ALGAR HABITAT RESTORATION PROJECT

IMPROVING FEN RESTORATION OUTCOMES

PTAC 20-ERPC-01

ABSTRACT

The benefits of linear restoration are well understood. Legacy seismic lines remain on the landscape for years, many requiring some type of intervention to regrow vegetation and become functional caribou habitat.

The Algar Caribou Habitat Restoration Program was initiated in 2011 by six oil sands companies (CNOOC Petroleum North America ULC (formerly Nexen Energy ULC) is the lead organization) to improve undisturbed caribou habitat by restoring historic linear footprint off-lease and within the East Side Athabasca River caribou range in northeast Alberta. This was the first large-scale linear restoration program implemented in Alberta. As part of the action plan, approximately 340 km of legacy seismic lines, over a 56,000-hectare area, were treated by winter planting and/or natural regeneration protection over four years. Because the region is largely covered by wetlands, winter planting techniques were used to gain access into the area using winter roads. This project was the first to operationalize winter planting on a large scale.

During the analysis of collected linear restoration monitoring data along with supporting field observations - early information suggested that treatments may not be successfully placing linear disturbance within fens on a trajectory to restoration within the time frame anticipated or desired. The project for 2021 analyzed this through the capture of high-resolution data and a deep dive analysis into confirming this finding as well as understanding the cause(s) and effects of it, thereby identifying strategies to improve fen restoration outcomes.

The results of the survey aligned with previous ground-based sampling that fens can meet the framework criteria but are challenged on many sites. Stocking levels were on average at the target minimums however only 57% percent of the surveyed segments were achieving the Framework criteria. The difference between rich fens and poor fens was only marginal suggesting alternative criteria or treatments may need to be considered for fen sites in general. The biggest challenge appears to be the difference in success rates at different line segments. Some sites have little to no growth of trees while others are quite productive. Ensuring that the trees can be out of the water, have some structure to grow on, and are not overly outcompeted for light resources appear to all have an impact on site success. Further research in these areas may help improve fen site restoration prescriptions to achieve objectives.

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EXECUTIVE SUMMARY

Woodland caribou (*Rangifer tarandus caribou*) boreal and southern mountain populations are designated as Threatened under Canada's Species at Risk Act [1] and Alberta's Wildlife Act [2]. Many tools will be used towards achieving self-sustaining caribou populations in Alberta including habitat restoration on seismic lines [3].

Seismic lines represent a significant contribution to disturbance in caribou habitat and because they are so prevalent, successfully re-establishing tree cover could increase undisturbed habitat more than other management tools [3]. Legacy seismic lines remain on the landscape for years, many requiring some type of intervention to become functional caribou habitat [3]. The challenge is that linear restoration is expensive. Restoration costs can range between $8,000 and $17,000 per kilometre depending on required treatments and the landscape characteristics of the ranges (e.g., remote locations, wet areas, etc.) [4].

This project is directly related to key public policy issues of biodiversity and habitat reclamation/restoration. Specifically, this project seeks to address key knowledge gaps in the effectiveness of the linear restoration on fens in achieving restoration goals of caribou habitat restoration and reduced predation risk. This research will benefit both industry and government, as they seek innovative and cost-effective solutions for restoring caribou habitat.

This project's results will help address knowledge gaps and aid in caribou recovery in Alberta and elsewhere in the boreal forest. If techniques for fen restoration are improved or opportunities for efficiencies are incorporated, the ability to scale up linear restoration projects is enhanced.

Monitoring has been ongoing in Algar since 2011. Monitoring data along with supporting field observations information suggest that treatments may not be successfully placing linear disturbance within fens on a trajectory to restoration within the time frame anticipated or desired. The project for 2021 analyzed this through the capture of high-resolution data and a deep dive analysis into confirming this trend could be observed at other sites within Algar and attempt to further our understanding the cause(s) and effects of it, thereby identifying strategies to improve fen restoration outcomes.

For this analysis, we are using the criteria outlined in the Draft Provincial Restoration and Establishment Framework for Legacy Seismic Lines in Alberta (the Framework) to assess the status of fen sites within Algar. Poor fens appear to be on track to meet the targets outlined in the Framework for stocking. The results of the survey aligned with previous ground-based sampling that fens can meet the framework criteria but are challenged on many sites. Stocking levels were on average at the target minimums however only 57% percent of the surveyed segments were achieving the Framework criteria. The difference between rich fens and poor fens was only marginal suggesting alternative criteria or treatments may need to be considered for fen sites in general. The biggest challenge appears to be the difference in success rates at different line segments. Some sites have little to no growth of trees while others are quite productive. Ensuring that the trees can be out of the water, have some structure to grow on, and are not overly outcompeted for light resources appear to all have an impact on site success. Further research in these areas may help improve fen site restoration prescriptions to achieve objectives.

Alternative requirements should be considered for linear restoration at fen sites. The Establishment Survey indicates acceptable success rates on some fen segments; however, it is still unclear why some sites are more successful than others. Restoration targets on rich fen sites might consider other vegetation criteria (not just trees) as indicators of site success.

The Algar Caribou Habitat Restoration Program continues to be a model example of collaboration and innovation in habitat recovery. It has provided a valuable case study with data and learnings that will inform future linear restoration projects and help achieve caribou habitat recovery objectives in Alberta.

BEST PRACTICES AND PROJECT OUTCOMES

The value derived from this project is not limited to the results from the field and analysis.

The outcomes of this research do show validation of previously identified results which indicated some degrees of site success on fen sites, however, there is room for correction. Previously, Silvacom identified some potential considerations for future versions of the Draft Provincial Restoration and Establishment Framework for Legacy Seismic Lines in Alberta (The Framework) [5]. Alternative requirements should be considered for linear restoration at rich fen and poor fen sites. Restoration targets on fen sites should consider other vegetation criteria (not just trees) as indicators of site success, especially in the medium term (10-20 years).

Key learnings about previous research outlined in the literature review helped provide context for how this study could be conducted and how the results of this project align with other research.

Key project outcomes:

- Testing of the monitoring practices for aerial surveys and aerial imagery analysis under the Establishment Survey of the Framework.
- Furthered our knowledge of restoration outcomes within fen ecosites to help develop more efficient linear restoration programs.
- Fen sites can achieve Framework establishment targets, but results are inconsistent. The effectiveness of the treatment is heavily dependent on several factors and needs to be adjusted to accommodate the conditions of the surrounding forest and relative benefit.
- Aerial assessments function well to cover large areas of a project and extract landscape line segment stocking rates. It is not as functional as ground surveys to identify site-specific conditions that may explain restoration success.

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BACKGROUND

ALGAR CARIBOU HABITAT RESTORATION PROJECT

The Algar Caribou Habitat Restoration Program was initiated in 2011 by six oil sands companies to improve undisturbed caribou habitat by restoring historic linear footprint off-lease and within the East Side Athabasca River caribou range in northeast Alberta. This industry-led initiative was the first large-scale linear restoration program implemented in Alberta. As part of the action plan, approximately 340 km of legacy seismic lines, over a 56,000-hectare area were treated by winter planting and/or natural regeneration protection over four years. Because the region is largely covered by wetlands, winter planting techniques were used to gain access into the area using winter roads. This project was the first to operationalize winter planting on a large scale.

Figure 1 Mounding and winter planting on a legacy seismic line in Algar

As part of an adaptive management approach, vegetation monitoring plots were established on pre-restoration treatment lines to capture pre- and-post-restoration conditions and study the change in conditions as a result of treatments. Ten years of monitoring and targeted studies have been conducted in the Algar area, spanning several treatment types including winter mounded and planted sites, alternative treatments like Leapfrog (see [6]), natural regeneration protection, and no treatment control sites. In addition, a parallel program led by Dr. Cole Burton of the University of British Columbia is monitoring the wildlife responses to seismic line restoration using the Algar area to do a camera trap survey. Furthermore, Algar has also been used as a case study in an Alberta Innovates funded project examining the potential additional ecosystem services benefits from linear restoration [7].

As part of the action plan for the Algar Caribou Habitat Restoration Program, a monitoring program was initiated in the Algar linear restoration area to objectively track the restoration success and gather learnings. Colloquially, this long-term multi-area monitoring program became known as "Algar" as it is henceforth referred to. The first monitoring of the project area was done in Area 1 in 2011.

