important for development of self-sustaining nutrient cycling. A few scenarios were mentioned in which species composition may be less important, including transition sites between wetland and upland (peat is less than 40 cm deep) and sites with partial pad removal where the focus is primarily on preventing erosion and weed establishment.

Some respondents suggested that species composition can include early successional species, but that agronomic species should be limited as they can outcompete native forest species. **Most agreed that some noxious weeds could be present, but the ecology and long-term impact needs to be considered on a species by species basis**. Noxious weeds were considered acceptable if they were not out competing desirable vegetation or impacting natural vegetation succession, or if they were declining over time. Respondents observed that small populations of some species (such as perennial sow-thistle) tend to decline as the canopy closes, noting that while noxious weed species may still be present in the seed bank, canopy closure has an overriding effect in directing weed population dynamics. One respondent pointed out that weed species can have positive effects as they facilitate the development of suitable soil conditions.

Current forested land criteria requirements for noxious weeds and herbaceous cover were criticized as respondents have observed that not only are these parameters not essential drivers of site recovery, but also that management practices to correct them simply to meet the criteria are detrimental to site recovery. For example, weed control that destroys woody vegetation in the attempt to remove noxious weeds.

Woody vegetation density (stem counts; currently a component of the forested land criteria) was also noted by respondents as a means of evaluating ecosystem function and equivalent land capability. One respondent noted that the stem counts required by the forested land criteria are not site specific and are not relative to the pre-disturbance or off-site conditions. They perceived that the stem counts in the criteria are based on averages that describe the majority of sites (i.e., mesic, open stands typical of the dry mixedwood natural subregion), but may not be appropriate (too high or too low) for other site types. Another respondent noted that they thought the stem count criteria were based on sufficient research and consultation to provide a sound basis for evaluation.

Additional measures of vegetation were also suggested by respondents, including tree and vegetation health as well as productivity, including tree height, tree diameter, mean annual increment and site index. These values could be compared to off-site or baseline information and would be used as indicators of growth limitations on site. One respondent suggested that mean annual increment would not necessarily have to be comparable to the control, but could be used to confirm that trees are growing.

In terms of soil components of ecosystem function and equivalent land capability, many respondents focused on the soil's ability to support productive and desirable vegetation, with some specifying that soils should be able to support vegetation productivity and composition similar to pre-disturbance or the surrounding area. Measures of vegetation productivity including site index, tree height and tree diameter were suggested as indicators that the soil quality has been replaced. Another respondent suggested the need to examine soil nutrient cycling, which is not currently captured in the forested land criteria, to determine if the site is self-sustaining.

The extent to which soil reclamation criteria are needed to assess ecosystem function was not consistent among respondents. One respondent believed the most important requirement should be that soils are not limiting vegetation growth, such as through rooting restrictions (compaction) in the upper 50 to 100 cm, and that further criteria requirements were secondary and often not necessary. Topsoil depth replacement criteria were criticized because, similar to noxious weed and herbaceous cover criteria, it has been observed to lead to reclamation practices (i.e., importing topsoil) that can be detrimental to site recovery without necessarily providing any benefit to site recovery. In contrast, replacing topsoil to a depth comparable to pre-disturbance or off-site conditions was considered by some respondents to be crucial for returning ecosystem function and achieving equivalent land capability, and they suggested that if soils were not replaced properly (i.e., at a similar depth and distribution as prior to disturbance), the site cannot be considered equivalent as there is too much uncertainty in terms of the long-term capability of the site, even if the vegetation meets the forested land criteria. Yet others suggest that topsoil depth is only relevant if there are limitations to vegetation growth.

On the topic of landscape components, respondents generally agreed that to achieve equivalent land capability and ecosystem function there can be no limiting factors affecting the landscape, meaning that the site is stable, non-erosive, and no slumping is occurring. Bare areas were noted to be an indication of limitations that can impact equivalent land capability. One respondent noted that microtopography and woody debris on the forest floor are part of the landscape component and contribute to return of ecosystem function and equivalent land capability. It was suggested that landscape components must also be considered in context of adjacent lands; contours on site should be similar to the adjacent topography and drainage on site should be conducive to supporting the vegetation species that are present in surrounding forest communities. The extent to which landscape contours should match adjacent topography was inconsistent among respondents, with some suggesting that perfectly smooth transitions should not be required (despite current criteria requirements) as long as the site is stable and does not present a safety hazard. Again, reclamation efforts to correct transitions (cut and fills) were deemed harmful to site recovery and unnecessary as vegetation establishment is not impacted by these irregularities in landscape contours.

In the case of mineral soil pads left in place in peatlands that are reclaimed to upland ecosystems, the response was similar. Respondents said that the key landscape components are that natural surface and subsurface drainage are not impeded (no ponding), slopes are stable, no excessive runoff or soil erosion is occurring, and vegetation trajectory is not affected by the landscape conditions (e.g., drainage and soil moisture conditions are compatible with desirable upland species). On the topic of contour, the focus is not on matching the topography of the pad to the adjacent land as is required on upland sites, but respondents suggested that the contour of pads should blend into existing landscape, meaning the edges should be re-contoured to create a more natural transition to the surrounding peatland (and resemble other upland areas in the region). One respondent suggested several swales could be cut through the pad, with the material removed formed into small hills.

Although not a component of the forested land criteria, provision of wildlife habitat and evidence of wildlife use of the wellsite, at levels comparable to off-site use, were considered factors in evaluating the functioning of upland ecosystems. One respondent suggested a species-specific approach that considers whether the expected wildlife species are using the site.

Respondents brought up site age and time since the last disturbance or activity occurred on site as an important factor in evaluating re-establishment of ecosystem function and equivalent land capability. One respondent pointed out that forest silviculture uses an 8 to 10 year benchmark and suggested that the risks of using a shorter timeframe for wellsites (e.g., three years of growth) are not known. Another respondent brought up the *Reforestation Standards of Alberta* (Alberta Agriculture and Forestry, 2018a), which specify that an establishment survey be conducted at 4 to 8 years after planting, and was of the opinion that when applying for a variance to criteria or a land use change that at least 4 years since planting are required to examine tree recovery. Site age and time since the last activity occurred was suggested to be especially important on sites where vegetation recovery meets forested land criteria despite site and soil characteristics that are deficient (e.g., topsoil depth, rooting restrictions). In these cases, a longer monitoring period is thought to be required to show sustainability of the vegetation trajectory, and lack of potential long-term adverse effects. One respondent has observed cases where soil limitations led to ecosystem "failures" with time, even on certified sites where the vegetation was considered acceptable. That being said, there was also a general sense from some respondents that site age may alter reclamation expectations; that sites that have been revegetating for 30 years would be given more leeway, and might be considered acceptable as long as they have some level of ecosystem function, even if the productivity is not quite equivalent to off-site areas.

3.2 PEATLANDS

3.2.1 *Peer-reviewed and Grey Literature Discussing Ecological Function of Peatland Ecosystems*

Peatlands have unique ecological significance in Canada, where they are defined as terrains covered by greater than 40 cm of organic material formed and accumulated in place due to incomplete decay of plants and animals under water saturated conditions (National Wetland Working Group, 1997). They cover approximately 12% of Canada's land area, with most of them occurring in the boreal and subarctic regions (Tarnocai et al., 2009). At the regional and landscape scale, peatlands regulate water supply, buffer against floods and droughts, supply natural resources (e.g., peat), and function as important habitat for many unique boreal flora and fauna (Benscoter and Vitt, 2008; Bonn et al., 2016a). The development and functioning of boreal peatlands depends on many interacting factors including climate, topography, hydrology, chemistry, and vegetation. Understanding these factors is crucial for evaluating the implications of reclamation activities within peatland ecosystems.

The majority of boreal peatlands in western Canada formed through cycles of paludification or swamping of previously dry mineral soil vegetated with non-wetland species (Kuhry and Turunen, 2006). After initiation, development of a peatland usually proceeds along two pathways (Kuhry and Turunen, 2006; Yu, 2006). First, newly formed wetlands (e.g., marshes) develop into either poor or rich fens that can persist on the landscape for thousands of years under the influence of overriding effects of allogenic (external) factors of climate and local water chemistry with little successional change. Secondly, early marshes and fens undergo successional changes driven by autogenic (internal) factors including the isolation of the growing peat surface from local groundwater as peat builds up, acidification, and oligotrophication, which leads to the eventual formation of bogs (Bauer et al., 2003). Ombrotrophic bogs and poor fens are late successional communities shaped by autogenic processes (true mosses to *Sphagnum* mosses transition) under unique hydrological and chemical regimes (pH less than 5.5). Understanding the type of peatland a mineral pad and/or access road is within is important when considering the implications for pad removal.

Hydrology is by far the most important factor for the development and functioning of natural peatlands. Broadly speaking, boreal peatlands can be divided into ombrogenous bogs and minerogenous fens based on topography, hydrology, and chemistry (Halsey et al., 2003; Vitt et al., 1994).

Bogs are different from all other types of peatlands in that bogs receive water and nutrient inputs only from precipitation (snowfall and rain) and the live growing surface is isolated from mineral rich water. They are usually dominated by oligotrophic (low nutrient demanding) species of peat mosses (genus

***Sphagnum*).** Fens can be topogenous (influenced by stagnant waters pooled in depressions), soligenous (influenced by seepage), or limnogenous (influenced by flood waters from water courses) (von Post and Granlund, 1926; Rydin and Jeglum, 2015). As such, **fens are supplied with water that had contact with mineral rich soils from the surrounding area. These minerogenous waters have nutritional and buffering effects and can support the development of a wide range of fen types, from sedge-dominated open fens to larch- or birch-dominated wooded fens** (Bragazza and Gerdol, 2002; Tahvanainen, 2004; Wood et al., 2016).

Calcareous rich fens are characterized by the large number of species of high fidelity (e.g., true mosses) to base cation-rich, basic to slightly acid environments. Poor fens have relatively few differential species in comparison. They are acid, have low base cations, little or no alkalinity, and are dominated by *Sphagnum* mosses.

Within each peatland type, vegetation can vary greatly, both structurally and compositionally. All peatlands can be dominated by a combination of species in the tree layer (black spruce, larch), the shrub layer (birch, willow), the field layer (sedges, forbs, and grasses), and the ground layer (mosses) (Zoltai and Vitt, 1995). Therefore, vegetation of a peatland is usually not a good indicator of basic peatland types (bogs, poor fens, and rich fens), unlike non-peat forming wetlands that can be easily distinguished by species in the tree layer (swamps) or the field layer (marshes). In Alberta, mature bogs are usually wooded with an open canopy while fens vary greatly from open to wooded. **A ground layer of bryophytes, often covering 80-100% of the surface, is a unique and defining characteristic of the majority of boreal peatland ecosystems. Bogs and poor fens are dominated by *Sphagnum* spp. while moderately rich and rich fens are dominated by true mosses (*Bryopsida*)** (Rydin and Jeglum, 2015)**.**

The development and succession of different vegetation as a peatland evolves is not only a result of local hydrology and water chemistry but also a self-regulated process driven by highly adapted vegetation, particularly mosses. Unlike higher plants, bryophytes lack vascular tissues to transport water and nutrients over long distances (Glime, 2009). Germination and growth of bryophytes are highly sensitive to moisture and temperature (Glime, 2007). This is critical for the introduction of suitable peatland vegetation, particularly bryophytes, in reclamation.

Peatlands, particularly bogs, have varying ground surface topography with high hummocks and low hollows. Hummocks are usually dry, while hollows range from dry (lichen dominated in mature bogs), to wet in fens. At the site level, peatland ground surface can be further divided into pools (small bodies of open water filled with submerged vegetation), carpets (areas where the mosses have emergent upper parts and form unconsolidated substrates), lawns (low, relatively level, moist habitats of consolidated peat), and hummocks (Rydin and Jeglum, 2015).

In most cases, reclamation cannot directly create conditions necessary for the establishment of a bog community on either peat or mineral substrates, regardless of how much mineral material is removed (Nwaishi et al., 2015; Rochefort et al., 2016; Vitt et al., 2011b). However, **microtopography is one feature of a natural peatland that could be replicated through site preparation such as mounding and scarification either on an entire site and/or to help blend the site into the natural landscape.**

Creating a variable ground surface will likely contribute to the overall vegetation diversity and resilience against environmental uncertainties. Higher microsites are critical for woody vegetation establishment in both uplands and wetlands.

For forested ecosystems, trees are widely used as a key indicator of achieving equivalent land capability and overall ecosystem functions. The rationale is that if the site can support the growth of a healthy tree canopy, it is a good indication that appropriate site conditions and processes are in place to support all other functions and vegetation layers. Similarly, a healthy, well developed ground layer dominated by *Sphagnum* and true mosses should be used when assessing peatlands.

The growth of ground layer mosses is both a result of suitable hydrologic and edaphic conditions and a contributing factor to the internal regulation of chemistry, succession, and overall ecosystem functions. Therefore, when considering the impacts of activity within a peatland, the ground layer can be assessed as an indicator of ecosystem health.

3.2.2 *Key Components for Evaluating Ecosystem Function of Reclaimed Wellsites Within Peatlands*

Peatland reclamation of oil and gas infrastructure built with borrowed mineral soil is relatively new in Alberta. Much has been learned about peatland restoration over the past 30 years: see reviews in Bonn et al. (2016b) and Chimner et al. (2017); however, research on reclaiming peatlands disturbed by oil and gas activities has just begun (Gauthier et al., 2018). To date, no research studies have been identified that focus on the implications of leaving a mineral soil pad in place within a peatland, therefore the majority of the information available on reclamation activities within peatlands is related to full or partial removal of mineral material.

Over the last decade, several studies have attempted to reclaim oil and gas well pads to functional peatlands or wetlands across Alberta. Projects have been initiated where mineral soil was either completely removed to expose and decompact buried peat (P-Pad approach[11]) which then received vegetation transferred from a donor site, or the mineral soil was partially removed to lower surface elevation (M-Pad approach) and the site was revegetated with either planted wetland species or left to naturally recolonize. Results indicated that both approaches were able to support the development of peatland vegetation and a net uptake of CO_2 driven by primary productivity of vascular species such as *Salix* spp. and *Carex* spp. (Borkenhagen and Cooper, 2016; Engering, 2018; Gauthier et al., 2018; Nwaishi et al., 2016; Shunina, 2014; Vitt et al., 2011b).

As indicated previously, research has shown that reclamation cannot directly create conditions necessary for the establishment of a bog community on either peat or mineral substrates, regardless of how much mineral material is removed. Instead, when removing a pad from within a bog, a fen type of community with a true moss dominated ground layer should be targeted initially with the assumption that these systems will either remain as fens or evolve towards poor fens and bogs following natural peatland development pathways. However, in some instances full or partial removal of mineral soil material may cause adverse environmental effects off site through repeated access by heavy equipment and disturbance of existing established borrow areas, which warrants further investigation into the feasibility and long term success of modified reclamation practices such as the initiation of peatland vegetation on remnant mineral substrate (partial removal) or leaving pads in place under appropriate conditions. Based on results of early field trials, initiation of the paludification process (initiation of fen vegetation on mineral substrate) after partial removal of mineral soil may be a very practical solution to reclaiming well pads and associated access roads to ensure the recovery of critical peatland functions.

A summary of the key factors affecting peatland function and thus considerations for the factors to evaluate when assessing reclaimed sites within peatlands is provided in Table 2. For a detailed summary of peatland development, bryophyte ecology, and ecosystem functions, refer to Appendix D. There are still many knowledge gaps when it comes to removing mineral fill and introducing suitable fen vegetation. See Appendix D for a list of characteristics a functional peatland or a reclaimed site on the trajectory towards becoming a functional peatland should have and Appendix B and D for detailed case studies of full and partial pad removal approaches to reclaim in-situ features to peatland.

[11] The "P" in P-pad approach refers to peat being present at the surface; the P-Pad approach can also include pad inversion techniques were pad material is placed below (buried under) the peat. The "M" in M-Pad approach refers to mineral material being present at the surface.

Table 2. Summary of key factors affecting peatland function.

Factor		Natural Peatland: Bogs	Natural Peatland: Fens
Hydrology	Local	precipitation/rain fed (ombrogenous)	multiple sources/inputs, flow through
	Regional	perched growing surface isolated from groundwater or mineral water	topogenous, soligenous, limnogenous, contact with mineral soil ground water exchange
	Water Table	20 cm below surface	at, near or above surface
	Drainage	drain away from bog surface to surrounding	poorly drained, pooling of water
Topography		overall flat, hummocky terrain	relatively flat, microtopographic features; patterned
Vegetation	Trees	black spruce	larch
	Shrubs	Labrador tea, small bog cranberry	birch, willow, leatherleaf
	Herbaceous	cloudberry, cotton grass, pitcher plant	sedges, buckbean, Solomon's seal
	Bryophytes	*Sphagnum* mosses	*Sphagnum* to true mosses to low moss
Chemistry	Acidity/ Alkalinity	acidic (pH 3-5), no to low alkalinity	acidic to neutral to alkaline
	Nutrient	low alkalinity, low available nutrients (N, P), low base cations	mid- to high alkalinity, elevated nutrients and cation
Soil		thick organic, moss peat	thick organic, moss to sedge to woody peat
Carbon Dynamics		low productivity and slow decomposition, recalcitrant plant biomass, net uptake of carbon and storage as peat	low to high productivity, slow to moderate decomposition, labile carbon, net uptake of carbon and storage of peat

4.0 UPLAND SITES WITH NATURAL VEGETATION ENCROACHMENT

This section describes the factors that would lead an operator to request a variance to criteria, and the Alberta Energy Regulator to grant approval. The section also provides information on the implications of the variance to criteria in terms of the range of landscape and soils conditions that would likely be present, summarizes the reclamation options for a variance to site criteria, and the certification criteria that are applied.

A site with natural vegetation encroachment is a site where vegetation has become established, but which presents one or more deficiencies in terms of current regulatory criteria. The common reclamation deficiencies encountered at these sites include:

- Cut and fills
- Subsidence
- Soil stockpiles/windrows left in place
- Topsoil not conserved
- Coarse woody material piles left in place
- Noxious weeds and undesirable species

4.1 KEY CHALLENGES

In the management of upland sites with natural vegetation encroachment, challenges arise when vegetation parameters meet the forested land criteria while soil and landscape parameters do not, but neither has hindered the establishment of forested site conditions. In these cases, there is room for interpretation within current legislation, policies and criteria as to what the acceptable conditions are for approval of a variance, and whether the site qualifies for a variance to criteria and therefore a reclamation certificate. As a result, operators, practitioners and regulators have difficulty in deciding whether a site requires further reclamation or whether the current conditions can be justified. More clarity is needed in terms of defining the acceptable conditions for determining when a site meets equivalent land capability and the requirements of a reclamation certificate application, including justifications for reclamation deficiencies.

