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ALGAR HABITAT RESTORATION

STUDYING OUTCOMES OF AN ALTERNATIVE TREATMENT TRIAL

MONITORING REPORT 2018

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 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.).

During the Algar Caribou Restoration project implementation, a few techniques were tested to boost production rates helping reduce program costs while striving to achieve restoration outcomes. One technique, in particular, was Leapfrog treatments, where a seismic line was treated for 100m followed by 100m of no treatment. This pattern was followed for the entire test treatment area. This concept allows operators to increase restoration production rates significantly by reducing the treatment area by half. The intent is for this treatment to deactivate the line from human, wildlife, and predator use as well as reduce line of sight and establish vegetation cover. The goals remain the same as fully treated areas, but at a higher production rate.

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 Leapfrog linear restoration treatments in achieving restoration goals of caribou habitat restoration and reduced predation risk. This research will benefit both industry and government (who is embracing linear restoration as a part of caribou range planning), as they seek innovative and cost-effective solutions for restoring caribou habitat. Key questions are:

- Is there a vegetation response on the untreated portions of Leapfrog lines and how does it compare to non-treated/control lines?
- Is vegetation response different between untreated and treated segments of the Leapfrog line and is there reduction in the response further from treatment edge?

This project's results will help address knowledge gaps and aide in caribou recovery in Alberta and elsewhere in the boreal forest. If Leapfrog techniques are proven to be effective at restoring functional caribou habitat, it may reduce future restoration treatment costs up to 50 percent.

Preliminary results indicate a potential vegetation (trees) response on untreated portions of a Leapfrog line and that the response is diminished as you move away from the treatment edge.

EXECUTIVE SUMMARY

Woodland caribou (*Rangifer tarandus caribou*) boreal and southern mountain populations are designated as Threatened under Canada's Species at Risk Act (Government of Canada, 2018) and Alberta's Wildlife Act (Alberta Environment and Parks, 2018). Many tools will be used towards achieving self sustaining caribou populations in Alberta including habitat restoration on seismic lines (Government of Alberta, 2017).

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 (Government of Alberta, 2017). Legacy seismic lines remain on the landscape for years, many requiring some type of intervention to become functional caribou habitat (Government of Alberta, 2017). 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.) (Pyper, Nishi, & McNeil, 2014).

During the Algar Caribou Restoration project implementation, a few techniques were tested to boost production rates helping reduce program costs while striving to achieve restoration outcomes. One technique, in particular, was Leapfrog treatments, where a seismic line was treated for 100m followed by 100m of no treatment. This pattern was followed for the entire test treatment area. This concept allows operators to increase restoration production rates significantly by reducing the treatment area by half. The intent is for this treatment to deactivate the line from human, wildlife, and predator use as well as reduce line of sight and establish vegetation cover. The goals remain the same as fully treated areas, but at a higher production rate.

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 Leapfrog linear restoration treatments in achieving restoration goals of caribou habitat restoration and reduced predation risk. This research will benefit both industry and government (who is embracing linear restoration as a part of caribou range planning), as they seek innovative and cost-effective solutions for restoring caribou habitat. Key questions are:

- Is there a vegetation response on the untreated portions of Leapfrog lines and how does it compare to non-treated/control lines?
- Is vegetation response different between untreated and treated segments of the Leapfrog line and is there reduction in the response further from treatment edge?

This project's results will help address knowledge gaps and aide in caribou recovery in Alberta and elsewhere in the boreal forest. If Leapfrog techniques are proven to be effective at restoring functional caribou habitat, it may reduce future restoration treatment costs significantly and help scale up linear restoration to meet provincial range plan objectives.

This project used ground survey and advanced high-resolution imagery products from a UAS survey to assess early vegetation response. Preliminary results of the project indicate potential vegetation response on untreated portions of the Leapfrog line, a possible edge effect. There was also some evidence of that effect diminishing as you move away from the treatment edge. Additional research with the imagery products may add additional insight into the observed trends.

Further research is need on additional site types, as the Leapfrog line was only one line in a mix of bogs and fens without any upland areas. Treatment segment length could also use further research to see if the benefits of Leapfrog could be replicated for different (shorter or longer) treatment lengths. Further research would also improve our understanding of the biggest expected benefit of the Leapfrog treatment, the cost efficiency of the treatment.

BEST PRACTICES AND PROJECT OUTCOMES

The value derived from this project is not limited to the results from the field and analysis. Silvacom and Ventus developed some new techniques for legacy seismic line restoration monitoring. Specifically, Silvacom developed a new plot design suited to understanding the effects of Leapfrog restoration to help improve restoration efficiencies in the future. Along with the plot survey information, imagery was captured and used to maximize the amount of information and decrease uncertainties in the results. The imagery and the analysis thereof from the project also sets a standard for seismic lines monitoring.

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:

- Developed monitoring practices using both ground plot surveys and aerial imagery.
- Preliminary results indicate vegetation (trees) closer to the edge of treatment experience more change than untreated portions further away from the edge of treatment.
- Untreated portions of the Leapfrog line appear to experience more vegetation changes than untreated lines.
- A Step in developing more efficient linear restoration programs

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BACKGROUND

ALGAR CARIBOU HABITAT RESTORATION PROJECT

The Algar Caribou Habitat Restoration Program was initiated in 2011 (*Figure 2*) 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 imitative 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 (*Map 1*), were treated by winter planting and/or natural regeneration protection over the course of 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. To-date six years of monitoring data have been collected in the Algar area, spanning several treatment types including winter mounded and planted sites, 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 camera trap survey. Lastly, 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 (Silvacom Ltd., 2018).