IMPROVING FEN RESTORATION OUTCOMES

Ground-based monitoring results have shown a trend of lower performance in fen sites. This project was designed to assess if this trend could be found in other fen sites across Algar using the Framework as the benchmark to measure restoration success. This also provided an opportunity to further test the Framework's monitoring protocols using aerial survey methodology. The project involved the capture of high-resolution data and a deep dive analysis into confirming ground monitoring fen results as well as understanding the underlying cause(s) and effects, thereby identifying strategies to improve fen restoration outcomes.

LITERATURE REVIEW

A literature review was conducted to supplement previous learnings from previous Algar monitoring and analysis, the information gathered in *the 2020 Algar Report* [6], and the aerial survey conducted in 2021.

FEN RESTORATION CONTEXT

Analysis of linear restoration monitoring data and supporting field observations suggest that treatments may not be successfully placing linear disturbance within fens on a trajectory to restoration within the time frame anticipated or desired. Building on the years of data collected at Algar, a literature scan was conducted on site-based restoration to help determine potential causes and site limiting factors.

The report *Algar Caribou Habitat Restoration Program – Assessing the Program Outcomes – 2020 Monitoring & Analysis (the 2020 Algar Report)* [6] identified several key learnings. Discussions with researchers were conducted to develop a baseline understanding of possible explanations for the results seen on rich fen plots in Algar. Researchers were unsurprised that there had been limited success at those sites. These are the key takeaways from those discussions:

- Reclamation might be more successful if the mounds were not flipped. Trials have been initiated using the "Hummock Transfer Technique" which aims to lift the ground from the area surrounding the disturbance and retain structure and vegetation by placing it upright on the line being restored.
- Mosses are necessary for long-term recovery. If sedges dominate, the line may be in arrested development.
- Rich fen recovery in the timeframe of the Framework is challenging because:
    - They are too wet and have limited soils pre-disturbance,
    - The peat itself does not have the same physical properties as other ecosites (mounds do not hold shape),
    - The mound structure allows for more exposure to oxygen which increases the mound decomposition rate,
    - Freeze-thaw cycles wash away the mounds, and
    - There is low nutrient availability in the mounds.
- Researchers questioned the reasonability of expecting to achieve a tree-dominated rich fen (an ecosite often dominated by shrubs and sedges with trees merely present) from restoration activities.
- Peatlands take hundreds of years to restore themselves without intervention and rich fens are the most difficult to accelerate.
- The goal could be to achieve leaf area maximization. Leaf area maximization is more achievable with shrubs and sedges which could establish a similar leaf area as a mature tree. This goal would help establish biomass for the fen to recover in tens of years. Trees would be able to establish on the decayed biomass of the shrubs and sedges over time.

LITERATURE SUMMARY

The key takeaways from the resources found are divided into two broad categories: Fen characteristics and restoration challenges, and best management practices.

FEN CHARACTERISTICS AND RESTORATION CHALLENGES

Understanding fen functionality, underlying characteristics, surrounding landscape, the impact of the seismic line creation, and others are all important aspects of developing best management practices for fen restoration. Several challenges exist when restoring fen habitat including the slow process of recovery, the limited fibrous material (especially post-disturbance), and the change in relative elevation due to compaction. For all these reasons, mounding was established as a first attempt to restore these sites to limit visibility and accessibility for predators down the lines. The following list summarizes key findings of fen characteristics and the related challenges to restoration:

- Fen systems recover slowly, over decades to more than a century, and restoring part of the vertical distribution of microhabitats could simulate successional recovery [8].
- The species of moss present is a key indicator of potential tree establishment. *Sphagnum*-dominated sites are more likely to succeed than where they are infrequent [9].
- Regeneration is inversely related to wetness, proximity to roads, lowland ecosites, and other factors. Wetness and presence of fen ecosites have negative effect on regeneration. Predictions of future regeneration rates on existing lines suggest that about one-third of existing linear disturbance footprints boreal landscapes will remain un-regenerated 50 years later [8]. Wetter sites are less likely to recover [10].
- Peat itself is mostly sedge peat and humus – not as fibrous – so does not have the physical properties of a sphagnum mound (not holding shape well) [9].
- Higher humification in mounds increases the likelihood of their deterioration. It is critical to maintain the structure and orientation of the hummock throughout the collection and transfer process (mounding) [11].
- Seismic lines change the local hydrology by flattening the surface, causing peat compaction, and decreased evapotranspiration due to the removal of shrubs and trees [12], [13]
- It is important to understand undisturbed fens to develop best management practices for restoration and determination of restoration success. The role of hydrology and creating nutrient-rich conditions should also be investigated [14].

BEST MANAGEMENT PRACTICES

Several studies have been conducted which identify possible solutions and opportunities to improve results off wetland restoration, particularly on fen sites. Mounding is considered a best management practice and the baseline for restoring these sites. However, opportunities exist to improve upon the historical strategies used to create the mounds. Specifically, instead of taking deep parent material from the line itself, causing deep holes and limited opportunities for growth on the lines, some studies are taking shallow parent material with a mix of adjacent vegetation (trees, shrubs, forbes, mosses, etc.) and placing those on the line [11]. This technique introduces both structural (mosses, peat, roots) and vegetation without creating holes. It is also possible to plant trees on this parent material to accelerate the visibility reduction goal. The following list outlines some of these and other best practices from the literature:

- Fen restoration in North America is in its early stage and the recognition of fen restoration as a valid and valuable restoration option for extracted peatlands is important for the development of best management practices. The restoration targets, the techniques to apply, and the expected outcomes require further examination [14].
- Conifer seedling density was more than five times higher on elevated spots than the mostly flat, flood-prone areas between them, and seedling density was positively related to mound height and strength of seed source. Higher mounds tended to have larger seedlings [10].
- Mounds increase seedling density [10]. Surrounding peatlands can be used to decide the proper density of transferred hummocks [11].
- Do not dig too far beyond the frozen ground layer. It will leave deep holes in the natural area that will regenerate slowly. Tall hummocks with highly decomposed peat at the base may not be able to regulate moisture as intended [11].
- Digging below the frozen layer will leave deep holes that regenerate slowly and tall hummocks with highly decomposed peat at the base may not regulate moisture as intended [11].
- Activities to be considered in the restoration of fen seismic lines are the removal and management of invasive species, restoration of groundwater hydrology, and re-introduction of fire. These factors are interrelated. For example, removal of invasives may not lead to the re-establishment of native plants if hydrology has shifted [15].
- Targeting only one type of environmental stressor does not lead to a recovery of fens, as it provides an insufficient level of stress to restore a functional ecosystem. In general, restoration efforts do not ensure the re-establishment and long-term persistence of fens. Restoration efforts result in the recovery of fen ecosystems, although more rigid actions are needed for restoring fully functional fens, by achieving high and constant levels of anoxia and nutrient stresses [16].
- It is possible to create fen initiation conditions by introducing foundation moss and vascular plant species at optimal water levels [17].
- Restoring the community structure and biomass accumulation that occurs in the initial stages of fen development appears to be a suitable target for peatland reclamation. These methods introduce a practical strategy to reclaim peatlands in the heavily impacted oil sands region of Alberta [17].
- Introducing a suite of fen moss species that inhabit a range of hydrologic niches under low shrubs or herbaceous plants improves moss establishment [17].
- If mosses like Sphagnum recolonize the seismic lines in poor fens and bogs active restoration measures may not be necessary. Mosses, the main driver in peat accumulation, grow more quickly, and without competition for light. The faster rate of peat accumulation will translate to a faster succession back to a forested bog [13]. This may not apply to fens as much as bogs.
- After hydrology, the second most important component in peatland restoration is the selection of an appropriate donor site [18].
- Many wetland plants establish on fen sites without active reintroduction. However, field trials show that reintroducing vegetation increases vegetation cover and species richness. Plots, where vegetation was reintroduced, show a vegetation cover twice as high as those without that intervention. Bryophytes are an important component of fen vegetation but often do not spontaneously recolonize sites [18].