The following are examples of reclamation deficiencies which require consistent definitions of the range of acceptable conditions:

- Height and size of cut and fills
- Size and depth of subsided areas

- Presence and size of soil stockpiles/windrows or coarse woody material piles left in place
- Lack of soil conservation
- Allowable quantity of noxious weeds and definition of when noxious weeds are considered to be controlled
- Presence and allowable quantity of undesirable species

Without a formal definition of acceptable conditions, operators, practitioners and regulators in different offices or regions may have differing views on what constitutes a reclamation deficiency and what the acceptable conditions are for professional justification, resulting in different levels of reclamation effort being applied by operators. To inform decisions on the acceptable conditions, more analysis is needed on the implications and trade-offs of correcting the reclamation deficiencies compared to any environmental implications associated with correcting them.

4.2 CONDITIONS ON SITES WITH NATURAL VEGETATION ENCROACHMENT

This section describes the range of conditions that are likely to be found at sites with natural vegetation encroachment, where vegetation meets the vegetation component of the criteria for forested lands in terms of desired plant species for the site's reclamation date, but (1) may not meet the criteria for weeds; and, (2) the site may fail to meet landscape or soil components of the forested land criteria (Alberta Environment and Sustainable Resource Development, 2013a). Table 3 provides the current forested lands criteria for the common reclamation landscape, soil and weed deficiencies that are discussed in this report.

Table 3. Current criteria requirements for common reclamation deficiencies.

Deficiency	Current Criteria	Section‡
Cut and fills	Landscape criteria (operability): • Macro- and meso-contours on site are comparable to off site • Macro- and meso-contours are not affecting site management • Macro- and meso-contours shall not result in excessive erosion, slumping/wasting or altered water flow patterns	9.5
Subsidence	Landscape criteria (stability): • Areas of subsidence are < $4m^2$ and unlikely to risk the site's stability • Any subsidence >4 m^2 occurring on site is consistent with that observed off-site	9.3.2

Deficiency	Current Criteria	Section‡
Soil stockpiles left in place	Landscape criteria (operability): • Macro- and meso-contours on site are comparable to off site • Macro- and meso-contours are not affecting site management • Macro- and meso-contours shall not result in excessive erosion, slumping/wasting or altered water flow patterns Soil criteria (depth and distribution): • Topsoil has been adequately replaced as per topsoil depth and distribution requirements by construction date	9.5, 11.1.3.1 and Table 3
Coarse woody material piles left in place	Landscape criteria (debris): • Coarse woody debris shall be spread over the site and may not be piled, windrowed or concentrated in one area as this may pose a fire-hazard, particularly in areas near settlements	9.6.1
Noxious weeds	Vegetation criteria (weeds): • Noxious weeds must be controlled as per the *Weed Control Act* • Presence on site must be comparable to off site or must be from a single point source off site	10.4 and Table 3
Undesirable species	Vegetation criteria (weeds): • Undesirable/problem species should be controlled and should not require species management of the site (i.e., herbicide application) • Presence on site must be comparable to off site or must be from a single point source off site	10.4 and Table 3
Lack of soil conservation (no topsoil)	Soil criteria (soil depth and distribution): • Topsoil has been adequately replaced as per topsoil depth requirements by construction date	11.1.3.1 and Table 3

‡Refers to the section of the *2010 Reclamation Criteria for Wellsites and Associated Facilities for Forested Lands* where the criteria for that parameter can be found (Alberta Environment and Sustainable Resource Development, 2013a).

Cut and fill is a construction technique for wellsites and access roads located on slopes whereby soil material is excavated from the upper slope portion of the site and used on the lower slope portion of the site to create a level surface for the drill rig and associated work areas. During reclamation it can be challenging to replace the excavated material correctly to match the off-site topography, particularly if snow gets mixed in with soils during replacement and settling (subsidence) of the placed material occurs. Best practice is to over build cut and fills with the expectation that the over built material will settle (Cenovus Energy, 2016; Osko et al., 2018b); however, it is difficult to predict actual settling rates. The height of cut and fills (i.e., the difference in elevation between on-site and off-site areas) varies with material type, but typically ranges from 0.2 to 1 m; in rarer cases can be greater than 3 m and up to 10 m in mountainous regions (Acden Vertex Limited Partnership, personal communication 2019).

Subsidence is defined as "lowering of the soil surface due to a reduction in volume through settling or other means" (Powter, 2002) and occurs in localized areas where soil settling occurs unevenly (e.g., at well centre, or in association with cut and fills). The presence of snow mixed in with soil materials during reclamation can result in subsidence. Subsided areas can typically range in size from 1 m^2 to 10 m^2 on well centres and over 100 m^2 on sumps or pits, and typically range in depth from 0.2 m to 0.6 m, although can be up to 1 m deep (Acden Vertex Limited Partnership, personal communication 2019). Slopes leading to subsided areas can range from gradual to abrupt. Subsided areas can be associated with slumping and erosion, or ponding.

Soil stockpiles that are left in place may include topsoil and subsoil stockpiles and are often less than 1 m tall but can range in height up to 3 m (Acden Vertex Limited Partnership, personal communication 2019). Soil stockpiles on wellsites are typically shaped as long, narrow windrows. Similarly, coarse woody debris piles left in place are often less than 1 m tall but have been observed to range up to 2 to 3 m high (Acden Vertex Limited Partnership, personal communication 2019). Piles are typically along the edges of wellsites, at the edge of the active work area, or on log decks.

Older sites may have been constructed and operated without first salvaging and stockpiling topsoil for reclamation, and management and use of the site has resulted in loss of the topsoil layer. This also occurs on sites that were constructed by placing a mineral soil pad on top of undisturbed peatlands or transitional soils, and that mineral soil pad is to remain in place at closure, the implications of which are discussed in Section 5. Another scenario that may have occurred on legacy sites is that topsoil and subsoil were salvaged together during construction, resulting in an admixed soil with lower organic matter, altered soil texture and other modified properties no longer consistent with the original topsoil.

Prohibited noxious and noxious weeds are those listed in the *Weed Control Regulation* (AR 19/2010) (Government of Alberta, 2010) under the *Weed Control Act* (Government of Alberta, 2008), while undesirable species are incompatible species as defined by the forested land criteria (Alberta Environment and Sustainable Resource Development, 2013a) to be species that are not appropriate for the target/representative forest ecosite and/or are not seeded species that were part of a seed mix that was appropriate to the time period in which reclamation took place. Prohibited noxious weeds are not commonly found in the boreal forest in Alberta (Small et al., 2018), and are not typically a concern for wellsites. Noxious weeds are more common, and occurrences can range from a single patch with less than 10 plants to site wide infestations with thousands of plants. Similar to what was found by Small et al. (2018) for oil sands operations, the typical noxious weed species on forested wellsites include perennial sow-thistle, scentless chamomile, Canada thistle, oxeye daisy, and common tansy (Acden Vertex Limited Partnership, personal communication 2019).

4.3 TRADITIONAL RECLAMATION APPROACH

Sites that fail to meet forested land criteria require active reclamation to correct the deficiencies (e.g., recontouring, spreading soil or woody material stockpiles, importing topsoil). Reclamation typically requires that heavy equipment be mobilized to, and used at the site, resulting in the removal of trees and other existing vegetation on the access road and on all or part of the wellsite, and potential soil compaction. Site access may also require creek crossing and ice road construction.

To correct landscape contour (cut and fill) and subsidence issues, topsoil that was replaced during original reclamation must be re-stripped from the area to allow subsoil to be recontoured. Recontouring is conducted to re-shape the on-site contours to match the surrounding topography and ensure that drainage patterns do not cause ponding or erosion on or off site. For subsided areas, recontouring may require the addition of material (typically imported peat, sand or clay or potentially material sourced from an elevated area on site) to fill the void and match the grade to the remainder of the site. Topsoil is then replaced once re-contouring is complete.

If there was insufficient topsoil conserved on the wellsite to meet the soil replacement depth criteria for the site's construction and reclamation date, or if topsoil was admixed with subsoil, topsoil must be sourced from an alternate location and transported to the wellsite to meet the forested land criteria without applying for a variance to criteria. Imported topsoil must be characterized before use (e.g., texture, lab analyses, volume, weeds) and be comparable to the control topsoil quality (e.g., chemistry, structure, texture) (Alberta Energy Regulator, 2018; Alberta Environment and Sustainable Resource Development, 2013a). Topsoil is often not locally available to import, in which case amendments or fertilizers can be applied to support vegetation re-establishment; a variance to criteria is required to allow for the insufficient topsoil depth. Use of amendments or fertilizers results in a delay to certification due to the required two year waiting period post-amendment/fertilization (Alberta Environment and Sustainable Resource Development, 2013a).

After soil recontouring and placement is complete, some operators choose to actively revegetate the site, typically through tree and/or shrub planting, while others opt to leave the site for natural vegetation recovery. Seeding grass and/or forb species is not currently a common practice on forested wellsites as current criteria require that species on site be matched to representative ecosites of control areas (Alberta

Environment and Sustainable Resource Development, 2013a); however, more proactive vegetation strategies to prevent weed establishment in weed prone areas (e.g., areas with higher levels of nearby activity) or erosion on steep slopes are employed in site-specific circumstances.

Sites that fail to meet forested land criteria in terms of noxious weeds require noxious weed control. Typically weed control is conducted through chemical herbicide application. Application strategies range from spot-spraying with back-pack sprayers to broadcast spraying with an ATV (all-terrain vehicle), UTV (utility vehicle) or truck mounted sprayers. Additionally, as with active reclamation practices, truck, ATV or UTV access to the site is required for weed control, resulting in vegetation removal or disturbance on the access road. Desirable vegetation on the site is also removed or disturbed by spray equipment as well as by herbicide overspray, particularly with broadcast spraying. Four to six years of herbicide application is common for heavily infested sites. Aggressive noxious weeds and non-native species can be difficult to manage when they are well established and a substantial seed and propagule bank has developed in the soil (Mihajlovich et al., 2014).

4.4 PROCESS AND FACTORS AFFECTING THE DECISION TO APPLY FOR A VARIANCE TO CRITERIA

A site with natural vegetation encroachment which presents one or more reclamation deficiencies in terms of current certification criteria can be eligible for a variance to criteria. Some sites may be eligible for a specific type of variance referred to as a vegetation override if the following conditions are met (Alberta Environment and Sustainable Resource Development, 2013a):

> *Where reasonable forest cover (i.e., amount, species and distribution) is present, and where additional activities are required to meet the conditions described in [the forested lands criteria] pose a risk to existing ecosystem function, a vegetation override may be appropriate. Equivalent capability for forested landscapes must be demonstrated.*

The definition for *reasonable forest cover* is not explicitly defined in the forested lands criteria, but could be assumed to refer to the current criteria for desired plant species density and cover. Sites that do not meet the criteria for reasonable forest cover, but that do meet the vegetation criteria specified for their construction and reclamation dates (e.g., 80% cover), while not eligible for a vegetation override, are still eligible for a variance to criteria.

Many outreach respondents largely agreed that criteria variances are applied for when the vegetation meets criteria but landscape, soil, or weed parameters have deficiencies. In particular, the stem density requirement is most often used to determine if a variance to criteria is warranted; industry may seek variances where woody stem density passes (regardless of composition of woody vegetation), but the herbaceous component does not, because woody vegetation is seen as the main driver of succession. One participant noted that the variance request can be denied if the vegetation is not desirable and lacks species diversity and evidence of structural layers, even if the woody stem density requirements are met, indicating that, as outreach participants also noted, variances are poorly defined and there is uncertainty in the thresholds that will be accepted by the regulator. From a regulatory point of view, the intent with a variance is still to ensure that the site will be on a trajectory towards a functional forested ecosystem, providing appropriate ecosystem services such as wildlife habitat as opposed to an anomaly which sticks out in the middle of a forest.

While some outreach respondents were firm that vegetation establishment is more important than other considerations, many acknowledged that there can be factors in addition to vegetation to consider in determining whether to apply for a variance to criteria, which in the context of this report is referred to as using a modified reclamation approach (i.e., leaving landscape, soil and/or weed deficiencies in place). **There are two main categories of factors to consider: the first is consequences of leaving the deficiencies in place (and whether the deficiency is impeding equivalent land capability and ecosystem function), and the second is consequences of conducting traditional reclamation practices.**

Consequences of leaving the reclamation deficiencies in place may include:

- On- and off-site impacts related to landscape, soils, and weeds
- Safety hazards
- Cumulative effects

Additionally, the negative consequence of leaving deficiencies in place must be considered in terms of the actual size and scale of the deficiency; deficiencies can be quite localized, and may not impact the ecological function of the wellsite as a whole.

Consequences of conducting traditional reclamation practices to correct deficiencies may include:

- Removal of existing trees and other vegetation
- Slowed ecological recovery
- Potential for weeds
- Weed control

Remoteness and access considerations are factors in both the consequence of leaving deficiencies in place and of conducting traditional reclamation practices to correct deficiencies.

4.4.1 *Consequences of Leaving Deficiencies in Place*

Based on outreach responses and an analysis conducted by the authors, the on- and off-site impacts of leaving deficiencies in place are as follows:

- Cut and fill can result in slumping, erosion, and altered drainage pathways on and off the site (e.g., damming, ponding)
- Subsided areas can result in slumping soils, erosion or ponding of water
- Soil windrows left in place can alter drainage pathways
- Woody debris piles left in place can prevent vegetation establishment within the area occupied by the pile and can be considered a fire hazard if they encroach into the surrounding undisturbed forest and act as a ladder fuel (Alberta Environment and Parks, 2018b)
- Subsidence, cut-and-fills and soil and woody material stockpiles left in place can all have impacts on the trafficability/operability of the site, restrict or alter wildlife movement and can be an aesthetic concern (appear unnatural) for recreational and traditional users
- Failure to re-distribute topsoil results in lack of topsoil on portions of the site. Lack of topsoil can result in delayed vegetation establishment due to lack of propagules and/or lack of organic matter and nutrients to support plant growth
- Noxious weeds can compete with desirable vegetation on site and slow vegetation recovery to targeted forest ecosystems and have the potential to spread off site into adjacent undisturbed areas and require weed control

Several outreach respondents agreed that whether or not these impacts occur as a result of the deficiency should be a key point in evaluating whether the deficiency is acceptable to be left in place. The presence of the deficiency itself may not necessarily be a problem if on- and off-site impacts do not occur as a result of the deficiency being left in place and vegetation recovery, ecosystem function and equivalent land capability are not impeded. For example, some respondents have observed that cut and fills that are up to 2 m high do not have an impact on the ecosystem function, provided that the cut and fill area is stable and not slumping or eroding. Deficiencies must also be considered in the context of natural forested conditions, as well as regulatory requirements and conditions created by reclamation practices in other industries that operate in forested areas, which will be discussed throughout the following sections.

4.4.1.1 Landscape Issues

Relevant literature related to landscape deficiencies and the potential consequences of leaving them in place and/or modified reclamation was reviewed; a summary of the information is provided, supported by interview responses.

It was determined that the main considerations for landscape deficiencies left in place include:

- **Whether impacts result from deficiencies, and the severity of these impacts: presence of slumping, erosion, altered hydrology and drainage pathways (damming, ponding), impaired trafficability/operability of the site, restricted wildlife movement, aesthetic concerns for recreational and traditional users**
- **Height and/or depth of the feature relative to the surrounding area (scale), and how it compares to similar features in undisturbed forests and reclamation in other industries**
- **Actual fire hazard of woody debris piles based on location of pile on site (edge, centre), surrounding timber type (deciduous vs. coniferous) and on-site vegetation (dense vs. sparse grass)**

Site stability was viewed among many respondents as an important factor to determine whether landscape deficiencies were acceptable to be left in place. The extent to which impacts caused by landscape features were considered acceptable was variable among respondents. While some respondents felt that any level of impact was not acceptable, others felt that there could be allowable levels. For example, one respondent suggested that only those deficiencies that are unstable require additional reclamation while others can be left in place. Other respondents implied that some levels of erosion could be considered acceptable, and only substantial erosion that does not stabilize itself through vegetation encroachment would be a concern for reclamation certification. The same view, though not explicitly stated, may apply for slumping or ponding.

Soil stockpiles left in place can be considered from a landscape and a soils perspective. From a landscape perspective, some would argue that if they are stable they can be left in place. From a soils perspective, the impact of stockpiles is on the topsoil depth and distribution on the remainder of the site, which is discussed in Section 4.4.1.2.

End land use is another factor to consider in evaluating landscape features left in place. One respondent pointed out that in the forestry industry, landscape features are considered in the context of operability for commercial forest equipment. As long as a cut and fill does not impede operability of commercial forest equipment, it would be deemed appropriate to be left in place for a commercial forest production end land use.

Many of the landscape deficiencies are comparable to landscape conditions created in other industries during reclamation, indicating that ecosystem function is likely not negatively influenced. For example, creation of a rough and loose microtopography (Polster, 2011) is a common practice during soil replacement at coal mines and oil sands mines; microtopography is created by progressively digging holes with an excavator bucket and dumping the material beside and partially inside the hole across a reclaimed area (Polster, 2011), or by spreading topsoil unevenly during replacement using either an excavator (Osko et al., 2018b) or a bulldozer that makes very few passes (Alberta Environment and Water, 2012; Archibald, 2014; Mackenzie and Naeth, 2010). Recent reclamation trials on reclaimed oil sands mining areas created microtopographic features (hills) up to 1.5 m tall, 3.5 to 5 m wide and spaced 1 to 2 m apart; these features promoted increased species diversity and plant abundance during natural vegetation establishment, particularly on east facing aspects (Melnik et al., 2018). Microtopographical diversity (size of microtopographical features not quantified) also promoted natural regeneration of aspen from seed in coal mine reclamation (Schott et al., 2014).

Similarly, although in a peatland, after removal of an oil sands in situ well pad, the underlying peat and approximately 10 cm of the remaining pad were reclaimed to a rough surface with mounds up to 1 m tall; transplanted woody vegetation had increased survival on upper portions of mounds and the microtopography was considered beneficial to mitigate a fluctuating water table (Shunina et al., 2016).

Mounding is used as a site preparation technique in the forestry industry to improve survival and growth of planted trees as well as natural regeneration of trees (e.g., white spruce) from seed due to warmer soil temperatures and reduced seedling smothering by leaf litter (several authors reviewed in Gärtner et al. (2011)). Mounds in the forestry industry range from 30 to 40 cm tall and approximately 0.5 to 0.6 m^2 in size (DeLong et al., 1997; Gradowski et al., 2008). Microtopographical variation is similar in height to the depths observed with subsidence, although subsided areas are typically larger than an individual mound.

Mounding has also been used in the oil and gas industry in the context of caribou habitat restoration trials on seismic lines, access roads, pipelines and wellsites in peatlands and forested areas, to create microsites to promote revegetation and limit human use of corridors. Recommended mounding practices are to dig holes approximately 75 cm deep and place the excavated material directly beside the hole at an application rate of 600 to 2,000 mounds/ha (Bentham and Coupal, 2015). Mounding at this scale successfully deters recreational use of linear features (e.g., ATVs).