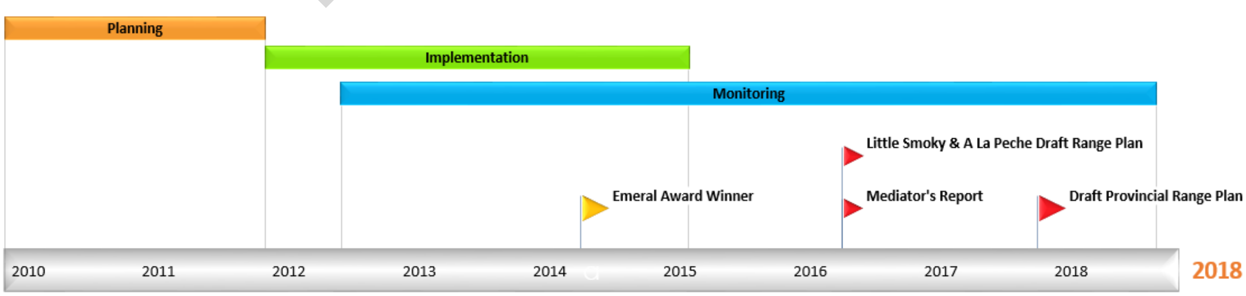
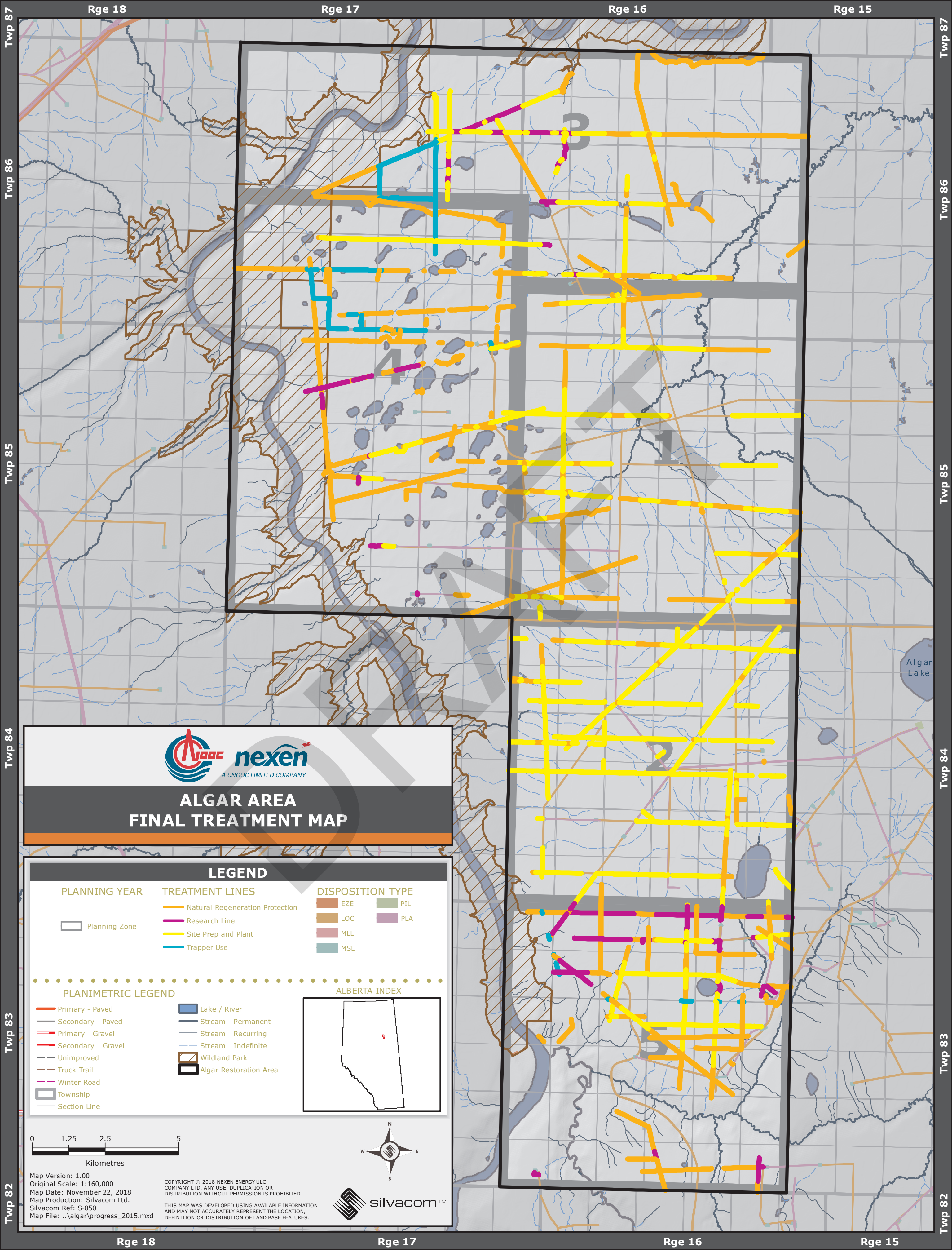


Figure 2. Timeline of Algar habitat restoration program



Rge 18
Rge 17
Rge 16
Rge 15
Twp 87
Twp 86
Twp 85
Twp 84
Twp 83
Twp 82
3
4
1
2
5
Algar Lake
DRAFT
nexen
A CNOOC LIMITED COMPANY
ALGAR AREA
FINAL TREATMENT MAP
LEGEND
PLANNING YEAR
Planning Zone
TREATMENT LINES
Natural Regeneration Protection
Research Line
Site Prep and Plant
Trapper Use
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
ALBERTA INDEX
0
1.25
2.5
5
Kilometres
N
W
E
S
Map Version: 1.00
Original Scale: 1:160,000
Map Date: November 22, 2018
Map Production: Silvacom Ltd.
Silvacom Ref: S-050
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SCALING UP LINEAR RESTORATION

Woodland caribou (Rangifer tarandus caribou) boreal and southern mountain populations are designated as Threatened under Canada's Species at Risk Act (Government of Canada, 2018) and Alberta's Wildlife Act (Alberta Environment and Parks, 2018). In 2012 and 2014, the Government of Canada adopted federal recovery strategies for each population respectively with goals to achieve self-sustaining local populations throughout their current distribution in Canada (Environment Canada , 2012) (Environment Canada, 2014). Pursuant to the objectives of the federal recovery strategies, the Government of Alberta released a Draft Provincial Woodland Caribou Range Plan (December 2017) (Government of Alberta, 2017) 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.

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 (Government of Alberta, 2017). Without intervention, legacy seismic lines can remain on the landscape for decades for a variety of reasons including terrain wetness, continued human use and clearing size (van Rensen, Nielsen, White, Vinge, & Lieffers, 2015). 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 (Government of Alberta, 2017). 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.) (Pyper, Nishi, & McNeil, 2014).

Restoration at the scale achieved in Algar is a significant investment and has helped highlight many tactical challenges and opportunities for delivering an effective and efficient program at both the range and provincial level. There are many important considerations when designing and sequencing a restoration program to fit into broader caribou objectives and opportunities (Government of Alberta, 2017). These may include but not limited to relevance to woodland caribou, accessibility, existing natural regeneration, forest harvest plans, future oil & gas development, current use of lines, etc.

During the Algar project implementation, a few techniques were tested in an attempt to boost production rates helping reduce program costs while striving to achieve restoration outcomes. One technique was termed Leapfrog treatment, where a seismic line was treated for 100m followed by 100m of no treatment. This pattern was followed for an entire test treatment line. *Figure 3* and *Figure 4* illustrate a comparison of the a fully treated line with a Leapfrog approach.

This concept allows operators to increase production rates significantly by reducing the treatment area by half. The intent is for this treatment to still deactivate the line from human, wildlife and predator use as well as reduce line of sight and establish vegetation cover. If Leapfrog techniques are proven to be effective at restoring functional caribou habitat, it may reduce future restoration treatment costs significantly and become part of the restoration toolbox to help achieve provincial range plan objectives.