- Field experiments in Québec have shown that the presence of spontaneous vegetation (vascular plants) increases the percent cover of reintroduced bryophytes [18].

DATA AND METHODOLOGIES

A combination of background research, literature review, and aerial sampling were used to gather data and information. The field data collection was conducted in two parts, first as an aerial assessment of the Algar lines, and the second a video visual assessment of Algar lines. This section discusses the data collection methodologies.

ESTABLISHMENT SURVEY

The Framework is intended to provide a clear process for restoration programs and describes:

- The development of an operational plan
- Quality control of treatment
- Survival assessments
- Establishment surveys
    - Aerial surveys
    - Ground surveys
- Relevant literature
- Tools for implementing stages of a restoration program (in the appendices)

Fall 2021 monitoring in Algar Area 1 marks the second opportunity for the Algar monitoring measurements to align with the Framework's recommendations for monitoring the Establishment Survey results of linear restoration. Establishment surveys are recommended in the Framework to occur between 8 and 10 years since restoration. Table 1 shows the number of growing seasons since implementation for each of the five project areas in Algar.

Table 1 Algar Area growing seasons since implementation (as of winter 2021-2022)

Algar Area	Growing Seasons
1	10
2	8-9
3	9
4	6
5	6

Figure 2 shows the process for restoration outlined in the Framework. This years' study follows the guidance outlined in the Framework for Establishment Surveys using an Aerial assessment.

Figure 2 Stage of the process as per the Framework

FIELD DATA COLLECTION

Two types of surveys may be conducted as establishment surveys: Reconnaissance Establishment Surveys and Ground-based Establishment Surveys. The Framework was used as a guide for conducting the aerial survey, however, the primary goal of this project is to better understand legacy seismic line restoration on fen sites. The Reconnaissance Establishment Surveys (aerial) survey applies to the activities conducted for this work. The Framework specifies all advanced regeneration and treats sites should be subject to an aerial survey if that is the type of survey conducted. As mentioned, the focus of this project is to understand the effectiveness of restoration on fens so poor fens and rich fens were the focus of the survey. The Framework describes Reconnaissance Establishment Surveys as having the goal to cover large program areas and efficiently use aerial survey methods or remote sensing. It is used to broadly characterize the establishment success of all treated and advanced regeneration line segments in a program area and determine their success [5].

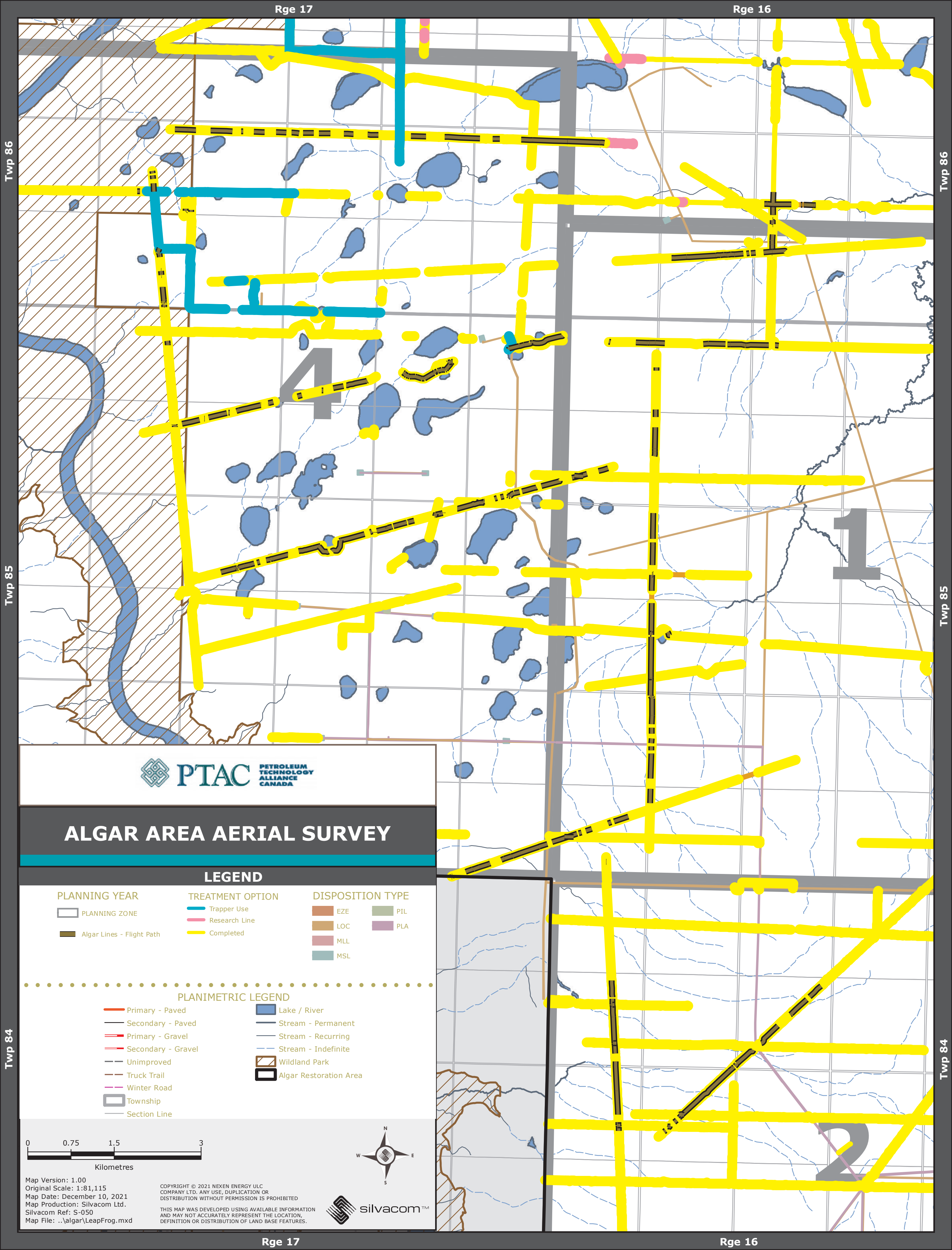
The Reconnaissance Establishment Survey should be completed with one of the four methods (Table 2):

Table 2 Reconnaissance Establishment Survey methods

Approach	Method	Requirements
Visual	Flying the treated and advanced regeneration areas of the program and visually assessing them.	A minimum of 50% of the program should be filmed for auditing purposes, including a complete recording of major lines
	Walking through the treated and advanced regeneration areas of the program and visually assessing them.	Appropriate for smaller programs
Digital	Flying the treated and advanced regeneration areas of the program and recording high-resolution photography or video (e.g., Forward-Looking Infrared (FLIR) and true colour imagery) and performing a desktop analysis.	The minimum spatial resolution

Approach	Method	Requirements
	Capturing LiDAR or other remote sensing information and performing a desktop analysis.	of 15 cm or better4

For this project, we incorporated two of the methods from above, one visual and one digital. The team completed a visual assessment from a helicopter, flying over many fen segments. Map 1 shows the Algar lines flown overlapping fen segments. A two-person team was flown to Algar, one analyst conducted the visual assessments and instructed the pilot on where to fly while the other analyst input the data. While flying, the high-resolution video was also captured. An assessment of the line segments was conducted using the video.



Rge 17
Rge 16
Twp 86
Twp 85
Twp 84
4
1
2
PTAC PETROLEUM TECHNOLOGY ALLIANCE CANADA
ALGAR AREA AERIAL SURVEY
LEGEND
PLANNING YEAR
PLANNING ZONE
Algar Lines - Flight Path
TREATMENT OPTION
Trapper Use
Research Line
Completed
DISPOSITION TYPE
EZE
LOC
MLL
MSL
PIL
PLA
PLANIMETRIC LEGEND
Primary - Paved
Secondary - Paved
Primary - Gravel
Secondary - Gravel
Unimproved
Truck Trail
Winter Road
Township
Section Line
Lake / River
Stream - Permanent
Stream - Recurring
Stream - Indefinite
Wildland Park
Algar Restoration Area
0
0.75
1.5
3
Kilometres
N
W
E
S
Map Version: 1.00
Original Scale: 1:81,115
Map Date: December 10, 2021
Map Production: Silvacom Ltd.
Silvacom Ref: S-050
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For each line segment several pieces of information collected. Table 3 outlines the fields that were either pre-determined (Algar Area and Line number) or entered based on observations collected during the flight.