Subsidence at well centre can be comparable to pit and mound microtopography created by windthrow in undisturbed forests (Figure 5), although the area occupied by subsided areas is often larger. Windthrow pits can be up to 55 cm deep and mounds up to 100 cm tall in pine dominated forests (Kuuluvainen and Juntunen, 1998), and in (28 year old) aspen dominated forests pit depths can range from 15 to 25 cm and mound height can range from 44 to 53 cm with total disturbed area of 1.6 to 2.1 m^2 (Lee and Sturgess, 2002). Pit and mound microtopography plays an important role in maintaining tree and understory populations and in increasing species and structural diversity in undisturbed forests (Kuuluvainen and Juntunen, 1998; Ulanova, 2000).

Figure 5. Windthrow in a forest stand in the Dry Mixedwood Natural Subregion of the Boreal Natural Region in central Alberta.

Coarse woody material piles left in place on wellsites may be comparable to conditions created by reclamation practices in other industries. Coarse woody material management on OSE sites can include a variety of spreading and windrowing techniques. In recent literature on OSE reclamation, coarse woody debris windrows are proposed as an alternative to spreading for dealing with coarse woody material at some sites (especially sites with high wood volumes) because windrows reduce the total area of soil in direct contact with coarse woody material (Frerichs, 2017; Frerichs et al., 2017). Open soils are warmer which may stimulate soil productivity and aspen suckering (Frerichs, 2017).

There are concerns that coarse woody material piles left in place are a fire hazard. Current requirements of the *Master Schedule of Standards and Conditions* (Alberta Environment and Parks, 2018b) are to ensure that (a) coarse woody material storage piles do not encroach into the surrounding undisturbed forest, (b) coarse woody material is spread during reclamation, (c) the amount of slash and coarse woody material within 5 m of the site edge is not to be greater than that found on the surrounding undisturbed forest floor, and (d) coarse woody material coverage is less than 50% of the ground surface. All of these are meant to minimize the creation of ladder fuels to undisturbed timber. Fire risks are considered to be higher in coniferous forests (Alberta Environment and Parks, 2018b), if the vegetation on site is grass dominated, particularly tall, dense grass populations as opposed to shorter and less dense grasses (Canadian Association of Petroleum Producers, 2008), and if the pile of woody material is located on the edge of the site vs. a more central location. The risk of fire spread presented by coarse woody material piles on wellsites is lower than on linear features as linear features can act as a wick and wildfire can spread long distances along them (Canadian Association of Petroleum Producers, 2008). Risk of fire spread from piles on wellsites is also considered to be lower than in forestry cutblock settings due to the small size of wellsites; cutblocks are much larger and windrows of woody material are more likely to contribute to fire spread (Frerichs, 2017).

For forest operations in Alberta, the *Alberta Timber Harvest Planning and Operating Ground Rules Framework for Renewal* require that residual slash be disposed of, typically through burning, within 24 months (Government of Alberta, 2016); however, the *Debris Management Standards for Timber Harvest Operations* (Alberta Agriculture and Forestry, 2018b) allow for debris retention provided that piles meet the following guidelines: height is less than 2 m, base diameter less than 3 m, distance between piles is greater than 15 m, distance from standing timber is greater than 25 m, and the pile is not intended for disposal.

4.4.1.2 Soil Issues

Relevant literature related to soil deficiencies and the potential consequences of leaving them in place and/or modified reclamation was reviewed; a summary of the information is provided, supported by interview responses.

It was determined that the main considerations regarding soil deficiencies left in place include:

- **Whether impacts result from deficiencies: evidence of delayed vegetation growth, reduced vegetation productivity, altered species composition or delayed successional pathways due to lack of topsoil**
- **The actual topsoil deficit: topsoil is present but the depth is reduced compared to the control vs. a complete lack of topsoil**
- **Site and soil conditions (soil moisture and nutrient regime (ecosite) and local availability of propagules)**

In terms of soil deficiencies or limitations that may or may not be acceptable to be left in place, topsoil depth and rooting restrictions (compaction) were brought up most frequently by outreach respondents. Rooting restriction was generally not considered by respondents to be acceptable to be left in place due to potential effects on vegetation growth and productivity; limitations to equivalent land capability in the longer term related to compaction and rooting restrictions have been observed. However, one respondent stated that rooting restrictions could be justified if the stem density was acceptable, although another respondent noted that site age would be a factor in these types of justifications, with long-term vegetation data required to show that there were no impacts.

There was significant disagreement among respondents on the issue of topsoil depth. Some felt that topsoil must be replaced to a depth (and variability) similar to what existed prior to disturbance or off-site in order to meet equivalent land capability, regardless of whether the vegetation has met the criteria. Others felt similarly, and noted that it was an issue of confidence and certainty in the long term trajectory of the site. On the subject of spreading topsoil piles left in place, one respondent suggested that the benefits that could be derived from spreading topsoil piles that were left in place should be a consideration, pointing out that current vegetation may be adequate, but excellent vegetation could be achieved if the topsoil was spread. In contrast, another respondent questioned whether topsoil that had been stockpiled for many years during the operational phase of the wellsite had retained its value as a topsoil material. Alternatively, others felt that reduced topsoil or lack of topsoil (whether through lack of or insufficient soil salvage, quality reduction over time, or failure to spread topsoil piles) could be justified if the vegetation meets the criteria, with one respondent noting that trees are capable of growth in a wide variety of conditions. Many felt that the effort required to correct topsoil depth issues were not worth the damage to the existing ecosystem that would occur as a result (discussed further in Section 4.4.2).

There is literature to suggest that the seed and propagule viability in the topsoil would be negatively impacted by stockpiling even after 1 to 2 years, depending on the size of the pile (discussed in Section 5.4.2.1). Research on impacts to organic matter and nutrient contents in long term stockpiles are inconclusive. Some studies show declines in organic matter over 10 years (e.g., Ghose (2001)), while others show no negative impact of stockpiling on organic matter over 5 to 10 years (e.g., Anderson et al. (2008); Gupta (2019)), but there are confounding factors. Some studies do not examine the effects on the same materials over time, rather samples were collected from materials of different ages; observed trends could be related to natural differences between these soils (e.g., if they came from different ecosites). One study measured total carbon and mineralizable nitrogen in a 22 year old topsoil stockpile in British Columbia and found that the values were higher than in situ mineral soil, but changes over time since stockpiling occurred were not measured (Bulmer et al., 2007). The impacts at multiple depths within the stockpile are not well studied; studies that do examine different depths exist, but are not long term (e.g., MacKenzie (2013); Visser et al. (1984)).

Research on vegetation recovery on sites with no topsoil (and on the use of amendments or soil enhancing techniques to correct topsoil deficiencies) has shown various results depending on the soil conditions and the targeted ecosite; further research specifically on wellsites is needed to validate outreach respondents views on topsoil depth. One study in northwestern Alberta looked at revegetation on forested wellsites with no topsoil. Some of the study sites were padded and others had topsoil stripped during construction (Schoonmaker, Dewey and Schreiber, unpublished data)[12]. Survival after four growing seasons ranged from 71 to 96% for both conifer (white and black spruce) and hardwood (trembling aspen and red-osier dogwood) species after decompaction (Schoonmaker, Dewey and Schreiber, unpublished data). Growth of planted species was positively impacted by decompaction treatments, especially for hardwoods (Schoonmaker, Dewey and Schreiber, unpublished data).

Another revegetation study conducted on a mineral soil pad with no topsoil, left in place in a treed poor fen in northern Alberta found that while jack pine and white spruce had higher survival, birch and balsam poplar survival was sufficient and are also considered candidates for planting under these conditions (Osko and Glasgow, 2010). Decompaction treatments improved growth of tree species (Osko and Glasgow, 2010). A peat amendment salvaged from a treed poor fen had a negative effect on survival and growth of planted balsam poplar and birch but had no effect on white spruce survival and growth, and positively impacted jack pine growth over five years; potential factors for negative effects of the amendment were suggested to be related to soil temperature, water retention and microbial activity (Osko and Glasgow, 2010). Neither of these revegetation studies included a comparison to a treatment with forest topsoil placement, and thus reduction in growth rates due to lack of topsoil was not quantified.

Planted lodgepole pine growth after 6 years on decompacted forest landings (forest floor removal during construction; A horizon may be partially or completely intact) was compared to cutblock areas (no soil disturbance) in northeastern BC. Sixty percent of studied forest landings had stem densities greater than 1,000 stems/ha (forested lands criteria for stem density is 2,000 stems/ha); height of lodgepole pine on forest landings was lower than on cutblock areas (Bulmer and Krzic, 2003). Tree growth was not impacted by reduced soil nutrient status as a result of forest floor removal in this study, but authors noted that long term growth may benefit from increased soil nutrients (Bulmer and Krzic, 2003).

A study on forest landings in interior B.C. found that lodgepole pine height was not enhanced after 8 years by decompaction or the application of wood waste amendments or 22 year old stockpiled topsoil[13] compared to untreated areas and was similar to expected height of lodgepole pine on cut blocks in the area; however, researchers noted that other species would likely respond differently as lodgepole pine

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[12] Some sites were noted to have admixed soils, with remnants of LFH and A horizon material at the surface (Schoonmaker, Dewey and Schreiber, unpublished data).

[13] As was noted previously for forest landings, during construction the forest floor is typically removed prior to/during construction and the A horizon is left partially or completely intact; removed forest floor and any portions of A horizon that were removed is referred to as topsoil in these studies

can thrive in disturbed soils (Bulmer et al., 2007). Planted tree survival on the stockpiled topsoil after 8 years, while not statistically significant, was reduced compared to most of the amendment treatments, but researchers noted that this may be related to rodent damage rather than soil conditions (Bulmer et al., 2007). Researchers also noted that prior to reclamation treatments, the landings were dominated by grasses with minimal tree regeneration 22 years after construction, despite mature trees in the surrounding area that could have provided a source of seed; whether the site was seeded after construction was not specified.

Another study on forest landings in interior B.C. found that growth of planted lodgepole pine after 2 years was improved by the combination of decompaction and the application of 1 year old stockpiled topsoil and burn pile debris (10 cm application; topsoil applied first and then decompacted, which resulted in incorporation into the underlying soil) compared to the use of decompaction alone (no topsoil replacement); growth with the combination of treatments was superior to lodgepole pine growth on adjacent cutblocks, while growth with decompaction alone was lower than on adjacent cutblocks (with undisturbed soils) (Campbell et al., 2008) [13]. Increased growth with the decompaction-topsoil treatment combination compared to decompaction alone was thought to be due to decreased bulk density and increased soil nitrogen and phosphorus. Decompaction alone did not result in reduced bulk density in this study, possibly due to soil texture (sandy loam) or low organic content. The relative influence of soil physical vs. soil chemical factors on growth could not be determined by this study. Increased growth on the landing compared to the cutblock can be explained by reduced grass competition and increased soil temperatures due to reduced shading on the landing.

While the use of amendments on forested wellsites has not been well studied, one project on a wellsite on agricultural land in Alberta showed that it is possible to create a functional topsoil and get a reclamation certificate using an amendment to compensate for lack of topsoil (Canada's Oil Sands Innovation Alliance, 2019). The amendment that was used was a combination of biochar or humalite (low grade weathered coal) and a mix of conventional organic amendments (saw dust, wheat straw and alfalfa), with adequate supplemental fertilizers (particularly nitrogen and phosphorus) (Bekele et al., 2013; 2015). Biochar or humalite provide a stable source of carbon that decomposes more slowly and was a surrogate for recalcitrant soil organic matter fractions that decompose over decades to centuries while the conventional organic amendment was a source of labile organic carbon which decomposes more quickly (days to several years or decades) (Bekele et al., 2013; 2015). Researchers did note that, depending on the application rate, use of either biochar or humalite can have unintended, detrimental soil effects (e.g., elevated boron, reduced phosphorus), but these effects depend on the texture and chemistry (e.g., pH) of the receiving subsoil and can be mitigated through appropriate pairing of amendment to the soil conditions.

On a reclaimed oil sands mine, two studies compared the vegetation cover on treatments with and without topsoil placement. With coarse textured Brunisolic soils salvaged from an *a* ecosite, vegetation cover in the third or fourth growing season ranged from 0.03 to 2% on treatments with no forest topsoil, but was only 6% on treatments with forest topsoil (Jones (2016)[14]; MacKenzie (2013)[15]). While statistically significant, the increase in vegetation cover provided by forest topsoil was almost trivial. The MacKenzie (2013) study also included several other topsoil materials. Total vegetation after three growing seasons on another coarse textured treatment with topsoil from a *b* ecosite was slight higher than for *a* ecosites, ranging from 2 to 17%. Coarse textured scenarios contrast significantly with a fine textured treatment with soils from a *d* ecosite; vegetation cover in the third growing season was substantially higher on topsoil treatments (20 to 60%) compared to treatments with no topsoil (2%) (Mackenzie, 2013). Species richness was higher for all topsoil treatments compared to the subsoil treatments, indicating that viable propagules were present in the material, but the more limiting soil conditions on the coarse textured treatments (e.g., lower water holding capacity) likely limited the growth of vegetation from these propagules. It is also likely that the density of propagules in the coarse textured topsoils from *a* and *b* ecosites was more limited than in the *d* ecosite; seed banks tend to be larger in richer, wetter upland ecosites (Mackenzie, 2013), which is discussed further in Section 4.4.2.1. Overall it appears that soil conditions had a more predominant effect on vegetation recovery for *a* ecosites scenarios than any benefit gained from the topsoil (i.e., organic matter and propagules). On the fine-textured site, the difference in vegetation cover between treatments with and without topsoil was either driven by a difference in propagules or a difference in soil nutrients and organic matter for growth; which was more influential was not quantified by the study.

On a wellsite with no topsoil, the availability of propagules would be different than on a reclaimed mine site, as wellsites are situated much closer to the surrounding forest, which allows for increased dispersal onto the site. Recovery on wellsites with no topsoil will depend on the inherent quality of the subsoil

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[14] The Jones (2016) study used directly placed topsoil (15 cm salvage depth and 20 cm placement depth) with an organic matter content of 2.6% and two subsoil materials with an organic matter content ranging form 0.77 to 0.98%. Vegetation data excluded the cover of planted trees. Slope of the reclamation area was <5%

[15] The MacKenzie (2013) study examined multiple salvage and placement depths for topsoil materials; topsoils were briefly stockpiled between from 6 months in the winter. Data presented here is for 10 and 30 cm salvage depths placed at 10 cm. Trees were not planted in this study. Slope of the reclamation area was 10 to 20%.

material for plant growth as well as how disturbance and reclamation impacted subsoil properties. Sites where subsoil was left in placed during the life of the wellsite may have different soil physical properties than sites where subsoil was disturbed (i.e., salvaged and replaced). Soils left in place may have been compacted by prolonged exposure to vehicle and equipment traffic, or these effects may have been mitigated through decompaction treatments during reclamation. Soil structure of disturbed soils may have been damaged during excavation and replacement. The ability of the site to recover with little or no topsoil will likely depend on the soil moisture and nutrient regime and the availability of species to invade the site from the surrounding area as, without topsoil, there will be no residual propagules available to vegetate the site. Sites with limiting moisture or nutrient conditions will be less capable of supporting vegetation growth than richer, wetter sites. Recovery will be swifter for sites surrounded by ecosites with species available to invade the site that are tolerant to a wider range of conditions. The ability of upland sites to develop and support ecosystem function without topsoil will be discussed further in the context of mineral soil pads left in place and reclaimed to upland forests in Section 5.5.3.

Effects of topsoil placement depth on vegetation response on forested wellsites in Alberta has not been studied in the scientific literature. Current forested land criteria requirements are to replace 80% of the pre-disturbance topsoil depth, although criteria varies with age of construction and reclamation (Alberta Environment and Sustainable Resource Development, 2013a). However, topsoil placement depth in forested ecosystems has been studied in the oil sands mining industry. Vegetation recovery was studied after three years on a 2 cm placement depth. While an improvement was observed compared to some but not all treatments with no topsoil, vegetation recovery was reduced in comparison to treatments with 5 and 10 cm placement depths in multiple placement scenarios of coarse and fine textured topsoils from different ecosites (*a*, *b* and *d*) placed on mineral substrates (Mackenzie, 2013). Most 5 and 10 cm placement scenarios met the 2 stems/10 m^2 woody stem density requirement of the forested land criteria after three years while the 2 cm placement depth scenarios did not. The 25% canopy cover criterion was met on some of the 5 and 10 cm treatments with fine textured soils from *d* ecosites, but on none of the coarse-textured *a* and *b* ecosite scenarios. Differing recovery trends from soils of different ecosites were linked to differences in seed and propagule bank abundance and composition between ecosites, as noted above and discussed further in Section 4.4.2.1 (Mackenzie, 2013). Differences between placement depths with the same soil is presumed to be related to topsoil organic matter and nutrient content and available water (Mackenzie, 2013).

Placement depths of 10 cm of forest topsoil has been found to be comparable to a 20 cm placement depth in terms of vegetation response after 5 to 7 years, on richer ecosites with finer textured substrates; however, with topsoil from *a* and *b* ecosites with poorer nutrient regimes and coarse textured substrates, placement depth did impact vegetation response in some studies (Archibald, 2014; Mackenzie and Naeth, 2010), but not others (Jones, 2016). Regardless of differences in vegetation response, all treatments met the 25% canopy cover criterion in the forested land criteria (Alberta Environment and Sustainable Resource Development, 2013a), with the exception of one of the *a* ecosite topsoil studies (Jones, 2016). Placement depths of 10 and 20 cm of coarse textured forest topsoil from a Brunisolic soil also had comparable planted aspen, pine and spruce seedling growth performance in the third year (Bockstette, 2018). From a soils perspective, 10 and 20 cm placement depths of forest topsoil from an *a* ecosite had similar bioavailable nutrient profiles in the first two years after placement (Howell and MacKenzie, 2017).

4.4.1.3 Weed Issues

The forested land criteria currently allows noxious weed and other undesirable/problem weed populations to be present on sites provided that weed populations on site are comparable to or smaller than off site, or if weed populations on site are greater than off site, the following conditions must be met: (1) the site is on public land, (2) all other forested land criteria are met, and (3) weeds are from a single off-site point source[16] (Alberta Environment and Sustainable Resource Development, 2013a). If these conditions are not met, a variance to criteria would be required.

It has been determined that the main considerations regarding weed populations left in place include:

- **Whether impacts result from deficiencies: desirable vegetation (natural recovery and planted) is outcompeted by weed populations or movement of noxious weeds into undisturbed areas**
- **Competitiveness of the noxious weed populations, which is impacted by the size and height of noxious weed populations (scale), species of noxious weeds present and its competitive ability, and the stage of development at which weed invasion occurs**

While some respondents believe that there can be no exceptions to the above criteria and others have noted that there is no tolerance from the regulator for deviation from those criteria, many respondents feel that there are instances of noxious and undesirable/problem weed occurrences above and beyond those allowed in the current forested lands criteria that should be considered acceptable to be left in place.