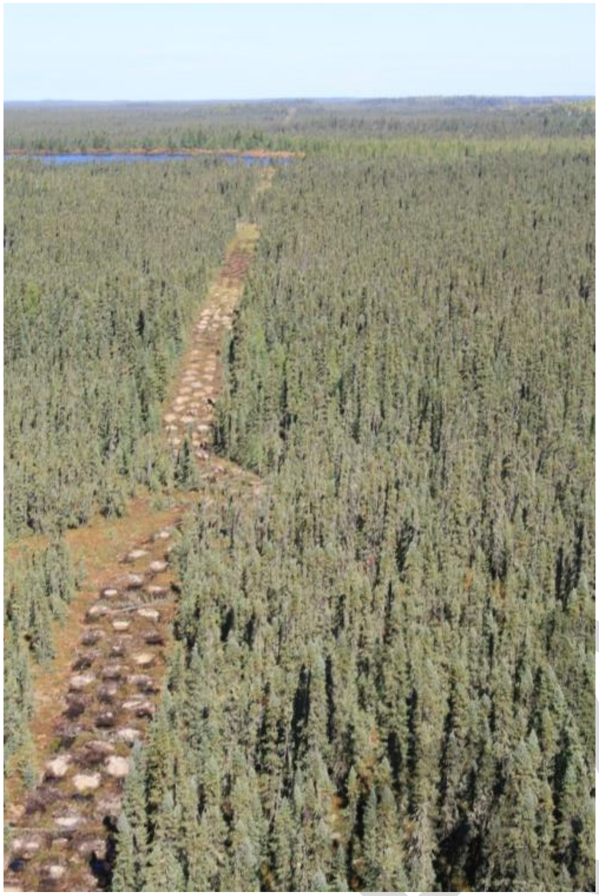


Figure 3. Fully treated line

Figure 4. Leapfrog treated line

STUDYING OUTCOMES OF THE LEAPFROG TRIAL

This project seeks to address key knowledge gaps in the effectiveness of the Leapfrog linear restoration treatments (*Figure 5*) in achieving restoration goals of caribou habitat restoration and reduced predation risk. This research will benefit both industry and government (who is embracing linear restoration as part of caribou range planning), as they seek innovative and cost-effective solutions for restoring caribou habitat.

Despite a portion of the leapfrog being untreated, there is a potential edge effect from the treated segment that may influence conditions for the neighbouring untreated segment. Seismic lines themselves create edge effects with surrounding forest influencing microclimatic conditions (Dabros, Pyper, & Castilla, Seismic ilnes in the boreal and artic ecosystems of North America: environmental impacts, challenges, and opportunities, 2018) (Dabros, Hammond, Pinzon, Pinno, & Langor, 2017) (Stern, Riva, & Nielsen, 2018) and therefore it may be possible for a vegetation response from the edge of the Leapfrog treatment.

This report outlines two key questions to be answered with the field work and analysis for this project and they are as follows:

- Is there a vegetation response on the untreated portions of Leapfrog lines and how does it compare to non-treated/control lines?
- Is vegetation response different between untreated and treated segments of the Leapfrog line and is there reduction in the response further from treatment edge?

Figure 5. Leapfrog treated line showing successful tree growth on mounds 3 years post treatment

DATA AND METHODOLOGIES

To answer the vegetation response questions, a combination of background research on potential treatment edge responses, desktop analysis, and field sampling were used to gather data and information. This section describes the background research, and the data collection methodologies.

BACKGROUND RESEARCH

Background research was conducted to understand the potential effects of treatment edges in the boreal forest. In Leapfrog treatment areas, there are six edge types in the treated lengths:

- the edge inside of the forest next to an untreated portion (1)
- the edge inside the cleared portion (2)
- the edge inside a clearing next to a treated section (3),
- the edge inside a treated section next to a clearing (4),
- the edge inside a forest next to a treated section (5), and
- the edge inside a treated section next to a forest (6).

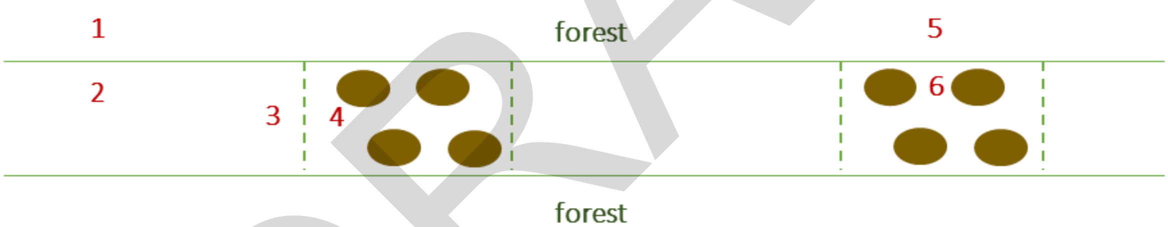


Figure 6. Treatment and disturbance edges

The types of responses to edge creation can be categorized into primary and secondary responses (Harper, et al., 2005).

PRIMARY RESPONSES

Primary edge effect responses are caused by the immediate creation of an edge. In the case of treatment, the immediate effects could change the areas interfacing (3) – (6).

Primary edge responses include (Harper, et al., 2005):

- Vegetation disturbance,
- Changes to soil processes/structure,
- Increased seed/pollen dispersal,
- Evapotranspiration changes,
- Nutrient cycling disruptions/changes, and

- Decomposition changes.

VEGETATION DISTURBANCE

During the treatment of seismic lines in Algar, heavy machinery was driven over winterized mosses, grasses, shrubs, and potentially trees. Heavy machinery dug through the snow, ice, vegetation, and soil to create mounds where seedlings were planted. During the driving, mounding, existing vegetation may have been disturbed. The heavy machinery also drove between treatment segments. The Leapfrog treatment of a seismic line creates edges of disturbed vegetation.

CHANGES TO SOIL PROCESS/STRUCTURE

During treatment of seismic lines, a portion of the area is treated with mounding: the ripping up of soil, the inversion of that soil, and the placement of that soil on the undisturbed ground. All three of these processes change the soil processes and structures in place on the seismic line. The mounded soil has new seedlings planted in it. The mound itself will have different structures than it did prior to treatment, and the processes in the mounded soil will change when the mound is no longer frozen. Processes that could change include, but aren't limited to: water retention, water gradients, nutrient gradients, nutrient movements and availability, and soil organisms present (Pyper, Nishi, & McNeil, 2014) (Von der Gönna, 1992). Treatment and travel between treated segments may result in changes to soil processes and structure due to the heavy machinery on the surface. Like with the vegetation, disturbance gradients may have been created which may create soil conditions for a vegetation response. The Leapfrog treatment of a seismic line creates edges of changes to soil process and structure.