Table 3 Data collection fields

Field	Description	Domain
Algar area	Algar planning area	1-5
Line number	Algar line number	Whole number
Stocking percent	Percent of the observable line stocked	Percent (%)
Stocking distribution even	Is the stocking distributed evenly on both sides of the lines?	Yes or No
Stocking percent of less stocked side	If not evenly distributed stocking, what percent stocking is the less stocked side?	Percent (%)
Human access	Evidence of human access	Yes or No
Acceptable trees	Acceptable trees?	Sw, Sb, Se, Pl, Pj, Px, Lt, Fb, Fa, Fd, Pb, Aw, Bw
Evidence of mounds	Evidence of mounds?	Yes or No
Status of competing vegetation	Description of competing vegetation	Description of competition (grasses, sedges, shrubs, overtop, etc.)
Forest condition	Comments on condition of the surrounding forest	General description of the surrounding forest
Comments	General comments on the line segment	General comments about noticeable attributes on the line segment. Describe if shadows are limiting visibility on the line.

We consider the pass/fail criteria from the Framework as a guideline for determining the success of the line segments' restoration (Table 4).

Table 4 Establishment targets for treated line segments

Site Type	Definition
Upland, Transitional, and Lowland Treed	• Greater than 70% stocking • Minimum 1000 stems per hectare (sph) • Minimum 50% stocking on each side • Less than 10% of sites have human access • Suitable tree species based on neighbouring forest
Upland Dry, and Lowland Low Density Treed	• Greater than 50% stocking • Minimum 800 stems per hectare (sph) • Minimum 40% stocking on each side • Less than 10% of sites have human access • Suitable tree species based on neighbouring forest

Framework aerial assessment success determinants of line segments are as defined in Table 5.

Table 5 Framework requirements for passing aerial evaluation

Status	Definition
Segment passes stocking criteria (SR)	The segment passes stocking, coverage, line use.
Segment passes with conditions (CSR)	The segment passes stocking requirements, but not all coverage and line use requirements.
Failure (NSR)	The segment does not pass stocking requirements

RESULTS

This section summarizes the results of the analysis conducted on data collected during the aerial flight and the visual assessment of the videos taken while flying. Analysts reviewed the video of the same line segments flown and surveyed. The Framework is used as a baseline indicator of success but is not directly relevant for each line segment as some of the areas have not reached sufficient growing seasons to be applicable. Furthermore, Algar was a proponent-led project and is not subject to Framework targets. However, the main goal of this analysis is to determine if treatment is generally successful at fen sites, so the Framework is a helpful guide.

Data was collected from multiple line segments during the flight (Table 6). The Framework outlines a minimum segment length of 50 metres in length. Sometimes, multiple line segments may be combined in the assessment as they may have had similar results, or, for the sake of covering as much area as possible, whole lines were only flown up to two times.

Table 6 Line segment type and count

Line Segment Type	Count
Poor Fen – Treated	13
Rich Fen – Treated	10
Grand Total	**23**

STOCKING

Stocking levels are the key component of aerial assessments and are defined as a measure of area occupied by trees (combination of density and distribution of trees across a site). Average stocking levels for line segments is summarized in Table 7. Note that not all line segments have reached the 8-10 year since implementation threshold for establishment surveys in the Framework [5] however for the purposes of this analysis it still provides a reasonable assessment on establishment progress.

In Table 7, we compare stocking rates of line types relative to the adjacent landscape tree density. Low density (lowland low density treed) and treed (lowland treed) sites apply where most or all the line segment was that classification. Treed lowland sites and low-density sites on average are at or near their respective stocking targets from the Framework (70%, 50%). This lines up well with the framework with higher expected stocking rates in the treed lowland areas as opposed to the low-density treed lowlands. The difference between the average stocking of the two site types was significant (P = 0.01). However, only a little over half (57%) of the surveyed segments meet the Framework criteria (Figure 3). Site type did not seem to be a factor in whether or not a segment met the criteria (P = 0.94). The combination of these results suggests having separate target criteria for the site types is warranted however it does not necessarily conclude whether or not those target values are achievable for fen sites.

Within the fen types, similar to previous ground observations the poor fen had a higher average stocking and level of segments meeting criteria compared to the rich fen (Figure 4). However, the difference was marginal and not significant (p = 0.13, p = 0.58).

Table 7 Average stocking percent for aerial survey and digital survey

Line Type	Treed Lowland		Low Density Treed		Combined	
	Avg Stocking	Meets Criteria	Avg Stocking	Meets Criteria	Avg Stocking	Meets Criteria
Poor Fen	72%	57%	50%	67%	62%	62%
Rich Fen	63%	50%	48%	50%	51%	50%
Combined	70%	56%	49%	57%	57%	57%

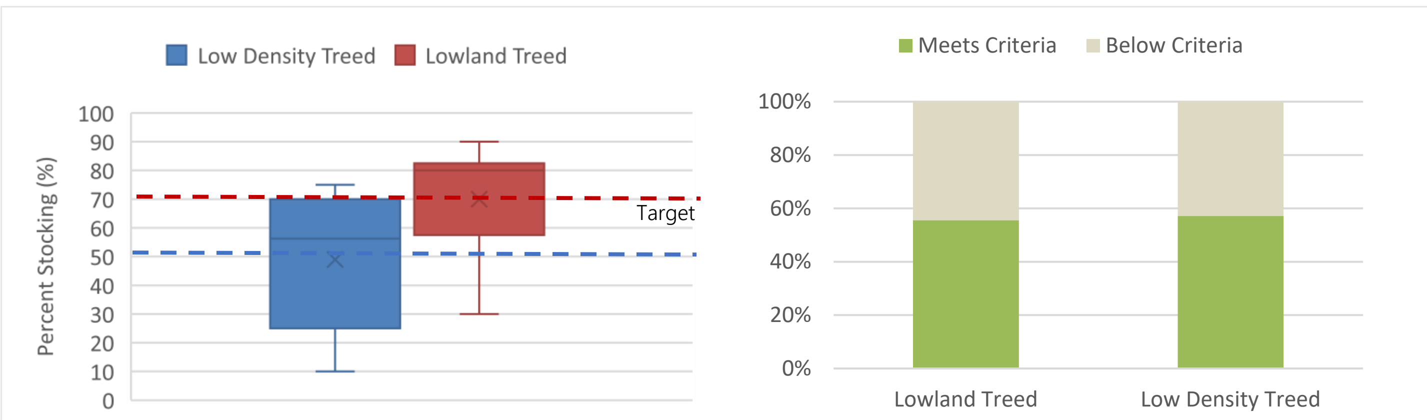

Figure 3 Percent stocking by site type and percent of line segments achieving Framework criteria

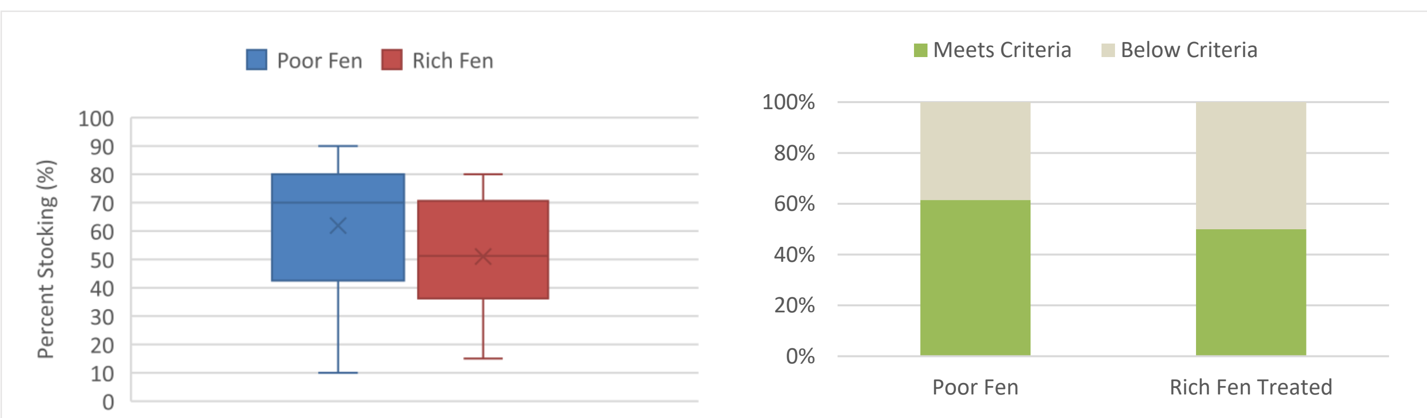

Figure 4 Percent stocking by fen type and percent of line segments achieving Framework criteria

DISCUSSION

Restoration on fens presents a unique challenge. Through our research and in discussions with experts it may be difficult to achieve fen restoration at the levels targeted in the Framework. However, alternative restoration technique opportunities exist and are currently being trialled elsewhere. We will discuss the results from the aerial assessment, video review, and literature review in the sections below.