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[16] Prohibited noxious weeds are treated differently than noxious weeds in the forested land criteria; prohibited weeds are not permitted on-site under any circumstances and must be destroyed as per the *Weed Control Act*. The discussions of weeds in Section 4.4.1.3 and in the remainder of the document concern noxious weeds only.)

From the literature, weed populations are considered to be a concern due to the potential for the following outcomes (Small et al., 2018), excluding the effects of weed control:

- Suppression of desirable native forbs, shrubs and trees through competition with weeds and subsequent impacts to natural vegetation succession
- Mortality of planted trees
- Spread into nearby areas
- Altered natural habitats and reduced diversity
- Changes to local nutrient cycling, water chemistry and hydrological regimes
- Non-compliance with the *Weed Control Act*

Outreach respondents were most concerned about the first two outcomes in the list, and most acknowledge that if these outcomes occur on site, weed control and removal, including control and removal of agronomic species, would be required before reclamation certification. Some respondents noted that agronomic species can have greater negative impacts on growth of desirable species than noxious weeds as they often become dominant more quickly.

Respondents felt weeds could be left in place in cases where these negative outcomes were not occurring, or if noxious weed populations were declining over time. According to one respondent, a demonstration that weeds were obviously being outcompeted by desired species lends weight to the application for a variance.

Outreach respondents suggested that the ecology of each noxious weed species and long-term impacts be considered in assessing weed outcomes and determining control requirements. Respondents have observed that small populations of some species (such as perennial sow-thistle) tend to decline as the canopy closes, noting that while noxious weed species may still be present in the seed bank, canopy closure has an overriding effect in directing weed population dynamics.

Practitioners in the oil sands mining and in situ industry have also expressed uncertainty around noxious weed best management practices for reclamation of forested areas and have been deliberating on whether long term management of all noxious weed species through chemical and manual methods is truly necessary. A literature review and risk analysis were undertaken to examine the issue (Schoonmaker et al., 2018; Small et al., 2018).

The weed literature indicates that the impact of noxious weeds on developing plant communities on the reclaimed site depends on the stage of development of the site (age), the height and extent of the weed population, the specific species in question and how well weed populations compete for nutrients, water and light (Small et al., 2018). If the height and extent of the weed infestation is small, it is unlikely that weeds will have a competitive advantage over trees or result in inhibited tree growth and development; whereas the opposite would be true if weed populations occupy a large area and/or are taller than the developing trees (Small et al., 2018). Juvenile vegetation is more at risk of being outcompeted by weeds as desirable vegetation is shorter and root system development is still in progress (Small et al., 2018). The literature review concludes that assessing the risk of weeds must consider impacts; if weeds are not competing with desired vegetation and are not acting as a limiting factor to the growth of desired vegetation, then removal of weeds would have a minimal impact.

Oil sands industry reclamation practitioners have observed perennial sow-thistle and scentless chamomile to be of low risk to the developing forest community as they are not aggressive and tend to disappear once other vegetation becomes established (Small et al., 2018). This was supported by a retrospective case study, which found that there was limited evidence of noxious weeds (perennial sow-thistle, scentless chamomile and Canada thistle) having a negative impact on woody vegetation development on six reclaimed oil sands in situ and mining sites in the first 4 to 10 years of development (Schoonmaker et al., 2018).

In terms of the potential for spread of noxious weeds on reclaimed sites into nearby adjacent areas, boreal forests have been presumed to be resistant to noxious weed invasion due to “harsh climates, low light levels, poor soil nutrient availability, low soil pH, low productivity, and dense covering of the ground by plants, especially bryophytes” (Langor et al., 2014). Non-native and invasive plants have typically not been observed, or have been found in low numbers, more than 20 to 30 m from boreal forest edges (Small et al., 2018). This suggests that weed growth and development is not supported by the mature forested environment edges (Small et al., 2018), which does support the theory that canopy closure would reduce weed populations.

Like outreach respondents for this study, a common theory among oil sands practitioners is that once trees achieve canopy closure on a reclaimed site, this will result in a reduction of noxious weeds due to shading and insufficient resources for growth; however, the literature review concludes that **further study is required to validate this theory, including a long term study that shows empirical evidence of noxious weed presence or absence after canopy closure** (Small et al., 2018).

In addition to ecological discussions on weed control, respondents also commented on regulatory requirements for weed control. Several noted that there were inconsistencies between industries in terms of weed control requirements. The weed control literature review for the oil sands industry also identified differences in weed policy and guidance for wellsite reclamation certification compared to public lands, forestry and oil sands mining and in situ operations (Small et al., 2018). The forested land criteria mainly refers to the *Weed Control Act* requirements to eradicate prohibited noxious weeds and control noxious weeds, but does have acceptable limits for noxious weeds on site, as described above.

Weed management in the forestry industry, through the *Weed Management in Forestry Operations* Directive (Alberta Sustainable Resource Development, 2001), allows for flexibility in weed management (Small et al., 2018) and takes into account the size of the land base, the type of weed species (prohibited noxious vs. noxious), the isolation of the weed occurrence, the size of the infestation, abundance of the species in question on a regional basis and the ecological impact of that species.

On public lands, the *Master Schedule of Standards and Conditions* (Alberta Environment and Parks, 2018b) describes several circumstances in which weed management is restricted and specifically states that these restrictions apply regardless of the requirements of the *Weed Control Act* (Government of Alberta, 2008). For example, vegetation control is not permitted during certain periods between May and August.

Weed management requirements for in situ oil sands operations (i.e., approval conditions) allow for different noxious weed management strategies for reclaimed sites (i.e., sites with vegetation that has established and is self-sustaining) as opposed to active sites (Alberta Energy Regulator, 2015a), which takes into account the interaction between native plant communities and noxious weeds (Small et al., 2018).

Outreach respondents also raised concerns about the consequences of weed control, and many felt that the damage to desired vegetation was an important consideration in the decision of whether weed populations should be controlled, which will be discussed further in Section 4.4.2.3.

4.4.1.4 Safety

In addition to ecological impacts of leaving deficiencies in place, irregular features such as steep slopes from cut and fills, subsided depressions prone to collapse or large industrial debris could be a physical hazard to recreational and traditional users and wildlife. Some outreach participants noted that safety would be considered a determining factor in the decision to leave features in place.

Factors that influence the safety of deficiencies left in place include:

- **Height and/or depth of the feature relative to surrounding area (scale). Greater depths or heights of features present increased hazard levels**

- **Slope of the feature. For example, gradual slopes into subsided areas present less of a safety hazard than abrupt drops**
- **Remoteness and access to the site (discussed in Section 4.4.3)**

4.4.1.5 Cumulative Effects

Another aspect to consider in terms of leaving deficiencies in place on upland sites with natural vegetation encroachment is the cumulative impact on the site, regional and landscape scale. While individual deficiencies can be justified and negative consequences deemed acceptably low to allow them to be left in place, there may be a cumulative impact if the same deficiency is left in place on many wellsites and access roads within the same area or if multiple deficiencies are left in place on an individual site.

Factors to consider in the discussion of cumulative effects include:

- **The actual negative impact of the deficiency left in place**
- **The cumulative impact of multiple deficiencies on overall ecological function**
- **Number of other sites in the local and regional area that had the same deficiency left in place**
- **Size of the local or regional area over which cumulative effects are determined**
- **Scale and impact of other human impacts in the local or regional area**
- **Sensitivity of the ecosystem, or receptors within that ecosystem to cumulative effects**

Note that this discussion on cumulative effects is focused on deficiencies left in place in upland forests, and does not include mineral soil pads left in place and the implications of a land use change to convert the site to upland forest which is discussed in Section 5.4.

4.4.2 *Consequences of Correcting Deficiencies through Traditional Reclamation Approaches*

As a counterpoint to the consequences of leaving deficiencies in place, the impacts of reclaiming these deficiencies must also be considered. There was significant concern among respondents that the environmental cost of implementing traditional reclamation practices to fix deficiencies would be higher than the benefits that would be gained in ecosystem function. Respondents referred to the concept of net environmental benefit to rationalise these trade-offs between environmental costs and benefits. The main costs emphasized by respondents were disturbance to established vegetation, delayed ecological recovery and alteration of the recovery trajectory in terms of plant community type and composition (including the introduction of weeds), lengthened reclamation certification timelines, and damage caused by herbicide application. There was some inconsistency among respondents in terms of what constitutes delayed ecological recovery; one respondent suggested that 5 to 10 years would only be considered a minor setback on the scale of the 200+ year planning horizon that government is focused on, while others were concerned about setbacks regardless of their time frame.

4.4.2.1 Removal of Existing Vegetation and Impacts to Ecological Recovery

Removal of vegetation and topsoil was studied in boreal Norway; different severities of disturbance were examined: removal of vegetation; removal of vegetation and the L horizon layer (undecomposed litter); removal of all of the forest floor layers; and removal of vegetation, forest floor and the Ae horizon (i.e., this treatment is equivalent to typical full disturbance construction practices on wellsites) (Rydgren et al., 2004). Vegetation recovery on each of the treatments proceeded at different rates; none of the treatments, including the vegetation removal only treatment, had recovered to pre-disturbance levels after 7 years and recovery was expected to take an additional 5 to 25 years. Disturbance severity changed the types of species that recovered: in the 'litter removal only' treatment there was better recovery of species that regenerate from roots and rhizomes, while in treatments that removed the forest floor, species that regenerate from seed and that have an abundant seed bank were favoured.

Several studies have shown that recovery on sites reclaimed with topsoil that was stripped, stockpiled and replaced (i.e., full disturbance construction) is slower than on sites where topsoil was left in place (i.e., minimal disturbance construction). On wellfields on grassland and sagebrush lands in Wyoming, negative impacts to soil (particularly soil organic matter, total nitrogen, mycorrhizal spores and microbial biomass carbon) were more pronounced after soil removal and stockpiling, and effects were more long lasting (greater than 7 years) than when topsoil was left in place and exposed to development activities (primarily heavy vehicle traffic) (Stahl et al., 2002). On OSE wellsites in northeastern Alberta, vegetation community recovery after 5 years was significantly different on full disturbance sites (topsoil was stripped, stockpiled less than 3 weeks in the winter and replaced) compared to minimum disturbance sites where topsoil was left in place (Jones et al., 2018); differences were more apparent in year 1 than in year 5[17]. In another, longer term study of OSE wellsites in northeastern Alberta, vegetation recovery on minimum disturbance (topsoil left in place) and full disturbance (topsoil stripped, stockpiled for three to four weeks and replaced) wellsites remained different after 10 years[18] (Frerichs et al., 2017). Recovery differences in

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[17] Total vegetation cover and richness were similar after 5 years; however, the proportion of forest species, tree height and aspen regeneration was still much lower on full disturbance sites (Jones et al., 2018).

[18] Understory species composition differed significantly between treatments and vegetation on minimum disturbance sites was more similar to species compositions on 10 year old clear cuts. Aspen density and height were higher on low disturbance wellsites than full disturbance wellsites after 10 years, although total deciduous tree density was comparable on both sites types (Frerichs et al., 2017).

both studies were attributed to be damage to propagules (severing, wounding, fragmentation), dilution and burial of propagules, and altered expression of propagules through mixing the layers in the seed bank (Frerichs, 2017; Jones et al., 2018; Landhäusser et al., 2015; Osko and Glasgow, 2010; Wachowski et al., 2014).

Propagule losses during salvage, stockpiling and placement of forest topsoil have been documented in several studies in the mining industry. In oil sands mining reclamation, a 90 to 95% loss of propagule density was observed after soil salvage, soil storage in a stockpile for 4 to 6 months in the fall and winter and placement in a reclamation area (Archibald, 2014; Mackenzie, 2013; Mackenzie and Naeth, 2010; Naeth et al., 2013). Similar losses have been reported in Australian jarrah forests (Koch et al., 1996). Longer term stockpiling (greater than 8 months) has additional negative impacts on soil propagules banks. Seed and propagule viability can decline substantially within the first 8 months and by 16 months there may be no viable propagules and few viable seeds at depths exceeding 1 m (Archibald, 2014; Mackenzie, 2013; Mackenzie and Naeth, 2010; Naeth et al., 2013). Loss of viability is due to anaerobic conditions (Archibald, 2014; Mackenzie, 2013; Mackenzie and Naeth, 2010; Naeth et al., 2013), high temperature and moisture (Rokich et al., 2000), in situ germination (Mackenzie, 2013; Rivera et al., 2012) and decay or rotting (Archibald, 2014; Mackenzie, 2013; Mackenzie and Naeth, 2010; Naeth et al., 2013)[19]. While not relevant to the discussion of re-disturbing sites for reclamation as sites that would be re-stripped would not have this material stockpiled for more than a few days, stockpiling effects are important to note as soils would have been stockpiled during the original disturbance to the wellsite when it was constructed.

Propagule survival and expression at the placement (reclaimed) site is further affected by salvage depth. In the context of forest reclamation, topsoil is ideally salvaged as the LFH and the underlying Ah, Ahe and Ae mineral horizons; however, if the A horizons are greater than 15 cm, best practice is to limit the salvage depth to 15 cm and any additional Ae material below 15 cm should be salvaged separately (Alberta Environment and Sustainable Resource Development, 2013a). The actual depth at which salvage occurs affects the ratio of the litter layer to mineral soil. Increased mineral content may result in dilution of the propagule bank found in the litter layers, resulting in fewer propagules at the surface at placement; effects of differences in salvage depths on vegetation response may become more pronounced with deeper

[19] Despite propagule losses, these and other studies still conclude that use of forest floor material in oil sands mining reclamation is beneficial and that this material does perform better in terms of native plant establishment than other cover soil options (Archibald, 2014; Mackenzie, 2013; Mackenzie and Naeth, 2010; Naeth et al., 2013); however, this work is in the context of not having topsoil at all or using topsoil that has been stockpiled or that has been sourced from peatlands. In the context of wellsites and access roads, there may be a benefit of leaving topsoil in place rather than removing it and saving it for use at the end of reclamation (Frerichs et al., 2017).

salvage depths (Archibald, 2014; Mackenzie, 2013; Mackenzie and Naeth, 2010; Naeth et al., 2013)[20]. Deeper salvage depths (e.g., greater than 20 or 30 cm), while they tend to have negative impacts on propagule availability overall, may be beneficial for aspen regeneration from root propagules as the greater salvage depth can provide greater soil contact for root fragments (Wachowski, 2012)[16].

The effect of the number of passes used during salvage and whether materials were piled separately or together was studied on OSE wellsites in northeastern Alberta; results were collected after 10 years of development. When the LFH and upper Ae horizon were salvaged together in one pass (although they were piled separately from lower Ae and portions of the B horizon), wellsites had greater balsam poplar density than when the LFH and Ae horizon (with some B horizon) were salvaged as two separate passes (densities of other tree species were not affected), and greater total deciduous tree density than when just the LFH horizon was salvaged (Frerichs et al., 2017)[16]. When LFH and Ae horizons were salvaged in two separate passes but piled together, wellsites had greater aspen and birch density and greater survival of planted spruce than when LFH and Ae horizons were salvaged in two separate passes but piled separately; differences were presumed to be due to the smaller surface area to volume ratio of the single pile which reduced root exposure to desiccation and freezing (Frerichs et al., 2017).

Propagule losses during salvage, stockpiling and placement may have more severe consequences for sites that had lower total abundances of propagules before disturbance. Outreach respondents noted that sites with shallow topsoil and sites with coarse textured soils and may be slower to recover from a second disturbance. Literature indicates that slower recovery on coarse textured sites is likely related to more limiting environmental conditions as well as lower propagule density. More productive stands on fertile soils have seed bank densities from 1,010 seeds/m^2 (Fyles, 1989) to 9,108 seeds/m^2 (Mackenzie and Naeth, 2010), whereas seed densities in coarse textured soils can be lower (e.g., 505 seeds/m^2 in a pine-alder forest (Fyles, 1989)). Propagule density and species richness of the propagule bank has been found to be positively correlated to soil water (Grandin, 2001). Propagule density also declines with forest age in some forests (Hills and Morris, 1992), although there have been noted exceptions (Granstrom, 1982).

Not only is excavation, stockpiling and replacement of soil relevant to the re-disturbance of the site for reclamation, but it is also pertinent in the context of understanding the previous history of site recovery. Once topsoil salvage and replacement during reclamation has occurred on a wellsite, the soil quality and

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[20] These studies on salvage effects were conducted using topsoil materials that were only stockpiled for a short period of time, whereas on forested wellsites topsoil is stockpiled throughout the active life of the wellsite, which can vary widely; therefore, the studies are not necessarily representative of the conditions that would be encountered on wellsites.

propagule bank is unavoidably reduced from the original undisturbed forest, and while the site can still recover into a functioning forested ecosystem after disturbance, its ability to recover a second time from a second disturbance may be more limited. Recruitment from the seed and propagule bank after the second disturbance will likely be reduced compared to the first disturbance as the site has not had as much time to re-develop the same propagule bank it had prior to initial disturbance.

Literature on recovery and succession after disturbance suggests that the frequency of disturbance is an important factor; when a second high intensity disturbance (i.e., soil re-stripping) occurs before the site has recovered from the first high intensity disturbance (i.e., initial construction and reclamation), the residual species that were present after the first disturbance (including species in the seed and propagule bank) may not be the same as after the second, and if the residual species required to direct succession along the desired pathway towards upland forest are not present after the second disturbance, recovery to upland forest may be delayed or may not be possible (Turner et al., 1998). Sites with natural vegetation encroachment may not be resilient to the kind of damage that would be required to correct landscape and soil deficiencies. This concept has been discussed in the context of oil sands reclamation; natural ecosystems have resilience in the early stages of development after disturbance due to an inherent historical legacy (i.e., seed and propagule bank, litter, coarse dead organic matter and nutrient capital), while reclaimed ecosystems have low resilience due to a lack of this historical legacy, although reclamation practices can be used to supplement the historical legacy and therefore increase resilience (Pyper et al., 2013; Welham, 2013). It is important to note that this lack of resiliency is not an indication that these sites are not ready to be issued a reclamation certificate – certification is achieved when it can be reasonably concluded that a site is on a trajectory to equivalent land capability.