SEED AND POLLEN DISPERSAL

When a seismic line is created, there is an increase in seed and pollen dispersal (Roberts, S. Cuiti, Willier, & Nielson, 2018). When treated, some aspects of treatment may contribute to increased seed dispersal, and others may contribute to decreased seed dispersal (Von der Gönna, 1992). The addition of seeds if the treatment is seeded will contribute immediately to a seed bed. The process of mounding may unearth or cover seed sources. Invasive plants already present in the forest or in clearings can spread like other seeds as well. Treatment processes may cause seed or pollen to disperse further by spreading with machines or by the jostling of the forest during treatment creating an opportunity for seed and pollen to disperse further. We suspect that along the line, the seed dispersal will continue to be higher than in undisturbed forests through wind until the seedlings are established and filling in the lines. At such a point as the seedlings reach larger sizes and maturity, they will begin contributing to seed and pollen sources and dispersal as well. This means, that as a primary response, seed and pollen dispersal will probably be like advanced pre- and post-treatment until seedlings are established and producing their own seeds.

EVAPOTRANSPIRATION CHANGES

In general, we expect evapotranspiration to change along treated seismic lines. Immediately following treatment, the effect would be a decrease in evapotranspiration from the initial disturbance to existing low vegetation to create mounds. As vegetation re-establishes following treatment with larger plant species, evapotranspiration should increase as more vegetation establishes.

NUTRIENT CYCLING DISRUPTION/CHANGES

We expect nutrient cycling to change along treated seismic lines. New nutrients would be released by treatment, and other nutrients may be removed, or moved due to treatment (Pyper, Nishi, & McNeil, 2014) (Von der Gönna, 1992). For example, if water flows change due to treatment, the gradient along which some nutrients are distributed may change. If soil is dug, inverted, and mounded, the distribution of nutrients will change within that soil (Von der Gönna, 1992). Treatment may also result in added nutrients to the soil accessible to plants when mound inversion occurs and when profiles are exposed when a mound is dug. Nutrients are removed from holes during treatment and placed elsewhere in a different arrangement.

SECONDARY RESPONSES

Secondary responses are the indirect effects of creating an edge – changes in abiotic and biotic gradients (Harper, et al., 2005). In the case of Leapfrog treatment areas, secondary responses could impact the interfacing edges of (3) – (6). Some common secondary responses include:

- Sapling density,
- Understory cover,
- Shrub and tree height,
- Windthrow, and
- Species composition.

Some of the change will be immediate – due to planting – and some will be delayed and in response to changed abiotic and biotic factors. The factors may be different depending on the edges which are interfacing and depending on the forest stand types which interface with the clearings and the treatment areas. There are many other variables and they depend on many abiotic factors such as the:

- distance from the forested edge,
- the wind speed,
- wind direction,
- amount of solar radiation,
- latitude,
- season,
- local topography,
- aspect,
- slope,
- seismic line direction,
- etc.

And biotic factors such as:

- permeability of canopy trees to solar radiation,
- species composition,
- species distribution,
- species behavior,
- etc.

Secondary responses are very difficult to quantify because of the variety of factors interacting.

Overall, based on the available literature mostly focused on cutblock edges and making inferences with respect to seismic line treatment edges, it is expected that the treatment edges influence vegetation. The evidence from other research indicates that effect to diminish as you move away from the edge (Harper, et al., 2005) (Roberts, S. Cuiti, Willier, & Nielson, 2018).

DESKTOP ANALYSIS

Part of the commitment to understand the vegetation responses on Leapfrog treated lines, how changes occur on those lines, and how those compare to treated areas and non-treated areas was to conduct some remote sensing and desktop analysis activities.

Silvacom stratified site conditions of the pilot Leapfrog line and control research lines using inventory data sets including Alberta Vegetation Inventory (AVI) (Forest Management Branch, Forestry Division, Alberta Agriculture and Forestry. Government of Alberta, 2017),). Using that same information, Silvacom members identified target sample sites across site conditions and line treatments to narrow the focus and maximize efficiency of the remote sensing analysis. One of the legacy seismic lines in Algar was treated with the Leapfrog treatment, this line was chosen as the Leapfrog line for the monitoring. Two research lines were chosen as comparison lines for the research because of their similarities to the Leapfrog line. Using the AVI and Ecosite Phases, it was determined that the research lines were similar to the Leapfrog line as far as species composition, ecosite type, and adjacent forest density.

Figure 7 illustrates what the Leapfrog treatment line looks like from above, and Figure 8 and Figure 9 show fully treated and control (for research purposes) lines respectively in Algar. These types of images were used in conjunction with the AVI and ecosite phases to determine similar lines to the Leapfrog treated line.

Figure 7. Imagery of Leapfrog line

Figure 8. Imagery of a fully treated line

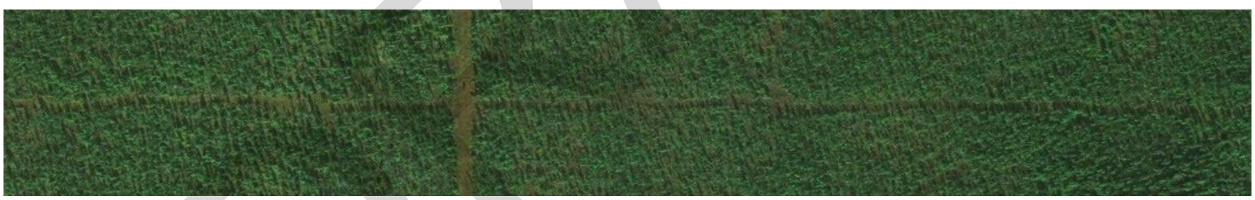
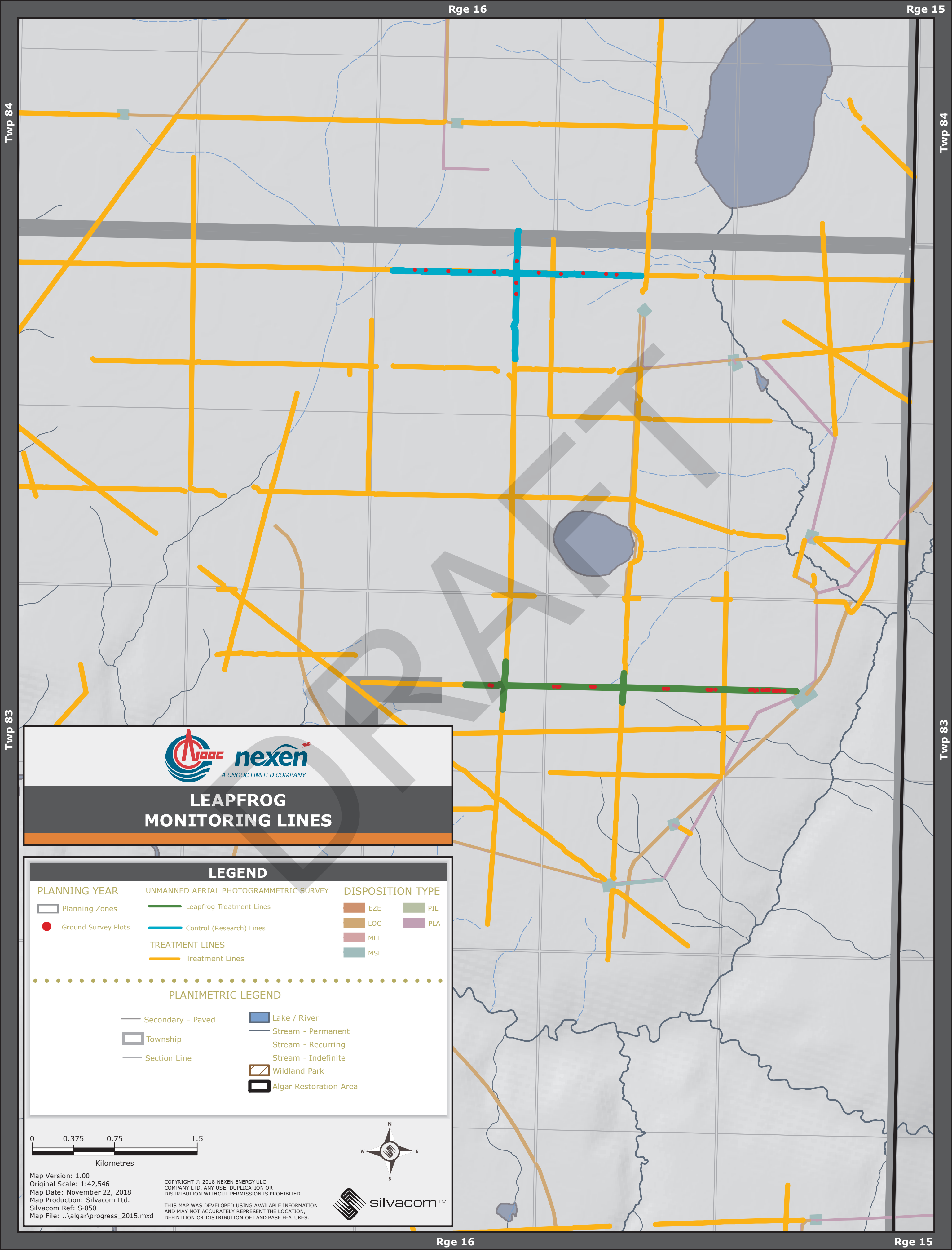