POOR FENS

Figure 5 shows a line segment of a poor fen that was treated. Planted trees appear here, but most of the coverage is by natural trees and shrubs which observationally has been the case at many of these sites in Algar. Natural ingress of shrubs appears to come in very quickly and help reduce sightlines and mobility access, especially where the adjacent area has deciduous coverage. Figure 6 and Figure 7 show successful stocking on poor fen segments. There appears to be some competition and the mounds seem to have flattened somewhat, but the trees and other vegetation are growing.

A different story appears in Figure 8, Figure 9, and Figure 10 where fewer trees are remaining after treatment, the segments are very wet and grasses/sedges appear to be the dominant vegetation. Figure 10 shows a line segment of importance to understanding the expected success rate of planting trees in some of these sites. The tree density in the surrounding forest is relatively low – it is unlikely that conditions on the line will be sufficient for trees to grow there. Open water appears to remain a limiting factor in many of the sites – these water holes limit vegetation capacity which could lengthen the recovery time for those portions – although this does seem to be countered by what is shown in Figure 7. Figure 11 is an image of a line left untreated for research purposes, there does not appear to be much tree growth there, but smaller vegetation is present which may set the stage for the long-term recovery of the line. Figure 6, Figure 7, Figure 8, Figure 10, and Figure 11 are good examples of why timing considerations of the survey are important. In those figures, you can see the Tamarack trees have dropped their needles – this would limit the ability of a surveyor to see smaller, natural tamarack trees, especially when contrasted against the taller sedges and grasses. However, it was noted that had we attempted the survey earlier in the season, while there was still lots of green on leaves, it may have been much more difficult to spot the trees themselves.

Overall, the general takeaway from poor fen segments is that multiple environmental characteristics are determining the success of the restoration efforts. Ensuring that the trees can be out of the water, have some structure, and are not overly outcompeted for light resources appear to all have an impact on site success. Furthermore, there are underlying environmental conditions that are not well understood by the project team. We do not know the microsite conditions that exist on each line segment, such as hydrological conditions, water level, nutrient regime, soil or peat conditions, and more. These details would help inform some of the results. The surrounding vegetation appears to be a strong indicator of the likelihood of success, which is how the Framework is set up. It may be pertinent to consider poor fens (lowland treed) as a separate category from lowland treed. Alternatively, we may see higher success rates of line deactivation from techniques like the HTT [11]. Based on the observations and analysis from past observations and this years' analysis, poor fens are not reaching the stocking levels outlined in the Framework. Many sites show lots of natural growth of shrubs which does not count towards stocking in the Framework, it does however limit the visibility down the lines and increase the structural integrity of the site, thus making long-term restoration of the lines more likely.

Mound height is another factor not analyzed here. The evidence suggests that wetter sites tend to have more trouble re-establishing tree growth because the line was pushed down and compacted closer to the water table. Higher mounds might provide more opportunities for trees to establish themselves over time.

Previous analysis on poor fens did show higher levels of success, so it might be that being able to see the trees, especially natural ingrown trees, was limited. It has also been suggested that on fen sites it may be pertinent to consider other factors that tree growth for restoration success. Leaf area maximization is something that may be valuable to consider when looking at site success on poor fen sites. The more shrubs and trees that grow, the less visibility there is on the lines and the more likely that trees will grow in those spots in the long term.


Figure 5 Line 2-7 poor fen - treated

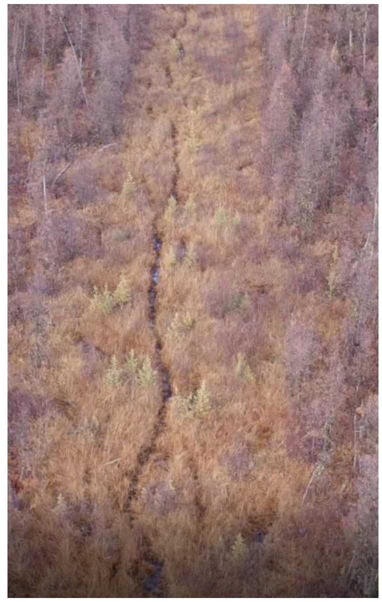
Figure 6 Line 1-8 poor fen, treated, visible successful stocking

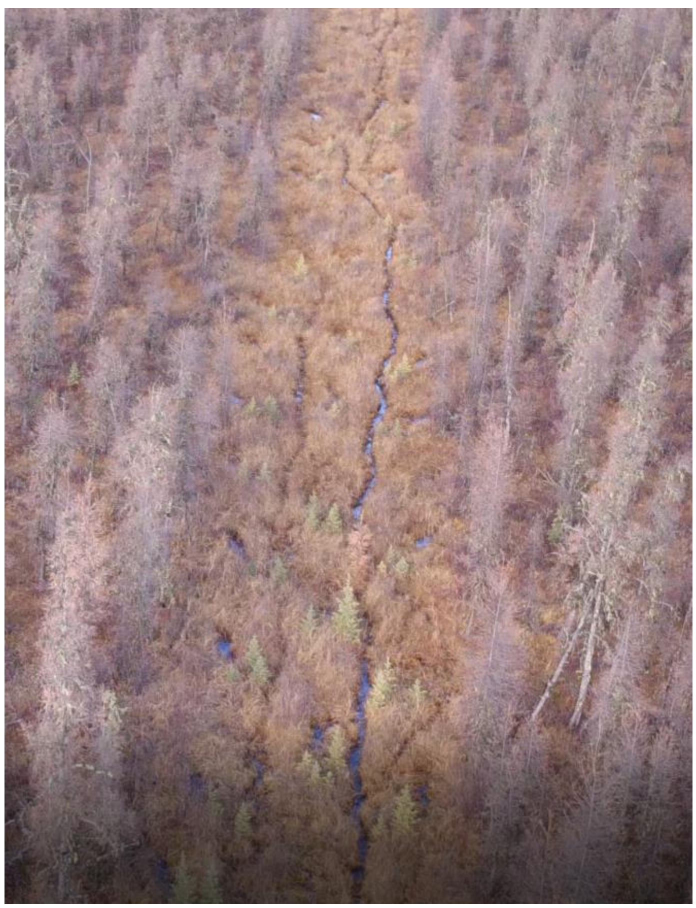
Figure 7 Line 1-8 poor fen, treated, visible successful stocking

Figure 8 Line 2-1 poor fen, water in holes, limited trees, grass/sedge competition, saturated water

Figure 9 Line 2-1 poor fen, no visible trees, holes present, heavy water

Figure 10 Line 2-1 adjacent to the area shown in Figure 6, but low stocking in surrounding landscape