In summary, the effect of vegetation removal and soil disturbance on the rate of site recovery can be influenced by several factors, including:

- **Extent of vegetation removal and soil disturbance (scale)**
- **Site history and construction practices (i.e., minimal vs. full disturbance)**
- **Ecosite, which is an indicator of the environmental conditions, but also the type of species that make up the plant community and their ability and strategies for ingress onto the site**
- **Composition of the propagule bank, and how it was impacted during the original disturbance (salvage depth, stockpiling duration) and during reclamation**
- **Time since original disturbance, diversity of the recovered plant community and resilience of the recovered site**

4.4.2.2 Potential for Weeds

Another potential negative consequence of conducting traditional reclamation practices to correct deficiencies is weed invasion. Heavy equipment and vehicles that access the site to conduct reclamation work can be vectors for weed seeds and propagules. As previously discussed in Section 4.4.1.3, there are several potential negative outcomes of weed invasion. At newly disturbed sites, the primary concern is that weeds may establish before desirable native forb, shrub and tree seedlings and as a result out-compete, suppress and exclude their establishment. As noted earlier, desirable vegetation is more susceptible to weed invasion in its juvenile state due to height and root system development, and weeds would likely have the competitive advantage, particularly if they are able to occupy a large area and achieve taller canopies than desirable vegetation (Small et al., 2018). The potential for weeds is compounded at newly disturbed sites by the removal of vegetation and disturbance to soil which eliminates the competitive pressure exerted by existing vegetation and creates an open seed bed for weed establishment. Weed seeds that are present in the seed bank from prior disturbances and that have remained viable have the opportunity to germinate, establish and spread. Growth and spread of rhizomatous weed species that are present on site may be stimulated by soil disturbance through fragmentation and re-sprouting of rhizomes.

The potential problems discussed around weeds within the context of this report are specifically in reference to weeds invading sites that are disturbed to correct reclamation deficiencies. Previously (Section 4.3.1.4), weeds were discussed in the context of fully vegetated sites where weeds have persisted over time, and where the dynamics between weeds and desirable vegetation would be different.

The potential for weed invasion after reclamation will be influenced by several factors:

- **Extent of the vegetation removal and soil disturbance (scale). A smaller disturbance area reduces the potential for weed establishment**
- **Presence of weed populations currently on site and presence of weed seeds and propagules in the seed bank from previous weed populations**
- **Species-specific traits of weed species on and near the site related to dispersal (e.g., seed vs. rhizomes) and competitiveness**
- **Proximity of the site to other active sites, industrial traffic or agricultural areas, (discussed further in Section 4.4)**

4.4.2.3 Weed Control

Weed control is another component of traditional reclamation practices required to meet the forested land criteria (Alberta Environment and Sustainable Resource Development, 2013a). The negative consequences of the use of herbicides for weed control, based on outreach responses and on a recent literature review of weed control in the oil sands industry (Small et al., 2018), are as follows:

- Removal of and disturbance to vegetation on access roads
- Damage and mortality of desirable native vegetation from herbicide overspray, particularly as a result of broadcast spraying
- Impacts to ecological recovery. The removal of native forbs, shrubs or trees from the plant community through herbicide mortality impacts the composition, structure and function of the plant community and can alter the successional pathway of the site as a whole, which then has impacts on habitat provision and biodiversity (Alberta Sustainable Resource Development, 2004). Herbicide mortality can result in the loss of one to many species. When larger areas of vegetation are damaged, these large gaps are susceptible to invasion by another invasive non-native species
- Delay in reclamation certification application by at least one growing season (Alberta Environment and Sustainable Resource Development, 2013a)
- Time and resources spent on weed management

The negative consequences of herbicide application will be influenced by several factors:

- **Extent of weed population (scale)**
- **Choice of application method: broadcast vs. spot spraying**
- **Weed species and difficulty of control by herbicide**
- **Availability and composition of propagules to replace vegetation destroyed by herbicide application**

4.4.3 *Remoteness and Access Considerations*

Several outreach respondents noted that remoteness of the site and access considerations must be taken into account in the decision to implement traditional reclamation approaches to correct deficiencies. In terms of potential negative consequences of implementing reclamation activities, disturbance to the access road was the primary focus point. To access remote sites, longer access roads must be cleared of vegetation, and the additional environmental impacts associated with this activity must be considered when weighing the net environmental benefit of reclamation to correct deficiencies. The number of creek crossings that are required to access a site was also raised as a factor to consider in the environmental cost of reclamation, especially as these areas are considered more sensitive to disturbance. The remoteness of the site also affects the exposure of the site to weed propagules. Sites that are closer to other active sites, industrial traffic or agricultural areas will likely receive more weed propagules through wind dispersal than more remote sites.

In terms of the impact of foregoing reclamation and leaving deficiencies in place, respondents noted that the remoteness of the site affects the potential use of the site by recreational users. At remote sites that are distant from populated areas or industrial facilities, the potential risk for recreational and traditional users is much lower. Access to the wellsite is another related factor. Wellsites with conspicuous, straight access roads that are accessible from public highways present a higher risk than wellsites with less visible access roads or those with access deterrents such as woody debris or other obstacles.

4.4.4 *Location Land Use Considerations*

Outreach respondents noted several specific considerations related to where the site is located and the land use of the site, including:

- Species at risk habitat (most notably caribou). Reclaimed wellsites in species at risk habitat have the additional requirement of supporting the species at risk; the tolerance for deficiencies may be lower in species at risk habitat
- Pre-existing agreements and conditions with an overlapping tenure holder or stakeholders such as an FMA, grazing lease disposition or traditional users. Forest productivity and operability of the site for forestry equipment should be considerations when wellsites are located in FMAs. For grazing leases, the suitability of the wellsite for livestock grazing becomes a factor. Traditional users have requirements related to safety and compatibility of the site for their traditional use One respondent noted that if there are multiple stakeholders that may be impacted, then it is generally harder to justify leaving deficiencies in place.
- White Area. Reclamation of forested sites in the White Area should consider the potential for cultivation.
- Timber value. From a forestry perspective, more productive timber areas are valued differently than marginal ones, and end goals for the site should take this into account
- Integrated land management. For example, the potential for the site for be used for recreational purposes (camping, staging for off-road vehicles, etc.)

4.5 FACTORS AFFECTING THE DECISION TO ALLOW A VARIANCE TO CRITERIA

This section discusses the process for applying and approving a variance request, the information that must be submitted and factors affecting the decision to grant approval. This section does not discuss the technical (ecological) aspects of requests for variances as this was discussed in Section 4.4. This section assumes that when a mineral soil pad in a peatland is to be left in place the site becomes an upland forest site and the variance to criteria provisions in the forested criteria applies; considerations related to the change in land use are discussed below in Section 5.5.

The current guidelines for applying for a variance to criteria are provided in SED 002 (Alberta Energy Regulator, 2018). Several respondents noted that communication with the decision makers early in the process to discuss the potential site limitations (ideally before a complete DSA or any reclamation work is done) is critical to gaining acceptance. Applicants have the option of getting variance requests pre-approved by the AER, before they apply for a reclamation certificate, which enables the reclamation certificate application to go through the “Baseline Review” process. Consultation with the AER indicated this is the preferred option and will ensure a site progresses through the certification process as efficiently as possible. Alternatively, applicants submit the request for variance with the reclamation certification application, and it goes through the “Additional Review” application process, which involves additional scrutiny from the regulator. Several respondents, including reclamation practitioners, industry and within government, noted that that it was not clear whether the Land Manager (i.e., AEP for public lands) must also approve the variance request or whether the AER makes this determination on its own. The outreach response suggests that the AEP is not involved in the variance request process and AER is responsible for making the decision.

The forested land criteria and SED 002 specify that a variance request must include a justification explaining why the site should be permitted to vary from the criteria and a rationale for the request, supported by acceptable references (Alberta Energy Regulator, 2018). As was noted earlier in Section 2.2, there is no clear guidance as to the specific types of information required by the AER to accept a variance request. **Outreach respondents generally agreed that the key focus of the justification is to provide a strong argument as to why the limitation or deficiency will not have adverse effects or impede equivalent land capability and ecosystem function in the long term. Site specific supporting information was also emphasized as an important component of the variance request. Respondents noted that applications that are not approved are those with a poor rationale, departing from the normal process and criteria, and have a lack of, or poor quality of, supporting information.**

Respondents provided a number of information types that could be used to support applications/decisions, ranging from simply providing a detailed site assessment (DSA) to very specific examples of application content including site photos, aerial photos, remote sensing, survey plans, construction records, disturbance details, pre-disturbance biophysical information (if available), site history of recreational use and pre-existing trails/access roads, regional information such as reports from the landscape analysis tool (LAT reports), as well as any information related to current and future overlapping land uses related to those factors identified in Section 4.4.4. Additional biophysical data collection not required by the forested lands criteria, but which demonstrates ecosystem function and equivalent land capability such as annual increment, wildlife use of the site, or comparisons of vegetation composition (ecosites) on and off site were recommended. Comprehensive packages of information are generally well received. Some respondents suggested that information from literature or case studies has not generally been part of applications in which they were involved and that they preferred to focus on site-specific information. Others suggest that scientific literature and case studies are important for providing context.

Several respondents mentioned the importance of time and long-term implications as factors in the approval of variance requests. Respondents noted that there could be a minimum amount of time required to justify sites on the basis that vegetation is not being affected by deficiencies that have the potential to limit growth and succession (e.g., lack of topsoil), or to assess whether planted tree survival is acceptable; a minimum of 4 years was mentioned by one respondent, others referred to Reforestation Standards of Alberta (Alberta Agriculture and Forestry, 2018a), in which establishment is assessed at 4 to 8 years and performance at 11 to 14 years. Longer term monitoring is considered beneficial as part of a variance request to show the rate of recovery and demonstrate that the site is not limited by the deficiencies. In general, a need for long term certainty (centuries) in recovery trajectories was identified; regulators want to be confident that variances they approve will not become liabilities for the province. Also, in the context of time/site age, there was some acknowledgement that sites that have been revegetating for a long time (30+ years) are more likely to be approved for a variance, even if the vegetation productivity or other factors are not fully equivalent to off-site conditions; the focus is on function in general rather than on the comparison to off-site areas.

Providing an ecological cost/benefit analysis as part of the justification for a variance request was also suggested by some respondents, to compare the potential benefits achieved through additional reclamation compared to any environmental costs that may be incurred (as discussed in Section 4.4). One respondent noted that if there are opportunities to improve the site with minimal effort (e.g., work by hand), the expectation is that these efforts should be undertaken, rather than being justified through a variance request.

There was concern among some respondents that variance requests for sites that meet the landscape, soil or vegetation standards of the day but do not necessarily meet current standards will not be approved. Some of the comments from regulators indicated that the standards of the day may be used as a reference in approval of variances, but if a detailed site history is provided it is weighted higher during the decision process.

There is uncertainty regarding the decision process as there is little guidance available as to the information required to inform the decision. The need to develop a standard assessment methodology or framework for approval of variances was identified by practitioners, industry and government, to provide clarity on the type of information required to make decisions, and how this information is evaluated. Several respondents noted that a publicly available database of case studies to provide information on decisions for and against certification that have been made by the regulators to date would be very helpful, to track what conditions have been deemed acceptable and those that are not acceptable. The goal would be to enable more consistent decisions by the regulator and a more streamlined request process for practitioners.

4.6 Reclamation Options for a Variance to Criteria

As an alternative to applying for a variance to criteria to enable certification of deficiencies, there may be site-specific instances where minor additional reclamation work could be conducted to improve landscape, soil and vegetation characteristics that will not significantly affect the existing desirable vegetation. As was noted in Section 4.5, there is an expectation from regulators that opportunities to improve the site with minimal effort should be undertaken.

The following is a list of potential reclamation work to correct deficiencies that could be conducted by hand at sites with natural vegetation encroachment:

- Reducing the height and steep slopes of cut and fills or subsided areas with hand shovels and stabilizing these areas by revegetating them with transplanted woody vegetation collected from surrounding off-site areas or purchased nursery stock
- Re-distribute soil from windrows left in place with hand shovels to reduce the height or to create gaps in the windrow. Soils can be spread across the site in a thin layer or in strategic locations to address any issues with vegetation growth; mounded microsites could be created to encourage ingress of additional species diversity
- Re-distributing woody debris piles across the site to eliminate forest fire risk
- If ponding is a concern, create a small drainage channel through a corner of the site
- Increase species richness and diversity by transplanting woody vegetation collected from surrounding off-site areas or purchased nursery stock
- Add an amendment to supplement small areas of the site with reduced or no topsoil that has poor vegetation establishment and/or growth

4.7 Summary of Main Considerations Influencing Variance Decisions

Table 3 summarizes the benefits and drawbacks of traditional vs. modified reclamation (i.e., leaving features in place) for upland forested sites eligible for a variance to criteria.

Table 3. Summary of benefits and drawbacks of traditional and modified reclamation for upland forested sites eligible for a variance to criteria.

<table>
<tr><th>Factor</th><th colspan="2">Traditional Reclamation</th><th colspan="2">Modified Reclamation</th></tr>
<tr><td>Landscape Impacts</td><td colspan="2">Benefit: Corrects landscape deficiencies</td><td colspan="2">Drawback: Landscape deficiencies left in place</td></tr>
<tr><td>Soil Impacts</td><td colspan="2">Benefit: Corrects soil deficiency, increased confidence in trajectory</td><td colspan="2">Drawback: Soil deficiency left in place, reduced confidence in trajectory</td></tr>
<tr><td>Weed Impacts</td><td>Benefit: Weed reduction and less uncertainty of weed effects on trajectory</td><td>Drawback: Herbicide application required</td><td>Benefit: Minimize herbicide application</td><td>Drawback: No weeds reduction and greater uncertainty of weed effects on trajectory</td></tr>
<tr><td>Safety</td><td colspan="2">Benefit: Safety hazards reduced</td><td colspan="2">Drawback: Safety hazards left in place</td></tr>
<tr><td>Cumulative Effects</td><td colspan="2">Benefit: No cumulative effects of deficiencies left in place</td><td colspan="2">Drawback: Cumulative effects of deficiencies left in place</td></tr>
<tr><td>Existing Vegetation</td><td colspan="2">Drawback: Disturbance to vegetation</td><td colspan="2">Benefit: No disturbance to vegetation</td></tr>
<tr><td>Ecological Recovery</td><td colspan="2">Drawback: Ecological impacts of re-disturbance</td><td colspan="2">Benefit: No ecological impacts of re-disturbance</td></tr>
<tr><td>Potential for Weeds</td><td colspan="2">Drawback: Higher potential for weeds due to increased disturbance</td><td colspan="2">Benefit: Lower potential for weeds due to reduced disturbance</td></tr>
<tr><td>Weed Control</td><td>Benefit: Forest land criteria is met</td><td>Drawback: Damage from herbicide, impacts to plant community development</td><td>Benefit: Reduced damage from herbicides and less impacts to plant community development</td><td>Drawback: Forested lands criteria is not met</td></tr>
</table>

5.0 MINERAL SOIL PADS IN PEATLANDS

5.1 KEY CHALLENGES

Leaving mineral soil features (well pad or access road) in place in peatland settings has not been well studied or assessed (Figure 6). Literature review and consultation have indicated that there is a lack of information and case studies available to industry, practitioners and regulators to justify decisions to either leave a mineral soil pad in place or to reclaim it by partial or complete removal of mineral soil material. **Challenges arise in the management of mineral soil pads with natural vegetation encroachment when the site is not causing any adverse impacts off site and the vegetation on site meets the forested land criteria (with or without a variance to criteria)**. A change in land use is required when assessing a site with different criteria from the original pre-existing conditions to the current surrounding or adjacent end land use (i.e., from peatlands to forested lands). In these cases, there is uncertainty regarding the process associated with a request for a change in land use, which is further discussed in Section 5.5. There is also uncertainty associated with the main factors to consider when assessing whether a mineral soil pad should be removed or can remain in place (Section 5.4). In addition, if the site is deemed acceptable to leave in place, there is uncertainty associated with the evaluation criteria, and the mechanism required to assess equivalent land capability, and what the implications are in terms of the Alberta Wetland Policy (Alberta Environment and Sustainable Resource Development, 2013b).

It is generally assumed that any effects a well pad or access road have in a peatland will continue over time. Depending on the type of feature construction and/or reclamation and the peatland setting the conditions may change over time. For example, subsidence of well pads in peatlands has been reported due to continued decomposition of peat under the weight of the well pad. Road subsidence can occur if the roads are no longer maintained and continue to lose material during spring melt and run off.

Given the lack of scientific evidence, case studies and the uncertainty associated with the current regulatory process, policies and criteria as to what the acceptable conditions are for a change in land use for a mineral soil pad within a peatland, very few sites are progressing through the certification process. Outreach response indicated that there is a tendency to default to “No” by AEP/AER regarding leaving mineral soil pads in place in peatlands. From the regulator’s perspective, given the uncertainties, it is easier to default to remove the mineral soil pad and return the mineral material to the borrow site (conservative approach), however very little ecological information is available to justify this decision. The ecological implications of pad removal need to be considered and weighed against the potential benefits, particularly for sites with established vegetation. More clarity is needed in terms of defining (1) the process for a land use change request, (2) considerations required to assess when it would be deemed acceptable for a mineral pad to remain in place and the ecological costs and benefits of removal, and (3) acceptable site conditions to meet equivalent land capability and the requirements of a reclamation certificate application, including justifications for reclamation deficiencies associated with upland sites within peatlands.

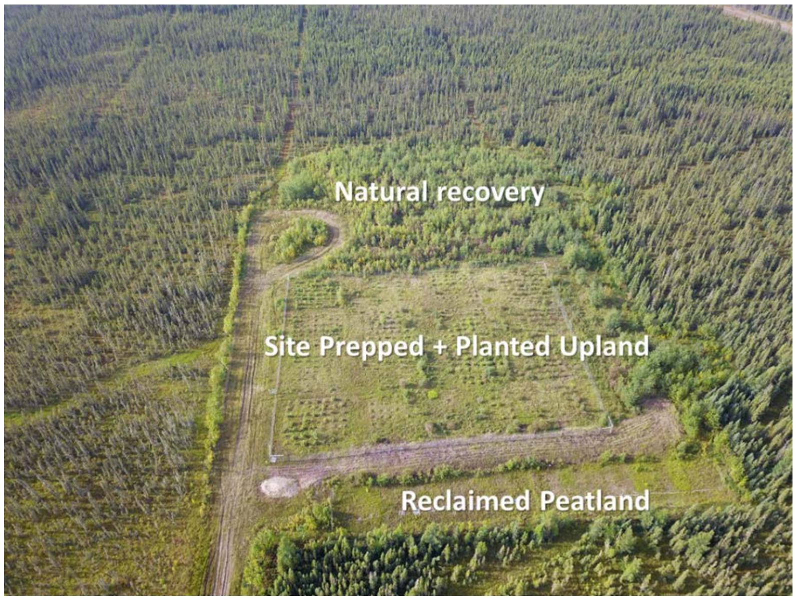

Figure 6. An example of a reclaimed well pad in a peatland.
Showing a naturally regenerated section (natural recovery), a fenced section with site preparation (mounding, ripping) and planting of seedlings, and a peatland section reclaimed by partial pad removal and donor fen moss transfer.