Figure 9. Imagery of two intersecting lines left untreated for research purposes

CROSSREFERENCE HERE *Map 2* shows the project area (Algar Area 5) with lines and plots surveyed during the project.



Rge 16
Rge 15
Twp 84
Twp 84
Twp 83
Twp 83
DRAFT
nexen
A CNOOC LIMITED COMPANY
LEAPFROG
MONITORING LINES
LEGEND
PLANNING YEAR
Planning Zones
Ground Survey Plots
UNMANNED AERIAL PHOTOGRAMMETRIC SURVEY
Leapfrog Treatment Lines
Control (Research) Lines
TREATMENT LINES
Treatment Lines
DISPOSITION TYPE
EZE
LOC
MLL
MSL
PIL
PLA
PLANIMETRIC LEGEND
Secondary - Paved
Township
Section Line
Lake / River
Stream - Permanent
Stream - Recurring
Stream - Indefinite
Wildland Park
Algar Restoration Area
0
0.375
0.75
1.5
Kilometres
N
W
E
S
Map Version: 1.00
Original Scale: 1:42,546
Map Date: November 22, 2018
Map Production: Silvacom Ltd.
Silvacom Ref: S-050
Map File: ..\algar\progress_2015.mxd
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Rge 16
Rge 15

FIELD DATA COLLECTION

GROUND SURVEY

The monitoring program involved three components for each sample plot. First, photos were taken to visually capture the line's condition. The second and third components were surveys to quantitatively capture the line's condition. A vegetation survey of a 10 m transect, and a vegetation survey of a 1.78 m radius plot were conducted. The transect survey aimed to collect naturally seeded tree counts and heights on untreated portions of lines and both naturally seeded and planted tree counts and heights on treated portions of lines. The 1.78 m radius plots were used to assess species richness. On top of the data collected within the transects and plots were information about the adjacent line characteristics like forest height, tree density, ecosite type, and more. An overview of the procedures and the information captured is provided below.

The field survey team used Collector for ArcGIS to input plot information. Each plot was recorded, and the GPS location saved in the program along with the survey information and the photo of the transect.

PLOT DESIGN

The plot design included both transects and circular plots at the same site. The plot design is similar to the plot design methodologies outlined in the Government of Alberta's *Provincial Restoration and Establishment Framework for Legacy Seismic Lines in Alberta* (Government of Alberta, 2017). Figure 10 illustrates an example of how monitoring occurred on a section of a Leapfrog line and Figure 11 shows an example of the Government of Alberta (GoA) recommended plot layout. Plot layout for the Leapfrog analysis differs mainly because of the research question associated with the effect on treatment at the treatment edge moving away from that edge. The GoA example leaves at least 10 m buffer from the edge of treatment which limits the information about the edge effect whereas in the Leapfrog plot layout, Silvacom has some measurements within three metres of the treatment edge.

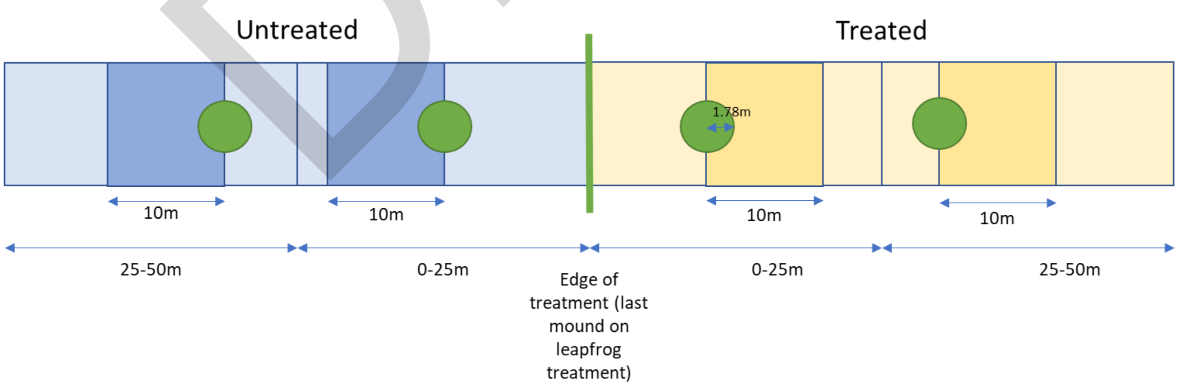


Figure 10. Leapfrog plot design example

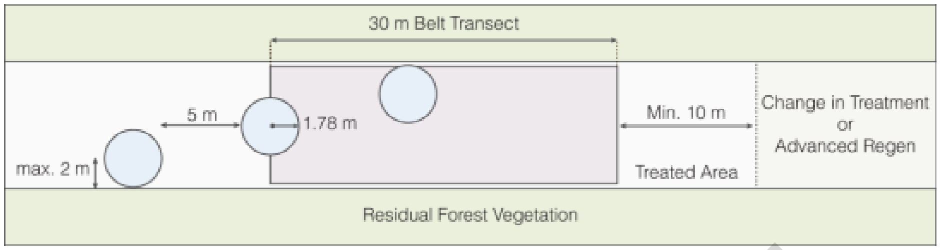


Figure 11. Government of Alberta example sample subplot layout within a Survival Assessment plot (Government of Alberta, 2017)