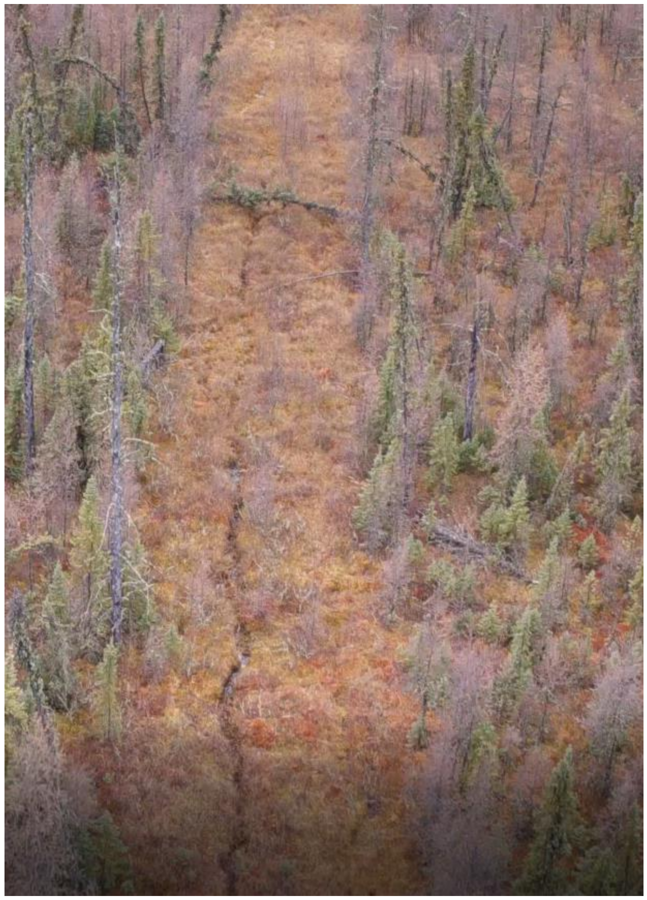

Figure 11 Line 4-22 poor fen research line

RICH FENS

Rich fens are mostly going to be considered lowland low density treed sites and held to a lower standard of stocking than poor fens. Analytical results and observations in Algar indicated limited success in stocking and survival of trees on these sites. That information holds after this analysis, however, about 50% of the rich fens are stocked and on average, the stocking on fen sites hit 51% which both meet the (50% stocking) target outlined for those site types in the Framework.

Figure 13 through Figure 20 show some of the poorly stocked line segments. Figure 15, Figure 16, Figure 19, and Figure 20 are good examples of very sparse tree density adjacent to the lines where it should be expected to have low tree density on the lines, even with intervention. Those sites are not productive as far as tree growth goes. Figure 21 through Figure 25 are examples of stocking that was higher than or met the Framework targets.

The biggest challenge appears to be the difference in success rates at different line segments. Some sites have little to no growth of trees while others are quite productive. Ensuring that the trees can be out of the water, have some structure to grow on, and are not overly outcompeted for light resources appear to all have an impact on site success. Similar to our analysis of poor fens, we do not know the microsite conditions that exist on each line segment. These details would help inform some of the results. We may see higher success rates of line deactivation from techniques like the HTT [11]. A good example of a lowland treed segment with pockets of lowland low density treed is seen in Figure 12 – the plot shown here is line 8, plot 2 in Algar Area 1 which was one of the indicating plots showing the need to understand why some fen areas are failing. You can see the area adjacent to the plot is less dense than just outside that area. Framework guidelines should take into consideration sites like this when developing targets.

Figure 12 Line 8, plot 2 in Area 1 of Algar. Lowland low density treed around the plot with lowland treed area north and south of the plot

Figure 13 Line 1-8 rich fen - treated

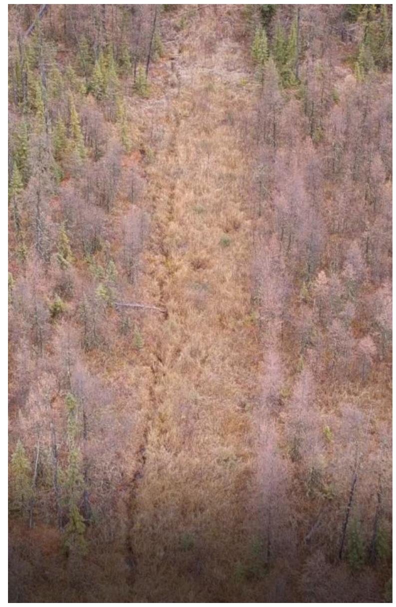

Figure 14 Line 4-4 rich fen - treated

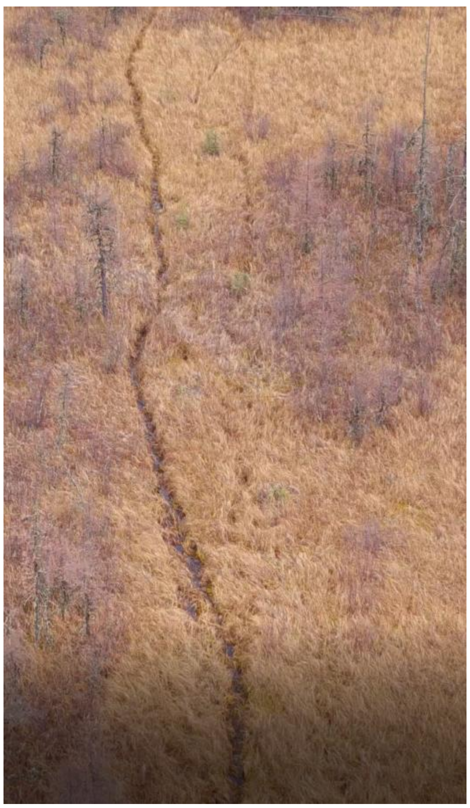

Figure 15 Line 4-4 rich fen - treated

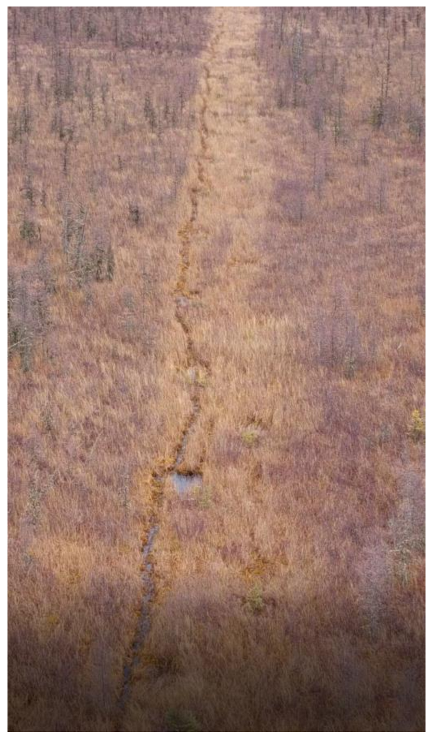

Figure 16 Line 4-4 rich fen - treated

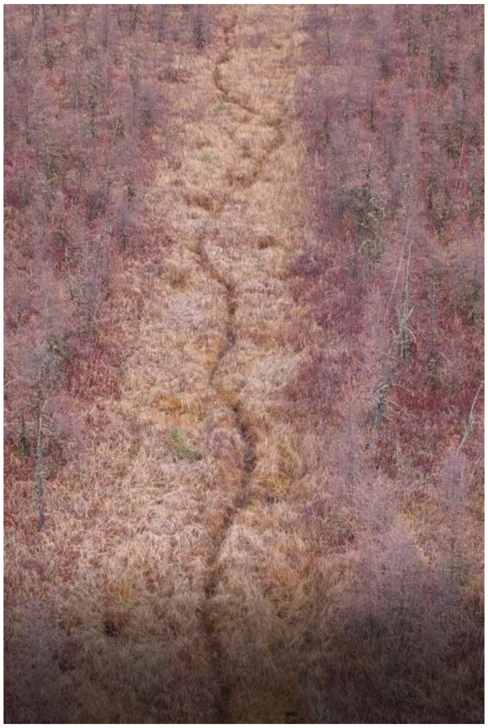

Figure 17 Line 4-4 rich fen – treated, game trail

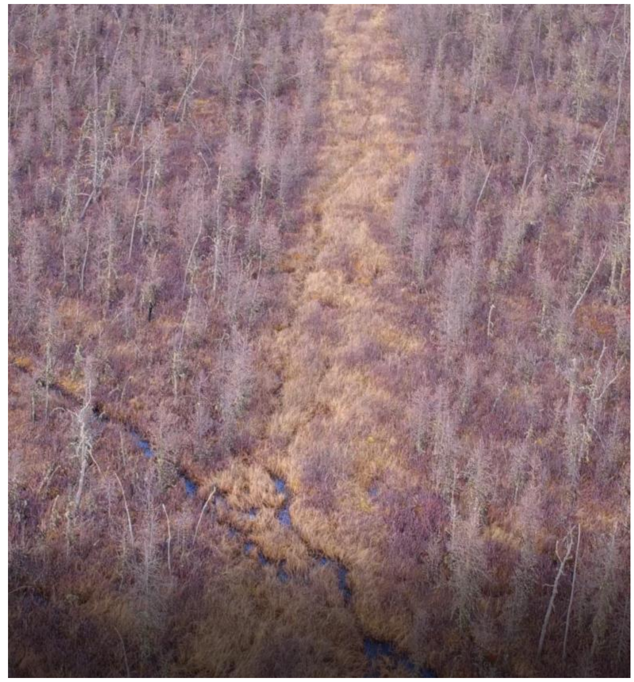

Figure 18 Line 1-8 rich fen - treated, game rail/water

Figure 19 Line 4-28 rich fen – treated, few trees, mostly just the water from holes, adjacent is not very dense