5.2 SITE CONDITIONS FOR MINERAL SOIL PADS IN PEATLANDS

Mineral soil pads in peatlands are constructed using fill material (typically clay) from a nearby borrow pit. This material is often unweathered parent material excavated from below the soil profile (i.e., C horizon material or deeper); quality of this material in terms of chemical and physical properties and its suitability as a reclamation substrate is variable across sites. Before mineral soil is placed on the wellsite, a geotextile is laid on the peat surface to act as a barrier between the peat and the pad; in some cases, a layer of corduroy (logs) is used instead of geotextile. Mineral soil pads are typically 0.5 to 1 m thick (though can be up to 1.5 to 2 m thick in rarer circumstances) (Acden Vertex Limited Partnership, personal communication 2019); pad thickness depends on the depth of the peat below the pad and engineering considerations related to pad material and peat bearing capacity and type of operations/load occurring on pad. The peat below the pad is compressed by the placement of the mineral soil fill. Most consolidation occurs within the first 30 to 50 days following the placement of the fill material (Osko et al., 2018a); however, additional, smaller scale consolidation occurs over time. The extent of compression and the timeframe over which it occurs depends on the peat physical characteristics, peat depth and the applied load (Osko et al., 2018a). Padded access roads often have culverts installed to prevent water flow disruptions.

Topsoil was often not salvaged prior to the construction of mineral soil pads; and therefore is not available to be used in reclamation. In some cases, reclamation practices are conducted at abandonment with the intent of setting the site on a trajectory towards an upland ecosystem and can include recontouring, various decompaction techniques (e.g., ripping or discing) and revegetation through planting nursery stock or transplanted vegetation or seeding of grasses to stabilize the site.

Conditions of mineral soil pads and associated access roads left in place can vary from being completely devoid of vegetation to fully functioning upland ecosystems. Outreach response indicated that there are well over 1,000 mineral soil pads within peatlands in the forested region of Alberta that have had natural vegetation encroachment on the well pad and/or access road. Many of these sites would exhibit similar conditions as upland sites described in Section 4.2 and have one or more deficiencies in terms of vegetation composition and/or density, soils and landscape requirements to meet the forested lands criteria (Alberta Environment and Sustainable Resource Development, 2013a), however have established a functioning ecosystem.

5.3 Reclamation Approach for Pad Removal

Reclamation approaches to reclaim mineral well pads and associated features include complete and partial mineral removal, burial/inversion of mineral and peat soil, and various revegetation techniques. Although ground layer vegetation (e.g., bryophytes) are mentioned in the context of evaluating ecological function, outreach respondents focused primarily on revegetation techniques for woody vegetation (e.g., planting of stock seedlings in reference to uplands and leaving pads in place). The following section provides information based on recent research and case studies regarding reclamation of well pads and access roads through complete or partial removal of the mineral material and reestablishment of peatland characteristics.

Outreach respondents indicated that AEP/AER generally recommend partial removal and re-contouring of mineral well pads and/or access roads for transitional areas between uplands and peatlands; however, there was considerable inconsistency in responses as to whether partial removal of mineral material was a viable reclamation option given the uncertainty in meeting either (or both) upland or peatland criteria. Several respondents specified that partial removal and/or alleviation of adverse growing conditions on a mineral soil pad, such as compaction (deep ripping), was required to achieve equivalent land capability in the long term and others indicated that they would prefer to either completely remove the pad or leave it in place unaltered. One of the authors pointed out that there is inconsistency in the term partial pad removal, and that while many use the term to refer to vertical removal of pad material (i.e. reduce the thickness of the pad), the term can also refer to partial removal from a geospatial perspective, (i.e., removal of the entire pad on portion(s) of the site to create drainage channels or swales). In general, there was an overall reluctance to evaluate or adopt new reclamation or management approaches by industry, even when encouraged by the regulator due to the risk of not receiving a reclamation certificate at the end of life. **There is a need for more innovation and applied field trials to evaluate feasibility of different management and reclamation strategies.** Research has shown that complete and/or partial removal of mineral soil pads can effectively result in restoring peatland function in some scenarios and can be ineffective in others. Various reclamation techniques have been trialed and depending on the surrounding peatland and strategies deployed, the sites have either recovered relatively quickly or are on an alternate trajectory (as discussed in Section 3.2.2). A summary of recent case studies evaluating complete mineral soil pad removal (Section 5.3.1) and partial mineral soil pad removal (Section 5.3.2) is provided below and detailed in Appendix B. Based on an evaluation of recent case studies and outreach it can be concluded that **factors that influence reclamation success for mineral pad removal, and thus influence the decision to remove a pad or leave it in place include:**

- **The type of wetland (e.g. bog; treed poor fen, open graminoid fens)**
- **Regional hydrology and topography**
- **The availability of donor materials (Sphagnum mosses vs. fen mosses) for revegetation of mineral or peat substrates**
- **Proximity of a receiving site for borrow material**
- **Ability of equipment to manipulate site topography ('fluff' underlying peat material, scarification of mineral surface)**
- **Trenching to connect water flow and substrate moisture conditions**
- **Natural ingress of trees, shrubs, herbs, and mosses from nearby sources**

A summary of key factors affecting peatland function under different reclamation approaches for mineral soil pads within peatlands is provided in Table 4.

Table 4. A summary of key factors affecting peatland function under different reclamation approaches for mineral soil pads within peatlands.

Factor		Reclamation Approach for Mineral Soil Pad		
		Complete Removal	**Partial Removal**	**Left in Place**
Hydrology	Local	flow through	flow through and around the pad	flow under and around the pad
	Regional	no blockage to flow	potential blockage to horizontal and vertical water flow	potential blockage to horizontal and vertical water flow
	Water Table	at, near, above or below surface	at or above surface	below surface
	Drainage	easily to poorly drained, seasonally flooded	easily drained, seasonally flooded to dry	easily drained, dry within the root zone
Topography		flat to depressed, can lead to ponding	flat to rough, could be elevated relative to surrounding	flat to rough, elevated relative to surrounding
Vegetation	Trees	black spruce + larch	larch, poplar	upland species
	Shrubs	willow, birch	willow, birch	willow, buffaloberry
	Herbaceous	sedges, buckbean, cattail	sedges, horsetail, cattail	grasses, horsetail, cattail
	Bryophytes	*Sphagnum* to true mosses	true mosses, liverworts	no to low moss
Chemistry	Acidity/ Alkalinity	highly acidic to neutral	slightly acidic to neutral to alkaline	slightly acidic to neutral to alkaline
	Nutrient	residual mineral influence from clay overburden; low to moderate nutrients and cations	residual mineral influence from clay overburden; variable nutrients, cations, and salinity	variable nutrients, cations, and salinity
Soil		thick to shallow organic, all types of peat	shallow to thick mineral, loose to compacted, with geotextile liner or corduroy	thick mineral, loose to compacted with geotextile liner or corduroy
Carbon Dynamics		low to moderate productivity and decomposition, net uptake of carbon, peat accumulation	moderate to high productivity, high decomposition, net carbon uptake, slow peat accumulation	similar to upland; no to low net carbon uptake, low soil storage of carbon

5.3.1 *Complete Mineral Soil Pad Removal*

Several techniques have been trialed with varying results to completely remove mineral soil pads and restore peatland function (Appendix B provides a summary of recent case studies); peatland ecosystems have successfully been initiated in some but not all cases. The following summary provides insight into the more successful reclamation trials.

In 2012, researchers initiated a trial to examine complete removal of a mineral pad with inversion of the underlying peat substrate with or without burial of some of the mineral soil material (referred to as IPAD) in a treed bog/poor fen complex (Bird et al., 2017b). Heavy equipment was used to remove the layer of mineral fill that was higher than the low points of the hollows in the surrounding natural peatland. The mineral soil was returned to a nearby borrow pit used in the original well pad construction. In areas where peat under the mineral pad was deeper than 1 m, the remaining mineral material and geotextile was completely removed and the buried peat (up to 1 m deep) was 'fluffed' with an excavator bucket (Appendix B). The result after site adjustment was the creation of a uniform, flat peat surface with an elevation approximately 10 cm below the adjacent natural peatland hollows at the four corners of the pad. The Moss Layer Transfer Technique (MLTT) developed for harvested peat fields was applied to transfer moss fragments, along with roots, rhizomes, seeds, and spores from the surrounding cutlines to the site. Key learnings to date from the IPAD or inversion technique for complete mineral pad removal include:

- The site is well on its way towards a functional peatland. The site has passed two separate assessments using the provincial peatland criteria, in 2015 and 2018 and thus is considered to be well on its way towards a functional peatland
- The site has excellent vegetation cover. Mosses account for almost half (50%) of all vegetation. *Sphagnum* moss developed in the drier areas while true mosses dominated the low-lying areas
- Cattail was no longer abundant and dominant in wet areas 3 and 5 years after reclamation activities, and overall there was very few weeds present
- There was a good amount of litter accumulating across the site; there was no obvious distinction among different treatment areas and the site was stable without signs of erosion, gullying or presence of industrial debris

Building on the learnings from the initial IPAD trial a second study was established in 2015 with complete removal of the mineral soil pad utilizing the peat inversion technique in a fen. Materials were returned to the original borrow pit at the time of reclamation. The buried peat was 'fluffed' to raise the surface elevation, then smoothed to remove air pockets and create a uniform surface. Donor moss was immediately transferred from a nearby cutline, and the site was re-vegetated with black spruce (Appendix B). Additional learnings from the fen study include (NAIT CBR, personal communication 2018):

- Complete pad removal in a fen led to more flooding in early years
- Donor material from a bog site had little influence on revegetation within the fen; there was very low establishment of *Sphagnum* mosses across the site
- Hydrology and soil chemistry played critical roles in vegetation development
- Vegetation was marsh-like but ground layer is dominated by true mosses
- There was a visible decline in cattail dominance in many areas on the site 3 years after reclamation activities

Another technique trialed was the burial of wood chips under peat within a circumneutral fen (Appendix B). During construction, an average of 1 m of wood chips were place directly on top of fen peat with a separating geotextile layer to develop an access road. In 2015, wood chips were inverted with buried peat to create a moist surface for fen vegetation reestablishment (Bird et al., 2017a). A similar approach to the IPAD technique was deployed and a dozer track packed the surface to reduce the elevation. The site was planted with black spruce and tamarack but otherwise left to naturally revegetate. Two years following reclamation activities results indicated:

- The road surface is level with surrounding areas
- Significant increases in overall vegetation cover since 2016, driven by exponential growth of sedges and the establishment of mosses
- Planted tree seedlings are visually healthy although, woody species remain low in abundance and cover

5.3.2 *Partial Mineral Soil Pad Removal*

Partial mineral soil pad removal is often considered by researchers and practitioners alike to be a viable solution to cost effectively reclaim mineral soil pads within peatlands when the goal is to establish a functioning peatland ecosystem. Appendix B provides a summary of several case studies which have evaluated various techniques for partial mineral soil pad removal from various peatland complexes. Paludification was first trialed in 2007 (Vitt et al., 2011b) to initiate fen revegetation on re-wetted mineral substrates on in-situ well pads. The majority of mineral soil material was removed and trenches were created to connect the pads with the surrounding peatlands. The lowered soil surface was either 'fluffed' or 'left as is', then amended with various materials including wood chips and stockpiled peat and planted with various wetland species including willow cuttings, sedge transplants, and tamarack trees. Assessments in 2017 indicated that the site would not meet the peatland criteria due to the presence of a high percentage of undesirable species.

Another study by Gauthier et al. (2018) which evaluated mechanical shaving and recontouring of the mineral soil material to the average elevation of the surrounding peatland water table within a fen, followed by revegetation by hand with the MLTT technique found that true mosses such as wooly feather moss (*Tomenthypnum nitens*) and tufted moss (*Aulacomnium palustre*), both typical of fens established quickly, covering up to 58% of ground cover after only one growing season. The origin of the plant community, rather than the substrate type, was the determining factor for vegetation growth. *Sphagnum* mosses were abundant in the donor communities but did not establish successfully on the reclaimed mineral pad. Vascular plant establishment was slow and highly variable. Field observations in 2018, indicated that (1) different soil adjustment and vegetation treatments were no longer discernable from each other (Appendix B); (2) cattail was not the dominant species on site; and (3) shrub cover increased significantly while ground layer cover by true moss was approaching 100% in some areas.

Partial removal, planting, and natural regeneration of a mineral linear feature (airstrip) built in the 1960s through the edge of a peatland complex was initiated in 2014 (NAIT CBR, personal communication 2018). No buried peat or nearby donor peat material could be found so the area was reclaimed as a mineral wetland with a variety of stock seedlings planted in 2015. After four growing seasons, the site hydrology had stabilized, and the wetland was dominated by obligate wetland species (up to 45% percent cover) with a community similar to marshes (sedge and graminoid dominance) typical of the region. True mosses accounted for up to 15% of the total cover in many parts of the site (Appendix B), although they were not introduced in the initial revegetation but had come on site through water flow or wind.

A study in northeastern Alberta included partial and complete mineral soil pad removal from a treed rich fen in 2002, followed by spontaneous colonization by plants (i.e., no active revegetation strategy). Progressive learnings associated with mineral soil removal resulted in several reclamation techniques for evaluation. Key learnings from the trial included:

- Partial pad removal leaving remnant fill in place does not hinder peatland vegetation, particularly moss, development if the surface is suitably saturated
- Open water areas are too deep for most wetland species to establish, although floating moss mats start to occur along the edges in some areas
- Achieving proper surface elevation and restoring hydrological connectivity is critical to reclaim mineral material soil pads and deep open water should be avoided as much as possible
- Remnant fill left during well pad reclamation to peatland does not appear to result in large mineral nitrogen pools or elevated N_2O emissions indicating that partial pad removal is likely a viable reclamation option considering biogeochemical function

Mineral soil pad construction influences the applicable reclamation techniques and success as was demonstrated by a study evaluating partial pad removal in a treed poor fen (Osko, 2018). The study trialed mounding to bring buried peat to the surface and incorporation of remaining fill underneath resulting in a rough (up to 1 m relief) mounded surface of exposed peat and thin fill veneer across the site (Appendix B). Sub-sections of the site was later compacted to create smooth macroplots (<15 cm relief). Both rough and smooth macroplots were divided into sub-plots to receive live fen moss transfer or left for natural recovery. These sub-plots were further divided to compare natural recovery (with or without moss transfer) to recovery through live transplants of black spruce, Labrador tea, and sedges from adjacent fens. Shunina et al. (2016) studied early development of vegetation in 2012 and 2013, one and two growing seasons after reclamation. Rough areas had higher species richness through natural recovery of trees, shrubs, and perennial herbs. Survival of transplanted woody species were also greater at the top and mid positions. Acrotelm (fen donor) application had no impact on overall vegetation growth during the first two seasons. By 2017, there was no difference in species richness and diversity among different surface roughness or moss application. Natural regeneration of larch, willow, birch was common across the site regardless of surface treatment or moss application; however, in 2017, the entire site was dominated by herbaceous species such as *Carex* spp. and cattail. Bryophyte species richness was higher in plots which received moss application. Typical fen mosses such as common hook moss (*Drepanocladus aduncus*), rusty hook moss (*Drepanocladus revolvens*), small red peat moss (*Sphagnum capillifolium*), and wooly feather moss (*Tomenthypnum nitens*) were commonly associated with plots that received moss application (Osko, 2018).

Partial removal of an access road was completed in northeastern Alberta in multiple phases (Osko, personal communication, 2018). The initial trials were carried out in three blocks in 2010 by removing 80 cm of the mineral fill from each block (Appendix B) followed by the establishment of study plots where several revegetation treatments were applied. Additional trials were established in 2018 to test two different approaches of mineral removal and transfer of moss donors onto rewetted peat or mineral substrates. Learnings from the study thus far indicate:

- Deep inundation due to poor hydrological connectivity with surrounding areas leads to cattail dominance
- Soil amendments had limited impact on vegetation
- Fen communities can establish in areas with suitable moisture

5.4 POTENTIAL ADVERSE ECOLOGICAL IMPACTS FROM MINERAL SOIL PADS IN PEATLANDS

Mineral soil pads and associated features affect a wide range of microclimatic, biogeochemical and hydrological parameters, which have the potential to alter ecosystem functions and services (Figure 7).

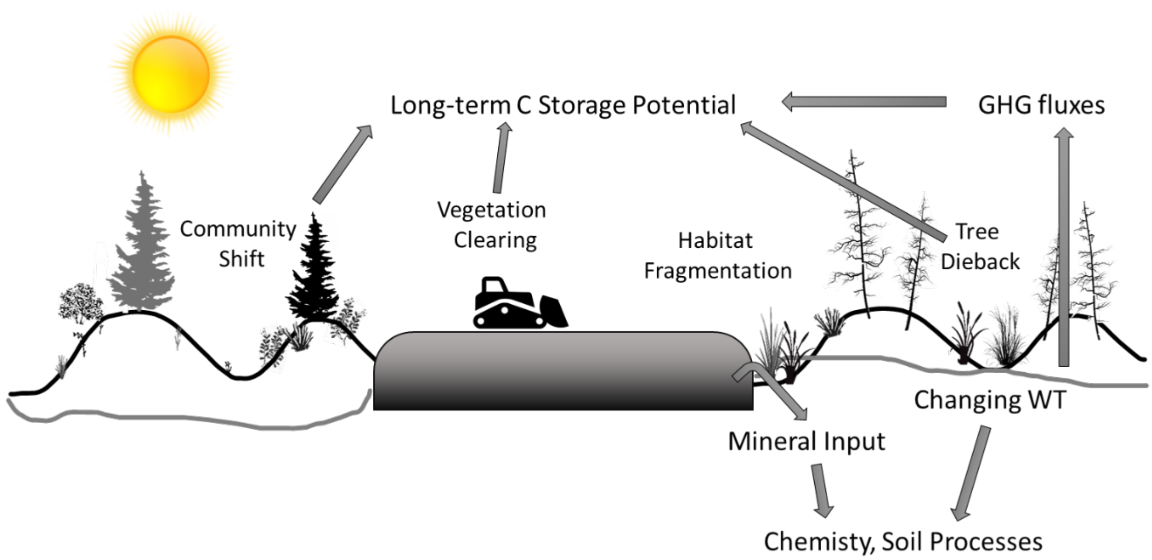

Figure 7. Illustration of a mineral soil footprint and its potential impact on vegetation, hydrology, chemistry and carbon balance of surrounding peatlands.