PLOT DATA COLLECTION PROCEDURES

Below is a summary of the steps taken for the vegetation survey:

1. Define the edge of the treatment along the Leapfrog line. When not working on a Leapfrog line, choose plots that are at least 200 m apart.
2. Each plot will have up to four 10m rectangular transects, two each direction. One of each direction will be in 0-25m from the edge of the treatment and one will be from 25-50m. Along with each of those four transects there will be 1.78m radii circular plots centered at the leading edge of those (closest to the main plot).
3. Use randomly assigned number between 2 and 13 to determine 10m transect starting point (starting at 0m and 25m from main plot centre). Mark the start and end points (10 metres) of the transects (see pre-generated sheet for starting points). Transects should start at least 2m from the start of the 0-25m and 25-50m sections.
4. Create a point in Collector for ArcGIS. The data collected is summarized in APPENDIX A.
5. At the leading edge (closest to the edge of the treatment type) start a circular plot of 1.78m radius. For the circular plot:
   5.1. Count the number of species for each of mosses, lichens, forbs, grasses, shrubs, and trees, note the percent ground cover, and the plot centre location (distance from edge – should be at the beginning of the 10m transect)
   5.2. Take a photo of a 1.2m high marker 10m from the plot centre facing the same direction as the transect at the centre of the circular plot location. Attach the photos using Collector for ArcGIS.

PHOTO PROCEDURE

Additionally, a line of sight photo was completed at each plot. A photo reference marker was placed at 10m from plot centre in the direction facing the transect. The midpoint on the photo reference marker was 1.2m off the ground which represents the approximate height of a mature Caribou[1] as a proxy indicator for visual line of sight. Figure 12 is an example of a plot photo taken during the measurements.

[1] Government of Canada's Species profile available at https://wildlif e-species.canada.ca/species-risk-registry/species/speciesDetails_e.cfm?sid=636

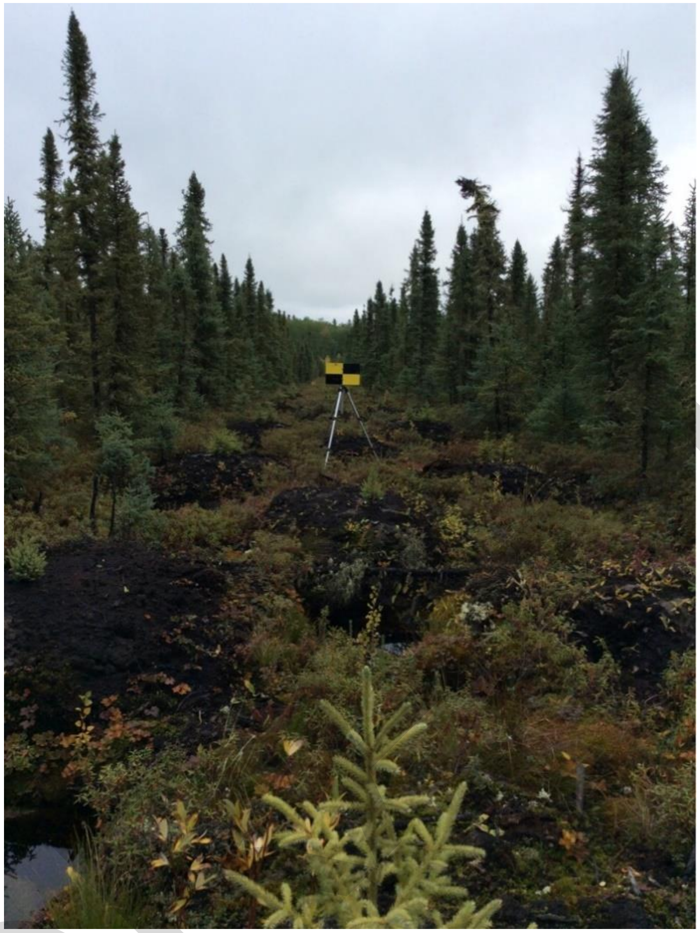


Figure 12. Example of line of site photo taken at a plot

UAS SURVEY

Following the initial stages of imagery acquisition, review, and determining appropriate sites, the next step was to acquire high resolution imagery of the sample sites to show post treatment conditions. Silvacom enlisted Ventus Geospatial Inc. (Ventus) to acquire the imagery. The lines were surveyed in with ground control points first, then Ventus surveyed the lines with their Unmanned Aerial System (UAS). First, the lines were flown with the Unmanned Aerial Vehicle (UAV) using an RGB sensor followed by a flight with a multispectral sensor. The UAS surveys produced RGB Visual Imagery, Multispectral Imagery, Normalized Difference Vegetation Index (NDVI), Digital Terrain Models, a Vegetation Height Model, Drawing Sets for Vegetation Height, and a Flythrough Video for the project to aid in analysis and visualization. Figure 2 shows some of the equipment used to collect the imagery for this project.

Figure 13. Image of Unmanned Aerial Vehicle (UAV) and other imagery acquisition equipment

Imagery and the associated analysis provide information about the amount of vegetation and the heights of that vegetation for the area flown. Using geospatial analysis, vegetation counts and heights along the survey lines were analyzed from the imagery outputs to conduct a preliminary assessment on vegetation response comparisons between treatments (Leapfrog, control/research).

RESULTS

The individual results of the ground plot and transects are summarized in APPENDIX A with summaries at the treatment level in the section below. Following the ground plot and transect treatment level summaries is a section covering the analysis of the data collected by the Ventus UAS and further analyzed by Silvacom.

GROUND SURVEY

PLOT SURVEY SUMMARY

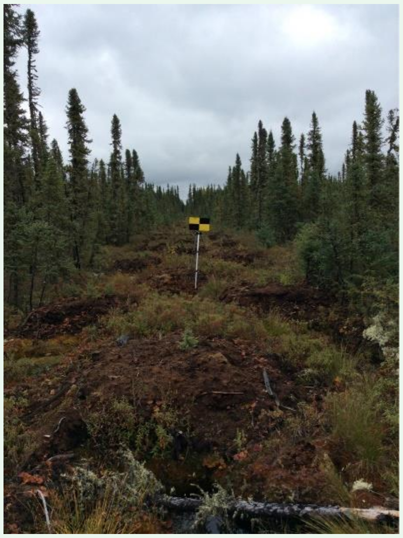
Below is a summary and description of the data and analysis derived from the field surveys. Table 1 outlines the number of plots for each type of treatment (Leapfrog Treated, Leapfrog Untreated, and Control) as well as the "distance from edge" (0-25 metres or 25-50 metres) category. There are more Leapfrog Untreated plots than other categories as those are the plots that help answer both research questions.