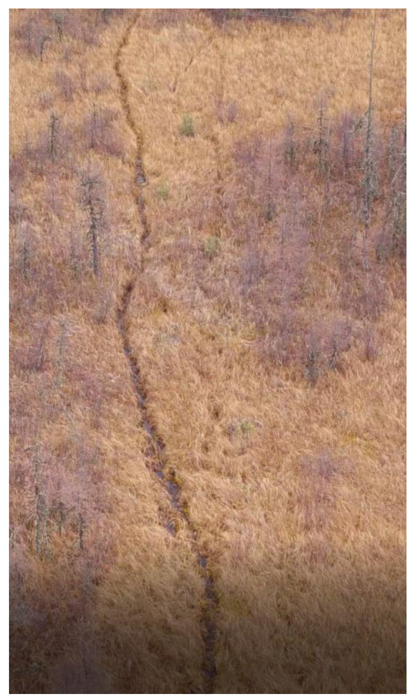

Figure 20 Line 1-4 rich fen - treated

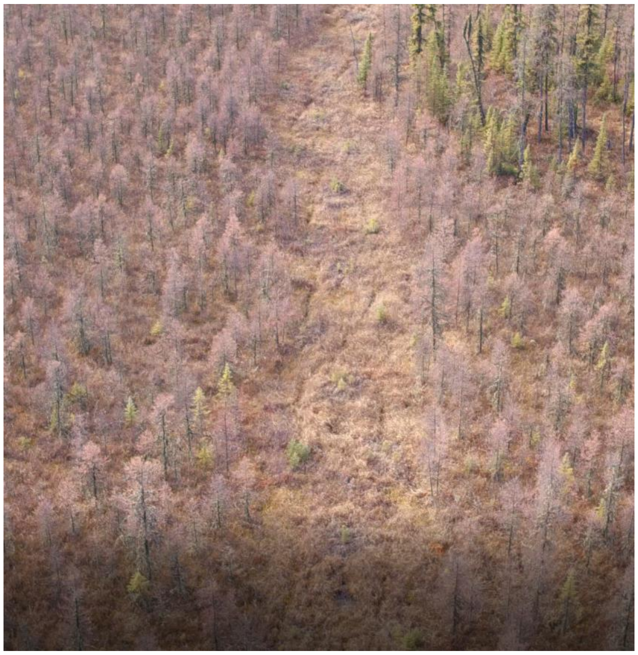

Figure 21 Line 4-28 rich fen – treated, uneven stocking

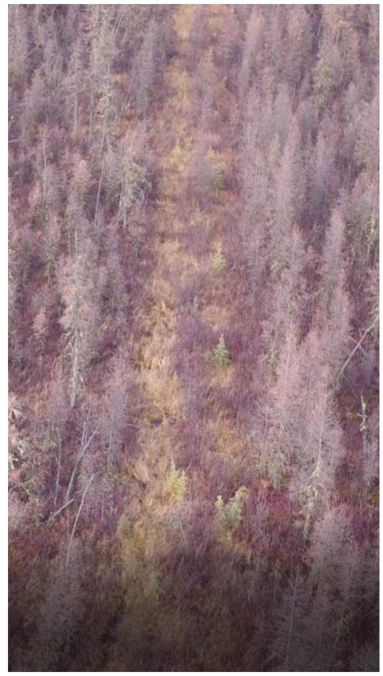

Figure 22 Line 1-8 rich fen - treated, more productive than nearby segment in Figure 18

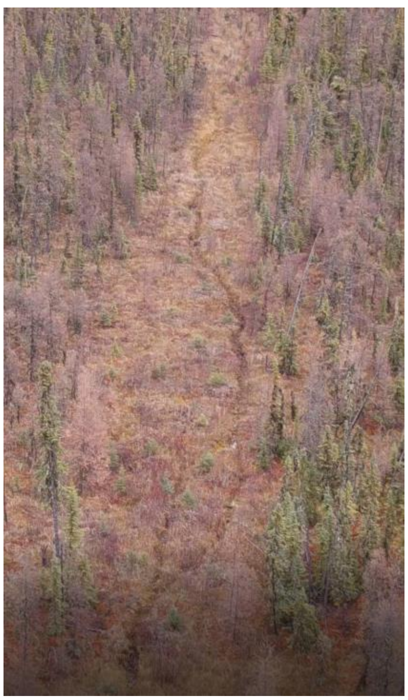

Figure 23 Line 4-4 rich fen - treated

Figure 24 Line 4-28 rich fen - treated, productive

Figure 25 Line 1-8 rich fen - treated

BOGS

Bogs and upland areas are included in the discussion to highlight examples of what we have seen previously on these sites. High levels of stocking with plenty of natural growth as well. Bogs show high levels of success with mounding and even the holes have started to recover, being covered in vegetation. There are several instances of trees growing on the edges of the holes, edges of the mounds, and the planted trees on the mounds. Figure 26, Figure 27, and Figure 28 show some examples of successful stocking on bog line segments. The bogs do not seem to have the same site limiting factors as the fens, there is less vegetation to compete with for light, the mounds do not flatten out as they do in fens, and the areas are not as wet overall.

Figure 26 Line 2-7 bog - treated with good stocking, taller trees

Figure 27 Line 1-8 bog - treated, good stocking

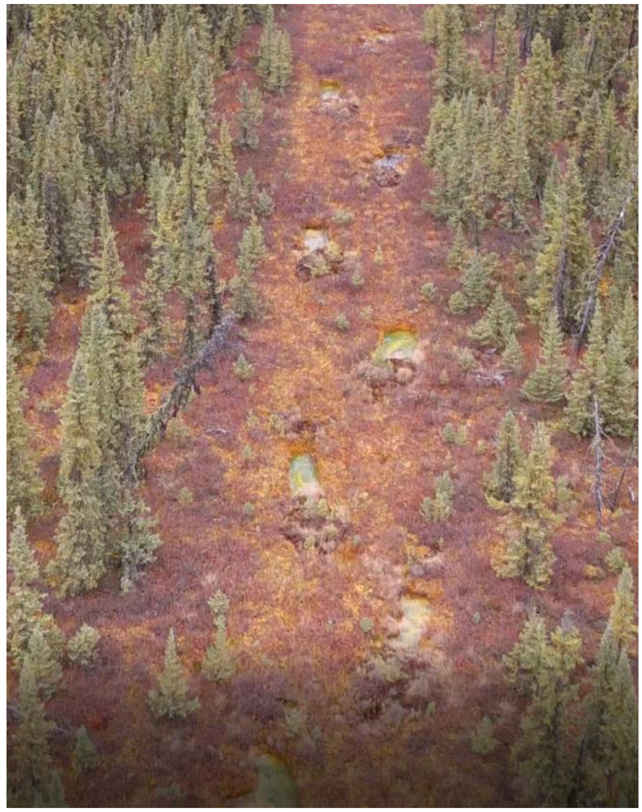

Figure 28 Line 3-21 bog - treated, uneven stocking, holes getting covered by vegetation

ESTABLISHMENT SURVEY DISCUSSION

The aerial assessment and the video review worked well for a broad-level assessment of the condition of line segments. The project team was able to focus on fen segments which allowed a more focused decision of which areas in Algar to visit.