The impact of mineral soil pads and roads on peatlands can be direct through the loss of peatland vegetation and leaching of nutrients from the pad; or indirect through the changes in hydrology and vegetation in the surrounding areas. These effects vary across spatial and temporal scales. Placement of mineral soil on peat surfaces eliminates delicate living surface vegetation, consequently terminating CO_2 uptake via photosynthesis and the potential for long-term carbon storage through peat formation which is the easiest impact to quantify given the current understanding of peatland ecology. Removal of trees from the pad or road footprint will remove most of the aboveground biomass and net primary productivity (NPP), potentially reducing the net carbon uptake unless the understory productivity increases to compensate for the loss. This direct biomass loss can be estimated using aboveground biomass of typical boreal peatlands at 750 and 775 g/m^2 for fens and bogs and avarage NPP of 131 ± 208 g C/m^2/yr in black spruce bogs of Alberta (Vitt et al. 2000, Wieder et al. 2009). Across North America, peatland biomass ranges from 351 to 7,300 g/m^2 and NPP ranges from 27 to 310 g/m^2/yr in treed sites (Campbell et al., 2000). Therefore, removal of the woody layer alone will reduce carbon uptake of the peatland by these amounts. Moreover, changes to local hydrology and thermal regime around the pad or road can also alter carbon exchange and storage, but direct quantification of such changes are not available.

Leaching of nutrients from mineral soil pads and roads can also alter the soil and water chemistry of the surrounding peatlands and lead to changes in plant growth, community composition, and the eventual loss of carbon sequestration and storage in the adjacent areas (Bocking et al., 2017; Johansen et al., 2017; Miller et al., 2015). Leaching from pad material can also impact the peat underlying the mineral soil pad itself. After five years some soil chemical and physical properties of the underlying peat in a treed fen in northeastern Alberta had changed (elevated ammonia, SAR, available sulphur, manganese and iron and reduced available phosphorus and potassium) compared to undisturbed controls, although many parameters were comparable to undisturbed control (most notably pH, total organic carbon, degree of decomposition, total nitrogen and bulk density) (Acden Vertex Limited Partnership, 2019). There were no differences in the growth of wetland grasses and sedges in greenhouse bioassays with material from under the pad and undisturbed soils (Acden Vertex Limited Partnership, 2019). Changes in soil quality were generally comparable to those noted during stockpiling of peat (Acden Vertex Limited Partnership, 2019).

Deposition of road dust on nearby peatlands is common and can affect chemistry and vegetation along roads. Dry deposition of nutrient-bearing aerosols can enhance *Sphagnum* growth (Gignac et al., 1994) through a fertilization effect. Wooded peatlands with trees of varying height received a higher amount of salt ions (Cl^-) and total influx of nutrients than open peatlands with no trees (Schauffler et al., 1996). Within 10 m of a road, dust loading increased by 355% compared to areas without roads, leading to an annual deposition of 647 g/m^2 of gravel road dust (Creuzer et al., 2016). This increase declined to 46% at 40 m from a road. However, the effect of dust loading on water and soil chemistry was minimal compared to natural areas. This indicates that the impact of dust deposition will depend on the peatland type (bog vs. fen, treed vs. open), prevailing wind direction, water chemistry (alkaline fen vs. acidic bog) and the effect is confounded by other factors such as changing hydrology and water table. Dust loading of well pads is less studied and it is unclear if the impact is similar to that of linear disturbances.

Construction of mineral soil access roads and pads can greatly affect hydrology around the disturbance but only a few studies have aimed to quantify such impacts on peatlands. The weight of mineral soil materials causes peat compaction and reduces local hydraulic conductivity (Gillies, 2011; Partington et al., 2016). This can change water table position and temperature regimes around mineral soil padded roads and greatly affect local water table and surface/subsurface water flow around these roads (Plach et al., 2017; Strack et al., 2018), with flooded conditions on the upstream areas and dry conditions in the downstream areas. The impacts of mineral soil padded roads may differ depending on the peatland type they are situated within and the direction of water flow relative to the road (perpendicular or parallel). Saraswati et al. (2019) studied two access roads built in a treed bog and a rich fen near Peace River, Alberta. They found that the construction of access roads disturbed the surface and sub-surface water flow at the bog, where the road was perpendicular to the water flow, but that the effect was minimal at the fen, where the water flow was parallel to the water flow. At the bog site, water flow was reduced and water table raised along the road. Culverts provide a point source of water transportation to the downstream areas but their effects were only evident close to the road and the water was not evenly distributed in the downstream areas. In the flooded areas, phenol oxidase and hydrolase activities were significantly higher than those in the undisturbed areas, suggesting that access roads may cause enhanced decomposition and ultimately carbon loss from the upstream side with a raised water table (Saraswati et al., 2019). This loss can be further exacerbated if the peat-forming bryophyte ground layer is replaced by vascular species (graminoids and *Typha*) which decompose more easily. On the downstream side, lowered water table may lead to vegetation shift and changes in net carbon balance. Wood (2010) found enriched water chemistry and shifts in vegetation communities within 50m of a mineral haul road on the upstream side. Downstream vegetation was less affected, and the water table responds differently to the road on the upstream and downstream sides. Munir et al. (2014) found a significant increase of coverage of shrubs and lichens in the hummocks and hollows in a treed bog after ten years of water table drawdown for peat harvesting. Drainage induced changes in vegetation led to a shift from a net sink of 70 to 92 g C/m^2 to a net source of 23 to 27 g C/m^2 (Munir et al., 2014). Willier (2017) found increased canopy cover and tree species composition on the downstream side of roads compared to the downstream side. Species richness increased on the upstream side of a bog and on the downstream side of a fen. Road orientation, substrate texture, landscape position, and peatland type all had impact on how the vegetation communities responded to roads. The long-term effect of changing water table and changing water flow on vegetation and ecosystem function as a result of mineral well pads and roads is unclear and requires additional research.

Canada's boreal forests are home to thousands of different species of birds, mammals, reptiles, amphibians, insects and fish. In Alberta, mature, treed bogs are important shelter and foraging ground for woodland caribou, a threatened species at risk. Human activities including in-situ exploration and extraction, forestry, and urban development are known to cause degradation and fragmentation of wildlife habitat in the boreal. Linear disturbances (e.g., all season roads, seismic lines) in particular have been considered the leading cause of caribou population decline (Boutin et al., 2012; Finnegan et al., 2018). Clearing and poor regeneration of the woody layer provides corridors that connect upland and lowland habitats, thus reducing the spatial separation between wolves and caribou (Latham et al., 2011). Facilitated by the easily travelable linear corridors, the likelihood that wolves will encounter and kill a caribou in already limited habitat (Latham et al., 2013) increases significantly. Roads with moderate traffic act as a semipermeable barriers to caribou movement (Dyer et al., 2002), which may exacerbate habitat loss through avoidance by caribou in already limited space (Dyer et al., 2002; Schindler et al., 2006). Wolf packs prefer areas close the roads (within 25 m of roads), trails, and railway lines compared to high-use roads and trails (Houle et al., 2010; Whittington et al., 2005). Industrial stream crossings can change abiotic habitat characteristics in freshwater ecosystems, restrict biotic connectivity and impact fish community structure at the whole-stream and within-stream scales (Maitland et al., 2016). Hanging culverts (e.g., outfall elevated above the stream surface) associated with roads crossing wetlands are known to cause stream fragmentation and create upstream movement barriers for fish communities (Park et al., 2008). Roads are also found associated with the invasion of exotic earthworms, facilitated by vehicle traffic and bait abandonment (Cameron et al., 2008). To conserve and restore fragmented habitat for caribou population, restoration of linear features has been a high priority initiative among government, industry, and the general public (Pigeon et al., 2016; Ray, 2014). Studies that have evaluated linear restoration effectiveness in terms of caribou habitat conservation are limited (Vinge and Lieffers, 2013) and evidence of positive impact on caribou population is scarce (Pyper et al., 2014).

In summary, the potential impacts of mineral soil pads and roads in boreal peatland ecosystems include:

- Clearing of vegetation and elimination of primary productivity and long-term carbon accumulation potential of the pad or road area
- Changes in greenhouse gas balance and long-term carbon sequestration potential over the affected areas
- Mineral soil impact on chemistry of the surrounding areas and underneath the pad or road through leaching and dust deposition
- Changes in water flow and local hydrology and loss of water regulation function
- Altered growth and shift in vegetation community around the footprint, especially associated with access roads
- Reduced habitat value and biodiversity (e.g., linear features, habitat fragmentation)
- Responses to mineral features depend on interacting factors such as landscape position, regional hydrological regime, substrate type, peatland setting, and the orientation and distance from mineral feature

5.5 PROCESS AND FACTORS AFFECTING THE DECISION TO LEAVE A MINERAL SOIL PAD IN PLACE

In the context of this section, only mineral soil pads left in place in a peatland that are reclaimed to upland forests are considered. Pads left in place in peatlands that have sunk into the peatland and are on a trajectory towards a peatland end land use (i.e., peat-forming species are developing) are not considered.

5.5.1 *Mineral Soil Pad Impacts*

The preceding section (Section 5.4) described the impacts that can occur when a mineral soil pad or road is left in place in a peatland. **In the decision to leave a mineral soil pad or road in place in a peatland, whether or not significant adverse effects occur is a key consideration. Outreach respondents tended to focus most on effects to hydrology (inhibition of off-site surface and subsurface water flow) as a key factor, but subsequent effects to vegetation in the surrounding peatland were also a significant concern.** Typical effects to surrounding vegetation observed by respondents included vegetation (tree) mortality, vegetation appearing unhealthy, or changes in the vegetation community composition. One outreach respondent specified that in the decision to leave a pad or road in place that hydrology data from piezometers are not required and that changes that can be observed such as ponding/damming/flooding or vegetation changes would be sufficient; there is uncertainty on this topic from other respondents and a more formalized approach to detect and quantify hydrology impacts may be required to inform decisions on whether to leave pads in place.

The frequency and severity of off-site hydrologic impacts (and subsequent effects on vegetation) have been found to vary with:

- **Wetland type (bog vs. fen)**
- **Direction of water flow relative to the feature (perpendicular vs. parallel)**
- **Type of feature (pad vs. road)**
- **Size of feature**

Some outreach respondents felt that impacts of mineral soil pads or roads left in place were more common in bogs rather than fens. Research noted in Section 5.3 and 5.4 suggests that the effect of wetland type must be considered in the context of the direction of water flow relative to the feature (whether water flow is parallel or perpendicular); impacts may occur in bogs if the water flow is perpendicular to the road, while impacts may not occur in fens if the flow is parallel to the road. The type of feature is also an important factor. **Outreach respondents felt that access roads were more likely to have impacts than well pads.** As was noted in Section 5.4, there has been little work on the actual impact of the well pad itself while the negative impact of access roads appears to be well documented, although processes and methodologies to quantify impact are still lacking. One outreach respondent noted that the size of the pad should be a consideration, as 4 m x 4 m pads at well centre are less likely to have an impact compared to a full lease (e.g., 100 m x 100 m).

Impacts to hydrology related to culvert removal along roads is another consideration. If the culverts remain in place, there is a potential for them to become blocked by debris over time and cease functioning as a conduit for water flow across the road. If the road is left in place but culverts have been removed and the mineral road fill above them was peeled back onto either side to create gaps along the road that act as channels for water flow, impacts to water flow may be reduced.

Respondents also noted concern about the impact of the mineral material on the surrounding peatland in terms of water and peat chemistry. Similarly, impacts to the former vegetation underlying the mineral soil pad or road footprint and resulting effects on carbon sequestration and wildlife habitat have already occurred during construction and cannot be avoided, but the permanent loss of these functions is a consideration if the pad or road is left in place.

Off-site effects, and acceptability of the mineral soil pad or road left in place, may also be affected by the stability of the pad or road, which can be modified by any reclamation practices that were implemented. Outreach respondents considered the occurrence of erosion, slumping and sedimentation into the surrounding peatland to be factors. Pads or roads that had been recontoured during abandonment to minimize these effects, and blend into the surrounding landscape are viewed more favourably (as discussed further in Section 5.4.2 on regional considerations).

5.5.2 *Cumulative Effects and Regional Considerations*

Cumulative impacts of multiple mineral soil pads and roads on local and regional peatland hydrology, chemistry, vegetation, and greenhouse gas fluxes, and how the impacts vary in different types of wetlands (bogs vs. fens) were highlighted by both regulator and industry outreach respondents as key considerations as well as key knowledge gaps in the decision to leave a mineral soil pad in place. **Currently, where pad or road density is high, networks of pads or roads are present, or the pad or road is in close proximity to other infrastructure, approval is less likely; however, there is a need for establishing a cumulative effect threshold based on scientific and geographical approaches to allow a proportion of wetland in a given area to be "lost" without significant degradation of function of the region. This is a major knowledge gap.**

As noted in Section 4.4.1.5, the factors to consider in the discussion of cumulative effects include:

- **Actual negative impact of the mineral soil pad or road left in place**
- **Number of other mineral soil pads or roads left in place in the local and regional area**
- **Size of the local or regional area over which cumulative effects are determined**
- **Scale and impact of other human impacts in the local or regional area**
- **Sensitivity of the ecosystem, or receptors within that ecosystem (e.g., caribou in peatlands), to cumulative effects**

Another regional consideration identified by outreach respondents was proximity of the site to other upland areas. If the surrounding area is a mosaic of upland forests, bogs and fens, or a transitional area between upland and peatland, an upland forest on a pad or road left in place is considered more appropriate by many outreach respondents than if the surrounding area is a large, uninterrupted fen or bog. Alternatively, some respondents suggested that landscape diversification of an area with a large proportion of peatland could be a rationale for leaving a mineral soil pad or road in place with an upland forest plant community; one respondent noted that uplands may act as wildlife refuge within a large peatland area.

Similarity of the pad or road left in place to both natural upland landforms and vegetation communities were also factors raised by outreach respondents. It is important to consider whether the pad left in place has been recontoured into a landform with a more natural appearance such as a hill, hummock or dune-like feature consistent with natural uplands, and whether the upland vegetation communities developed on pads are representative of locally common upland ecosites in the region or natural subregion.

Topography of the site relative to the immediate surrounding areas was another factor noted by respondents. If the site is in a transition zone between upland and peatland, it can more easily be recontoured to be compatible to the surroundings (i.e., pad material) can be moved to the upland portion of the wellsite) than if the site is surrounded by a peatland, which is generally flat; however, pads or roads surrounded by peatlands can be recontoured to have a gradual transition from the pad or road surface to the surrounding peatland, which some would consider more acceptable to be left in place (e.g., hills and dune-like features, as previously mentioned).

5.5.3 *Upland Function*

In addition to whether the mineral soil pad or road left in place has off-site impacts, **the ability of pad or road to support a functioning upland ecosystem is another important factor**. Outreach responses suggested that whether natural recovery or revegetation is proven successful is a factor that is weighed in approval, but regulators do not consider vegetation alone to be a high priority or an appropriate justification to leave a pad or road in place. Overall it seems that industry and consultants are more likely to consider vegetation re-establishment as a condition that would merit leaving a pad or road in place, whereas regulators consider the landscape and soil factors to be more important considerations for long term sustainability. Determination of the success of natural recovery or revegetation on mineral soil pads left in place varied among respondents. There was a focus on functioning forest ecosystems that meet the forested land criteria and is on a trajectory to achieve equivalent land capability, with seemingly low tolerance for sites dominated by grasses, agronomics or non-native species. There is a lack of clarity and consistency on the reclamation expectations for sites with mineral soil pads left in place that meet the standards of the day but not the current forested land criteria. Outreach responses on the requirements of a functional ecosystem on reclaimed wellsites is discussed further in Section 3.1.2.

Lack of topsoil on mineral soil pads left in place was seen by some respondents as a source of uncertainty in the ability of the pad to be successfully reclaimed. Others were more confident that amendments could be used to create a growing medium for plants in areas that were lacking. Reclamation of wellsites with no topsoil was discussed in Section 4.4.1.2 in the context of upland sites. Constraints related to lack of topsoil would be similar for mineral soil pads left in place; however, there are two main differences: (a) because the site is not surrounded by an upland forest, there is a lack of nearby propagules to disperse onto the site to compensate for the lack of propagules that would have been found in the topsoil and (b) the soil chemical and physical properties of the upland subsoil (B horizon) may be different than the mineral soil pad material which was excavated from a borrow pit, likely at a depth below the B horizon.

There are no peer-reviewed studies on mineral soil pad revegetation through natural recovery that examine propagule dispersal onto mineral soil pads, but reports and anecdotal evidence suggest that natural recovery in these circumstances is generally slow and that planting is typically needed to achieve certification within a reasonable timeframe (Osko and Glasgow, 2010).

Soil chemical and physical properties of the pad were noted by respondents to be a factor in the decision to leave a mineral soil pad in place. For example, pad material with elevated sulphate concentrations may not be acceptable to be left in place, although one respondent contended that the net environmental benefit of moving that material to a borrow pit where the elevated sulphate concentration would continue to be a problem should be a factor, as will be discussed in Section 5.4.4. In terms of soil physical properties, several respondents felt that the application of decompaction measures was a prerequisite for approval of a mineral soil pad left in place, to create a suitable growing medium for plants; there were uncertainties raised about the capability of the site to achieve equivalent land capability (despite vegetation encroachment) if compaction was not alleviated.

Respondents noted that whether geotextile or corduroy was present under the mineral soil pad or road was a factor in whether the pad or road could be left in place. Geotextiles left in place can create a hazard for wildlife, as there is potential for animals to become ensnared in pieces of geotextile exposed at the surface, typically around the edges of the pad. Removal of geotextile was noted by respondents to be challenging. **Respondents also commented on the impacts of geotextile and corduroy on rooting medium restrictions; responses were mixed. One respondent felt that filter cloth underneath the pad prevents root penetration and development and does not provide an appropriate rooting medium for plant growth, while another respondent found that geotextiles tend to settle below the water table and that it is the water table rather than the geotextile that limits root growth; a third respondent felt that this was an area of uncertainty that was not well understood.** Based on literature review and field measurements, the maximum rooting depth of the tree and shrub species of forested areas in Alberta has been found to be 1.5 m for fine-grained soils and 3.0 m for coarse-grained soils (Millennium EMS Solutions Ltd., 2013). Water table does play a role in determining rooting depth; in water saturated environments, rooting depths are shallow to avoid oxygen stress below the water table (Fan et al., 2017). The same species can have different rooting depths with different topographic positions and water table depths (Fan et al., 2017). As a result, mineral soil pad depth will be a key factor in whether rooting medium restrictions occur.

5.5.4 *Pad Removal and Net Environmental Benefit*

Net environmental benefit was frequently stated by practitioners and industry as a rationale to justify leaving mineral soil pads in place, noting that that the environmental costs of pad removal in some cases can outweigh the benefits and must be considered on a site by site basis. Damage to the borrow pit was a commonly cited environmental cost, as was damage to the existing vegetation on the access road to mobilize heavy equipment required to implement pad removal. The main benefits of pad removal are the re-creation of peatland ecosystems and restoration of peatland functions including carbon sequestration and wildlife habitat, as well as reduced uncertainty about cumulative effects of pads left in place. **While there were significantly different opinions on the subject of leaving pads in place, several**

respondents agree that there is a need to empirically and objectively evaluate the actual ecological costs and benefits of pad removal.