Table 1. Summary of treatment type and distance from edge plot counts

Leapfrog Treated		Leapfrog Untreated		Control
0-25 metres	25-50 metres	0-25 metres	25-50 metres	N/A
7	4	8	7	13

To help visualize the differences in the treatments and make multi-year comparisons, photos were taken at each plot in the same direction as the transect. Table 2 shows a comparison of each treatment type in photos and with the Mosaic RGB photo from the UAV, the monitoring conducted on the control plots occurred two days after the other plots as snowfall, wind, and rain limited the ability of the UAV and helicopter to fly the day after the other plots were surveyed. Conditions are visibly different as a result, not only because of the site differences but because of the significant changes in weather.

Table 2. Comparison images of leapfrog treated, leapfrog untreated, and control portions of lines.

Leapfrog Treated	Leapfrog Untreated	Control
		
		

<u>PLOT SUMMARIES</u>

Data was recorded and summarized at the plot level before aggerating results to understand the trends. Individual plot summaries are found in APPENDIX B. Table 3 is the template used for the plot summaries.

Table 3. Plot Summary example

<table>
<tr><th colspan="3">Plot ##-#</th></tr>
<tr><td>Distance from edge (m):</td><td></td><td rowspan="5">Photo of the line with marker</td></tr>
<tr><td>Adjacent Ecosite:</td><td></td></tr>
<tr><td>Adjacent Height (m):</td><td></td></tr>
<tr><td>Adjacent Density:</td><td></td></tr>
<tr><td>Line Width (m):</td><td></td></tr>
</table>

Transect Direction:		
Max Height Conifer (cm):		
Max Height Deciduous (cm):		
Stacked column chart of natural trees per hectare for 15-30 cm, 31-80 cm, 81-120 cm, and >120 cm groups		Stacked column chart of planted trees per hectare for 15-30 cm, 31-80 cm, 81-120 cm, and >120 cm groups – Only Leapfrog Treated plots have planted trees at the plot
Column chart of shrubs per hectare (<120 cm)		Species richness – stacked column count of species at the plot for mosses, lichens, forbs, grasses, shrubs, and trees

TREATMENT LEVEL RESULTS

To supplement the plot level data and provide context to the field monitoring and UAS/GIS analysis, treatment level results were analyzed. Analysis was conducted using the plot survey data and the UAS acquired data. This section summarizes both sets of data and the results of the analysis.

To answer the research questions about vegetation response from the edge and the difference between treatment types, we looked several variables:

- Trees/ha
- Maximum conifer height per plot (cm)
- Species richness (number of species for each of mosses, lichens, forbs, shrubs, grasses, and trees)

To determine each of those variables is influenced on legacy seismic lines under different treatment conditions, several factors were considered:

- Adjacent ecosite type
- Adjacent tree height
- Distance from treatment edge

- Treatment type

Using the results from the plot surveys, all the above variables and factors are considered to help answer the research questions. The distance from the treatment edge and the treatment type factors are directly linked to the research questions and as such are the focus of the analysis.

DISTANCE FROM THE TREATMENT EDGE VEGETATION EFFECTS ON UNTREATED LEAPFROG LINE

The plot surveys revealed a difference in the total trees per hectare on untreated portions of the Leapfrog line as the plots moved away from the treatment edge. The results were not significant enough to say that the effect is causal, however, a trend does seem to be present as seen in Figure 14.

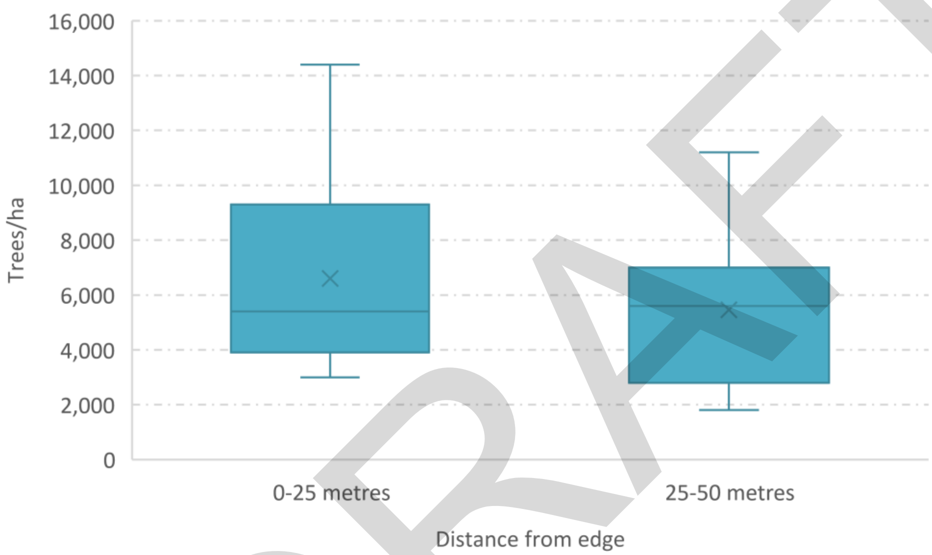


Figure 14. Total trees per hectare on untreated leapfrog plots by distance from edge

The maximum height of conifer trees (the predominant species being black spruce in the area) is also considered in the analysis. Similar to the total number of trees, the maximum height of trees appears to decline as the distance from the edge gets larger (Figure 15).

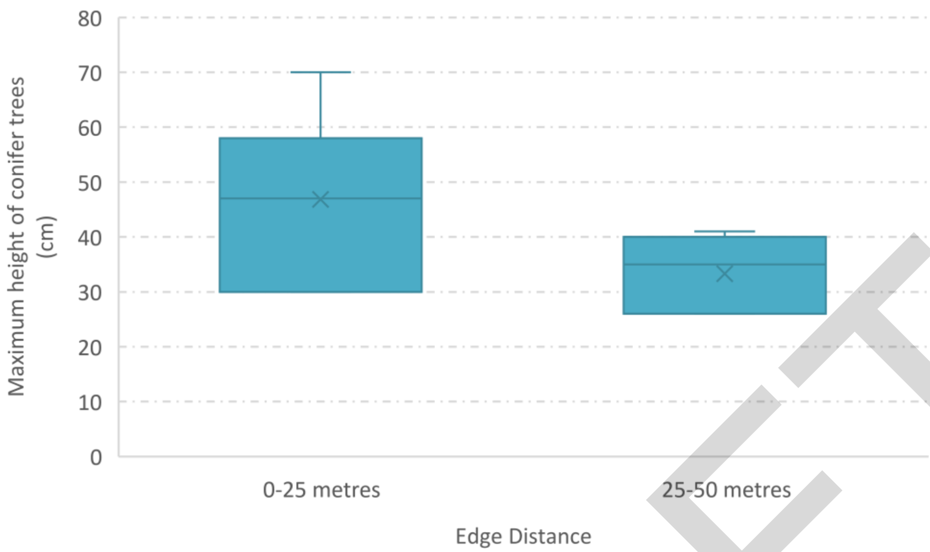


Figure 15. Maximum conifer height by distance from treatment edge on untreated Leapfrog line

Species richness was another variable considered when attempting to determine the effect of distance from the edge on vegetation. As seen in Figure 16, no difference in total species richness was seen during the field monitoring.