There are some limitations with the aerial survey and video review. First, the project team is only able to conduct a rough estimate of stocking of the trees with this method. A ground survey allows for a lot higher resolution of tree counts, albeit in a limited area. A combination of aerial and ground surveys would maximize accuracy. Mounds were difficult to spot from the air or video. Many times, grass or shrubs dominate the landscape limiting the ability to see mounds. Experience from the field suggests that sometimes mounds are there, but heavily covered in grass and shrubs. Grass is a heavy competitor in the fen sites – some sections more so than others (Figure 11, Figure 14, Figure 15, and Figure 16 are examples).

Another issue is without being on the ground and identifying microsite characteristics, it is more challenging to understand which factors are at play when determining stocking site success. This is an area of potential future research consideration.

Evidence of human presence has always been limited during Algar monitoring activities, but Line 4-22 appeared to have some indication that human activity has taken place recently (Figure 29).

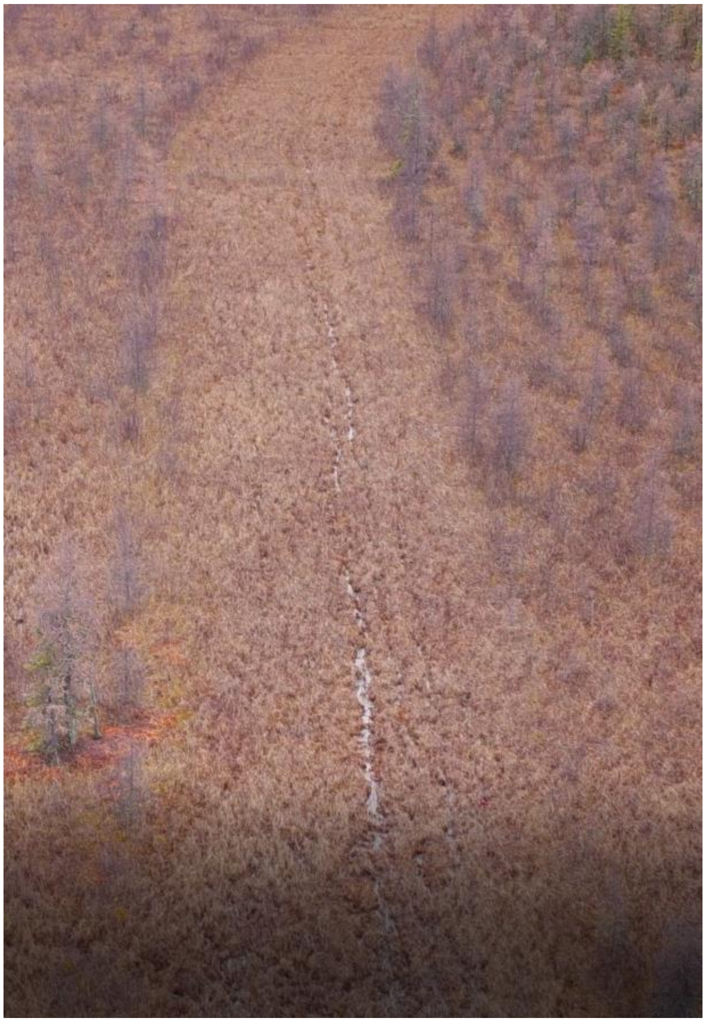

Figure 29 Line 4-22 rich fen with some indication of human activity. Poor growth

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSION

This analysis helped confirm previous ground-based monitoring that seismic recovery on fen sites is challenged with the current Framework criteria. Poor fens on average performed better than rich fens however that difference was only marginal and suggests other limiting factors on fens in general. The two-tiered approach to stocking targets that consider surrounding density does seem appropriate based on this analysis however the target levels may be difficult to achieve on fens with only half of the surveyed segments achieving the target. Alternative requirements should be considered for linear restoration at fen sites, especially when segments may have mixed levels of density to consider. The Establishment Survey indicates acceptable success rates on rich fens, however, it is still unclear why some sites are more successful than others. Mound height, location of the line segment in the fen, microsite conditions, surrounding vegetation, and more are all things to be considered and could be studied on the ground. Restoration targets on fen sites might consider other vegetation criteria (not just trees) as indicators of site success. For example, it has been suggested that maximizing leaf area on the line may be a more appropriate way to successfully restore these types of lines.

Further to the outcomes in fens, this project presented an opportunity to conduct/test an aerial-based survey following the Framework methodology. It is possible and efficient to assess large line segments and landscapes using an aerial assessment and video review. These tools worked well for a broad-level assessment of the condition of line segments. This technique allowed the project team to focus on fen segments which was the main consideration of this work. Some limitations were noted with the aerial assessment and video review - mounds were difficult to spot from the air or video. Many times, grass or shrubs dominate the landscape limiting the ability to see mounds. Previous ground monitoring programs in Algar suggest that sometimes mounds are there, but heavily covered in grass and shrubs. The project team is only able to conduct a rough estimate of the stocking of the trees with this method. A ground survey allows for a lot higher resolution of tree counts, albeit in a limited area. A combination of aerial and ground surveys would maximize accuracy. Another issue is without being on the ground and identifying microsite characteristics, it is more challenging to understand which factors are at play when determining stocking site success. This is an area of potential future research consideration.

OTHER RESEARCH OPPORTUNITIES IN ALGAR

Monitoring has been conducted in Algar since 2012. Even with nine years of data, analysis, and lessons learned, there is still much to understand about linear restoration on legacy seismic lines. Algar has the longest timeframe of data available and there still needs to be more insight into vegetation recovery on particular sites. There are several avenues of potential research and implementation which could inform and improve legacy seismic line restoration.

The project team has outlined some potential project ideas for development:

- Improving Fen Restoration Outcomes
    - Work with other groups (e.g. NAIT) to plan, implement and monitor alternative treatment trials on fen sites (small trials on sections of lines close to current operations/roads, etc.)
    - Algar area ground data collection to study the soil, hydrology, and other environmental conditions of fen sites to better understand site limiting factors
- Tools for improving the operational efficiency of linear restoration implementation

  - Leverage Algar monitoring database to develop a least-cost pathway model for the prioritization of ecosites. Model development and field verification.
- Tools for improving the efficiency of linear restoration monitoring
  - Establishment Survey using aerial/digital approach with ground verification on other ecosite types in Algar

OTHER POTENTIAL RESEARCH OPPORTUNITIES

Researchers identified several opportunities for future research. Some of these could be conducted at previously reclaimed sites, but many would require new implementation projects. Briefly, here are some of the key ideas discussed to look at during a new implementation project:

• Use the hummock transfer technique [11].

• Incorporate more woody material.

• Study biochar as a stabilizer.

• Somehow manipulate the water table at these sites (soil manipulation is a possibility).

• Attempt and study leaf area maximization rather than tree growth.

APPLICATION

The Government of Canada adopted federal recovery strategies for caribou populations with goals to achieve self-sustaining local populations throughout their current distribution in Canada [19] [20]. Pursuant to the objectives of the federal recovery strategies, the Government of Alberta released a Draft Provincial Woodland Caribou Range Plan (December 2017) [21] outlining key actions and commitments for supporting caribou recovery in Alberta. Among these are a commitment to recover caribou habitat through the restoration of legacy seismic lines and inactive oil & gas infrastructure. It is estimated that 150,000 km of legacy seismic footprint require varying levels of intervention to re-establish vegetation and encourage restoration within caribou ranges in the province [21].

Applying the monitoring techniques established for this project fall in line with the recommendations from the *Provincial Restoration and Establishment Framework for Legacy Seismic Lines in Alberta* [5]. Conducting an aerial assessment in conjunction with a video review of the flights increases the area monitored compared to ground surveys alone. However, several limitations are noted – including the limited ability to identify specific site characteristics which may impact restoration success. The success of rich fen stocking found during this exercise provides further evidence of the beneficial techniques piloted in Algar a decade ago. Winter planting and mounding works as well as the Framework targets expect. The results on fens suggest that alternative techniques need to be further trialled.

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