Some respondents point to the uncertainty of success in re-creating functional peatland ecosystems when pads are removed as a justification for leaving the pad in place. While some respondents have observed successful pad removal for both fens and bogs, and noted that the type of peatland is a factor in recovery from pad removal as fens tend to recover more quickly, there was uncertainty among respondents on the following topics:

- **Extent of peat compression under the pad, and how this is impacted by the thickness and overall weight of the pad**
- **Extent of peat rebound after the pad is removed and how this is impacted by the duration of the pad being in place and thickness of the pad**
- **Potential for and risk of minimal peat rebound and the creation of an open water body with cattails instead of a site on a trajectory to a functional peatland**
- **Impacts to underlying peat chemistry resulting from the pad material, and how those changes may impact a developing plant community after removal of the pad**

Research on many of these topics are underway, as described in Sections 5.3 (case studies) and Section 5.4. **As borrow pits are typically the only available location to put the clay material from the pad for conventional wellsites[21], the conditions of the borrow pit associated with the mineral soil pad and the type of ecosystem that has developed there are important factors. Respondents noted that borrow pits that are not revegetated or that are revegetated as upland sites are less likely to be viewed as mitigating factors in the decision to remove a pad.** In fact, if the borrow is degrading and not reclaimed, returning the clay material to that borrow pit would return it to a productive forest, creating an incentive for mineral soil pad removal. **Alternatively, if the borrow pit is revegetating into a wetland ecosystem that provides wildlife habitat (or even other uses such as fire control), it is more difficult to justify removing the pad.** Some respondents suggested that the wetland that would be destroyed on the borrow pit to replace the clay material could be a close equivalent to the wetland that will be created on the former mineral soil pad location. This is a value judgement that was not shared by all respondents. Implications of Alberta's Wetland Policy (Alberta Environment and Sustainable Resource Development, 2013b) for wetland avoidance, minimization of impacts and replacement must be considered. **Respondents also brought up challenging logistics in returning mineral fill to a borrow pit that has**

[21] Re-use of the fill material for construction of another pad or road is not discussed here as it is assumed to be rare in the context of conventional wellsites. One respondent noted that mineral fill from peatlands with less than 1.5 m of peat is easier to remove and re-use.

recovered to a wetland, including pumping the water out and working with saturated soils, as mitigating factors in the decision to leave a pad in place. The amount of mineral material that would require placement in a borrow pit (which is determined by the depth and size of the pad), was noted as another factor to consider. Overall, the importance of condition of the borrow pit as a factor in leaving a mineral soil pad in place was considered to be a lower priority by some respondents than impacts to hydrology and surrounding areas, cumulative effects and regional implications.

The damage to vegetation on the access road was raised by respondents as another source of environmental damage (cost) to pad removal. **As with upland sites, remoteness of the site, length of the access road and the number of creek crossings are factors associated with this that can increase the amount of environmental damage that is incurred.** Longer access roads represent a larger area requiring disturbance. Creek crossing are considered to be more sensitive to disturbance. **While several respondents suggested that remoteness of the site has often been a driving factor in leaving a mineral soil pad in place, one respondent noted that remoteness of the site should be given lower priority in the decision making process for padded sites than for upland sites, as the size and value of a pad removal project is large enough to warrant the disturbance to the access road, whereas for upland sites, the importance of fixing deficiencies may be smaller and therefore disturbance to the access road is more difficult to justify.**

Another potential environmental cost of pad removal raised by respondents was the potential for weeds and invasive species associated with excavating, hauling and placing pad material in a borrow area. This is discussed in further detail in the context of upland sites in Sections 4.4.2.2 and 4.4.2.3. Remoteness of the site and proximity to sources of weeds (active sites, industrial traffic or agricultural areas) will be factors in the potential for weeds.

5.5.5 *Location and Land Use Considerations*

Outreach respondents noted several specific considerations related to where the site is located and the land use of the site, including:

- Species at risk habitat (most notably caribou and caribou calving areas). Reclaimed wellsites in species at risk habitat have the additional requirement of supporting the species at risk; the tolerance for leaving mineral soil pads in place may be lower in species at risk habitat
- Pre-existing agreements and conditions with an overlapping tenure holder or stakeholders such as an FMA, grazing lease disposition or traditional users. Forest productivity and operability of the site for forestry equipment should be considerations when wellsites are located in FMAs. For grazing leases, the suitability of the wellsite for livestock grazing becomes a factor. Traditional

users have requirements related to safety and compatibility of the site for their traditional use One respondent noted that if there are multiple stakeholders that may be impacted, then it is generally harder to justify leaving deficiencies in place

- Recreational users. The potential for the site for be used for recreational purposes (camping, staging for off-road vehicles) and the adverse effects of trails on the peatland if the mineral soil pad was removed must be considered
- White Area. Reclamation of sites in the White Area should consider the potential for cultivation
- Proximity to private land. There may be an increased potential for future development if the site is close to private land
- Proximity to areas protected by other dispositions (PNT, CNT, provincial or federal park)

5.6 Process and Factors Affecting the Decision to Grant a Change of Land Use

This section discusses the application and approval process for a change in land use, the information that must be submitted and factors affecting the decision to grant approval. This section does not discuss the technical (ecological) aspects of a change in land use as this was discussed in Section 5.5.

Real world examples, a database of case studies are needed, and more research are required to understand the environmental implications of removing and/or leaving a mineral soil pads in place. Also access to current research findings would help understand the impact of mineral soil pads in peatlands. **Checklists, guidelines, and a basic framework need to be developed to generate appropriate justification for accepting or rejecting industry requests regarding mineral soil pads in peatlands.**

Guidance on the process of applying for a change in land use is provided in SED 002 (Alberta Energy Regulator, 2018). **Requests for a change in land use must be approved by the Land Manager (and any occupants) before a reclamation certificate application is submitted, and signed documentation of the approval of the change in land use must be submitted with the application** (Alberta Energy Regulator, 2018). Several respondents noted that communication with the regulators early in the process (ideally before any reclamation work is completed) is critical to approval of the request, as it allows for their input to be incorporated into reclamation plans as they are being developed. **Although SED 002 does specify that AEP is considered the Land Manager on public lands, and as such would be responsible for approving land use changes, several respondents, including reclamation practitioners, industry and government, noted that there continues to be confusion as to whether AEP or AER is responsible for approving the change in land use.**

The overall goal of the request for land use change application is to provide an appropriate rationale for change in land use with detailed, site-specific background information. **Responses from regulators suggest that they consider a rationale appropriate if it is ecologically- rather than cost-based; arguments**

based solely on the hypothetical risk of environmental damage caused by pad removal that are perceived to be driven by a desire to avoid reclamation are not viewed favourably. Decision makers want to see empirical data and ecological cost/benefit analysis specific to the site in question. Respondents noted that a request for a change in land use is very similar to a reclamation certificate application in that it must show that the site meets equivalent land capability and provides necessary ecosystem functions, but respondents also note that this alone is not sufficient. Requests must also show that there are no risks of adverse effects to off-site areas, and must consider cumulative effects and how the site fits into the regional landscape. Consideration of associated borrow pits is important; if a borrow pit is available for the mineral material to be returned to, requests for a change in land use tend not to be approved.

Respondents have noted a reluctance on the part of the regulator to approve changes in land use, and significant variability in response to requests. This hesitation appears to stem from a need for a more thorough understanding of the long terms effects of mineral soil pads left in place on peatland hydrology and vegetation and the cumulative effects of multiple pads. Additionally, there is a concern among regulators of appearing to value forests more highly than wetlands.

SED 002 provides the following list of information that applicants may provide for a change in land use, including guidance specific to the change from peatland to upland forest (Alberta Energy Regulator, 2018):

- Topography relative to adjacent developed land
- Pre-disturbance or off-site community type (e.g., ecosite phase, ecological range site, agronomic community or Alberta wetland classification)
- Current vegetation community type and site photos
- Adjacent land use: distance to cultivation, grassland, Green Area boundary (as relevant)
- Access: distance, topography, presence or absence of impact to hydrology and off-site vegetation
- Soil: A horizon and subsoil colour, texture, acidity, electrical conductivity, sodium adsorption ratio, and stoniness
- Climate class
- Agricultural capability class for cultivated lands (as appropriate)
- Development plan for alternative development (e.g., recreational site)
- Rationale for the change in land use
- Site description, photographs, survey plan of the site
- Peatland type
- Presence/absence of subsurface or surface water impacts to vegetation
- Absence/presence of locally common upland communities and type

Respondents suggested that in addition to this information, detailed site assessments (DSAs), site sketches with drainage direction, peat depth information, construction records, reclamation details, site history of recreational use and pre-existing trails/access roads, regional information such as reports from the landscape analysis tool (LAT reports), as well as any information related to current and future overlapping land uses related to those factors identified in Section 5.5.5. In particular, reclamation details provide an important source of information about how the limitations of the site were taken into account, and the mitigative measures and adaptive management that were applied. In cases where additional reclamation is intended, some respondents have had success with submitting a reclamation plan to AEP as part of the application. Additionally, one respondent remarked that an analysis of the suitability of the **target ecosite to the actual soil characteristics on the pad would strengthen the request.**

Agreements put in place when the disposition was granted or renewed were a primary consideration for approval of change in land use requests for many respondents, especially if the is still owned by the original owner. These agreements may have specified the reclamation plans that were intended to be employed, and if those plans included a return to equivalent land capability as existed prior to disturbance (with no change in land use), then this is the expectation from regulators.

As with requests for variances, several respondents mentioned the importance of time and long-term implications as factors in the approval of changes in land use. Respondents noted that a longer monitoring time frame to manage risks associated with the conditions on the pad left in place that have the potential to limit recovery of ecosystem function (e.g., lack of topsoil and local propagule sources) is viewed positively, and would provide more certainty that the site is on a trajectory to achieving equivalent land capability. As with requests for variances, a minimum of 4 years of vegetation growth was suggested by one respondent as a requirement for applications. Expectations for reclamation based on how long the site has been in place and the requirements under which is was constructed is another factor raised by respondents. **As was noted for upland sites, how this is evaluated in the approval process is not clearly defined.**

Several suggestions were made regarding the need for decision support tools and process flow descriptions to help users provide better information and help regulators make more consistent decisions. The need for a standardized assessment framework and methodology to approve requests for a change in land use was mentioned more than once. Several respondents noted that a publicly available database of case studies that would keep track of the following:

- Sites that were and were not certified (i.e., conditions that were and were not deemed acceptable)
- Reclamation practices that have worked or not worked in different areas of the province
- Sites that have long term results to focus on longer term implications for ecosystem function and equivalent land capability

Research findings and literature were noted by several respondents to be a necessary piece of understanding the environmental implications of pads left in place, and while not necessarily required to be included in applications, would serve to inform the application and approval decision making process. Knowledge gaps identified by respondents are discussed further in Section 7.0.

5.7 Summary of Main Considerations Influencing Pad Removal Decisions

Table 5 summarizes the benefits and drawbacks of mineral soil pad removal vs. leaving mineral soil pads in place in peatlands and reclaimed them to upland ecosystems.

Table 5. Summary of the main considerations for pad removal vs. leaving mineral soil pads in place in peatlands.

<table>
<tr><th>Factor</th><th>Pad Removal</th><th>Leaving Pads in Place</th></tr>
<tr><td>Pad Impacts</td><td>Benefit: Actual or potential pad impacts to hydrology, vegetation, greenhouse gas fluxes, peat chemistry and wildlife are removed; peatland ecosystem recovery may occur</td><td>Drawback: Actual or potential impacts to hydrology, vegetation, greenhouse gas fluxes, peat chemistry, or wildlife may occur; loss of peatland area that formerly existed under the pad</td></tr>
<tr><td>Cumulative Effects</td><td>Benefit: No cumulative effects of pads left in place</td><td>Drawback: Cumulative effects of pads left in place may occur</td></tr>
<tr><td>Proximity to Other Upland Areas</td><td colspan="2">Leaving a pad in place may be appropriate if the surrounding area is a mosaic of upland forests, bog and fens, or if it is located in a transitional area between upland and peatland; whereas, leaving a pad in place may be less appropriate if the surrounding area is a large, uninterrupted bog or fen</td></tr>
<tr><td>Similarity to Other Upland Areas</td><td colspan="2">Increased similarity of the upland ecosystem on the pad to natural upland landforms and vegetation communities in the region makes leaves the pad in place more appropriate</td></tr>
<tr><td>Upland Function</td><td colspan="2">Leaving a pad in place may be more appropriate if the pad has the ability to support a functioning upland ecosystem</td></tr>
<tr><td rowspan="2">Borrow Pit</td><td colspan="2">If the borrow pit is revegetating into a wetland ecosystem:</td></tr>
<tr><td>Drawback: Damage to wetland ecosystem that has developed on the borrow pit and logistical difficulties of returning clay fill material in wet environment</td><td>Benefit: No damage to wetland ecosystem that has developed on the borrow pit</td></tr>
</table>

Factor	Pad Removal	Leaving Pads in Place
	If the borrow pit is degraded, not reclaimed, or reclaimed to an upland site, the drawbacks of pad removal and the benefits of leaving the pad in place are reduced	
Pad Removal Uncertainties	*Drawback*: There is uncertainty in the success of pad removal to result in functional peatland ecosystems, depending on the ecological setting and construction practices	*Benefit*: Avoids uncertainties in pad removal success
Existing Vegetation	*Drawback:* Disturbance to vegetation	*Benefit:* No disturbance to vegetation
Potential for Weeds	*Drawback:* Higher potential for weeds and invasive species due to increased disturbance	*Benefit:* Lower potential for weeds and invasive species due to reduced disturbance

6.0 KNOWLEDGE GAPS AND RECOMMENDATIONS

This section summarizes the knowledge gaps identified through the literature review and outreach program that will need to be addressed before a final decision is made on alternative management and reclamation approaches for mineral soil pads in peatlands.

6.1 RATIONALE AND PROCESS FOR APPLYING A VARIANCE TO CRITERIA

The following knowledge gaps were identified regarding considerations for leaving reclamation deficiencies in place on upland sites and applying for a variance to criteria. Information on these subjects is required to inform a complete net environmental cost/benefit analysis for leaving deficiencies in place.

- Acceptable dimensions for landscape deficiencies (cut and fills, subsidence) to account specifically for operability constraints of forest harvest equipment
- Risk matrix for assessing fire hazard of woody debris piles left in place on wellsites
- Success rate of wellsites with no topsoil that achieve and maintain equivalent land capability in the long term and the factors that contribute to success or failure; analysis of whether there are differences in recovery on a wellsite with no topsoil vs. a pad left in place with no topsoil
- Empirical evidence showing noxious weed persistence after canopy closure (Small et al., 2018)
- Short- and long-term impacts of noxious weeds and undesirable species on forest species and community development as a whole, and quantification of the length of the resultant successional delay, if it occurs (Small et al., 2018)
- Short- and long-term impacts of herbicide application to control noxious weeds and undesirable species on forest plant community development, particularly as it relates to herbicide overspray (Small et al., 2018)
- Long term impacts of soil stockpiling on soil organic matter and nutrients, especially after stockpiled material is re-spread
- Empirical evidence of delayed ecosystem recovery after soils are re-stripped and re-placed a second time on a wellsite during reclamation to correct deficiencies and measurement of the length of the delay
- Cumulative impacts of leaving multiple deficiencies in place, and the threshold at which cumulative impacts degrade overall ecological function

- Magnitude of carbon emissions released during traditional reclamation to correct deficiencies (including site access) and whether these emissions are substantial enough to warrant their inclusion in the determination of the environmental net benefit associated with traditional vs. modified reclamation

6.2 Rationale and Process for Leaving a Mineral Soil Pad in Place

The following knowledge gaps were identified regarding considerations for leaving pads in place in peatlands and applying for a change in land use. Information on these subjects is required to inform a complete net environmental cost/benefit analysis for leaving pads in place in peatlands.

- Extent and severity of impacts related to well pads left in place in peatlands compared to impacts related to roads left in place in peatlands
- More thorough understanding of the relationship between peatland type (bog vs. fen), feature type (pad vs. road) and direction of water flow relative to the feature on the occurrence of impacts to hydrology
- Impacts of pads and roads left in place on groundwater
- Impacts of pads and roads left in place on wildlife habitat, wildlife movement and use of the landscape
- Cumulative impacts of multiple pads and roads on local and regional peatland hydrology, chemistry, vegetation and greenhouse gas fluxes and the threshold at which cumulative impacts degrade overall ecological function of the region
- Methods that can be used for measuring the occurrence and extent of current pad impacts to hydrology, as well as the potential for future impacts
- Success rate of pads left in place with no topsoil that achieve and maintain upland ecosystem function and equivalent land capability in the long term. Specific knowledge gaps related to upland ecosystem function on pads left in place include:
    - Relative importance of factors that influence successful reforestation of pads (e.g., soil quality, topsoil depth, compaction, dispersal vectors, historical revegetation efforts, time, surrounding peatland type, water quality and levels, etc.)
    - Potential for water table to rise into the root zone over time
    - Resiliency of upland ecosystems developed on pads left in place

- Success rate of pad removal in achieving peatland ecosystem function and equivalent land capability and the factors and reclamation practices that contribute to success or failure. Specific knowledge gaps related to pad removal include:
    - Extent of peat compression under the pad, and how this is impacted by the thickness and overall weight of the pad
    - Extent of peat rebound after the pad is removed and how this is impacted by the duration of the pad being in place and thickness of the pad
    - Potential for and risk of minimal peat rebound and the creation of an open water body with cattails instead of a site on a trajectory to a functional peatland
    - Impacts to underlying peat chemistry resulting from the pad material, and how those changes may impact a developing plant community after removal of the pad
- Magnitude of carbon emissions released during pad removal (including site access) and whether these emissions are substantial enough to warrant their inclusion in the determination of the environmental net benefit associated with pad removal vs. leaving the pad in place

6.3 RECOMMENDATIONS

The following recommendations are proposed.

- Seek clarification from government as to the required approvals for requests for variance to criteria on upland sites. Currently there is confusion as to whether AEP (as the landowner) is involved in the decision.
- Prepare a guidance document on how to best prepare variances on upland sites. The guidance document would help government and industry standardize methods to apply common variances to help streamline the certification process. Additionally, the guidance document would provide a library of resources and references to be used for common variances used for non-routine applications. The document would outline how to prepare good quality justifications which would help provide more consistency further streamlining the process.
- Collect data remotely and in the field via case studies or a more rigours experimental design to provide empirical evidence pads can be left in place to create functioning forests. Information collected would be used to determine factors that are needed to create successful forests on padded sites, this science based information would be used to help support reclamation

certificate applications for sites that will have pads left in place. Additionally, the data collected will provide industry better decision or risk-based tools to help prioritize and determine what sites require pad removal and what sites can be left in place. Data also would be used to help determine what factors (e.g., peatland type, pad type, hydrology, etc.) lead to impacts from pads.

- Develop decision support tool/policy framework recommendations for leaving pads in place on peatlands

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