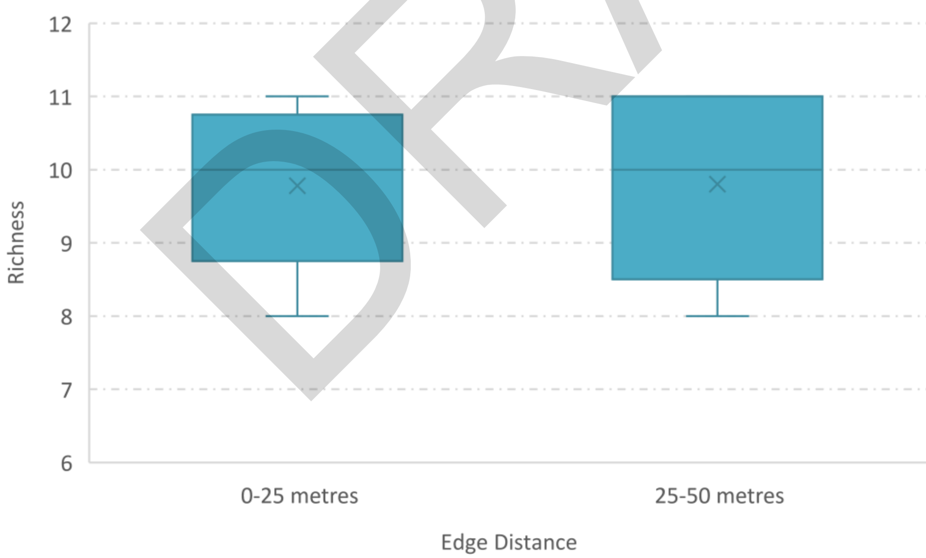


Figure 16. Species richness by distance from treatment edge on untreated Leapfrog line

TREATMENT TYPE EFFECTS

The primary intent with linear restoration on legacy seismic lines is to limit predator access and speed on those lines. Along with that goal is to restore the line to a trajectory of vegetative response like surrounding forest. With that in mind, we compare the treated and untreated portions on the Leapfrog line and we compare the untreated portion of the Leapfrog line to a control line.

The number of trees per hectare appears to be higher in both treated and untreated portions of the Leapfrog line relative to the control as seen in *Figure 17*.

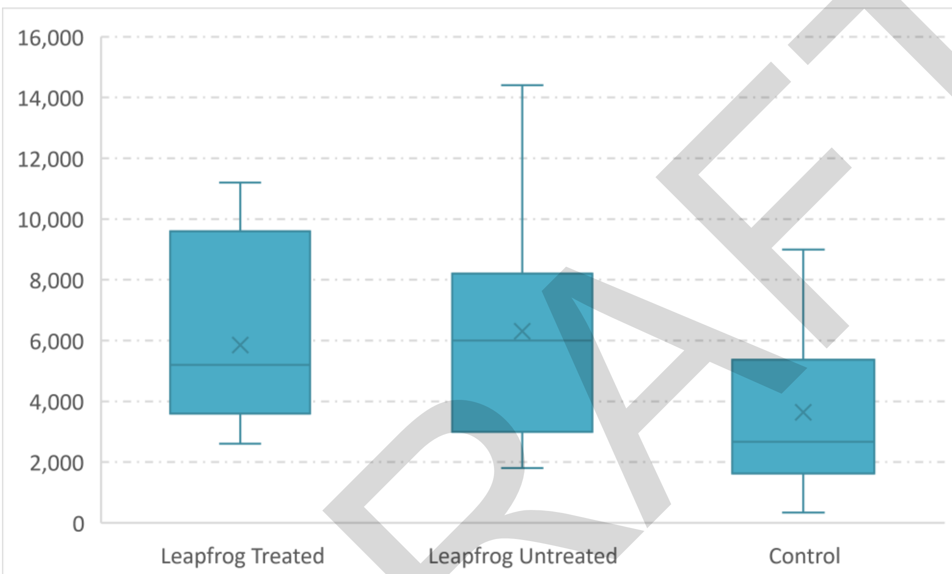


Figure 17. Total trees per hectare by treatment type

The maximum height of conifer trees appears to have the inverse relationship, where the control lines exhibit higher maximum heights than the Leapfrog plots. This might be the result of the number of growing seasons since the lines were treated (i.e. the control lines were disturbed longer ago than the treated lines which were disturbed during restoration and have had fewer growing seasons since disturbance) (Figure 18).

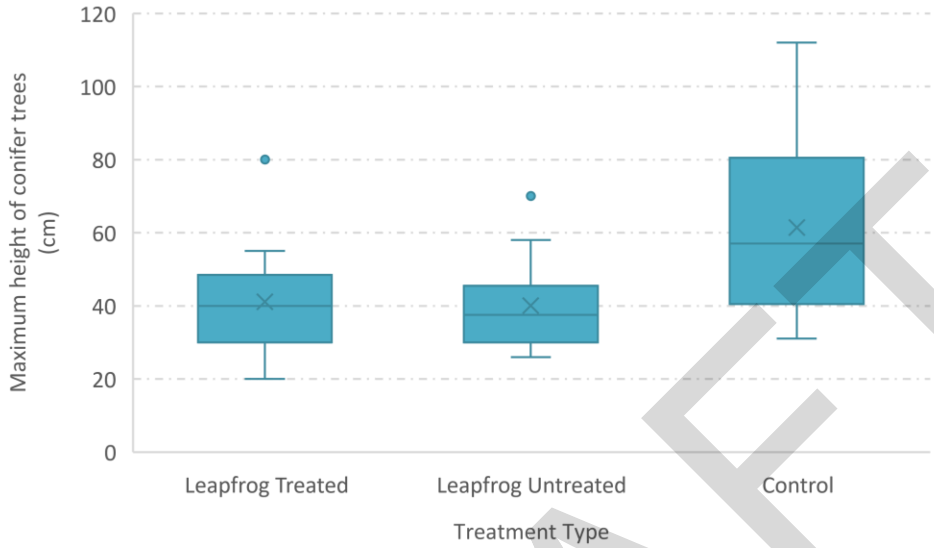


Figure 18. Maximum height of conifer trees by treatment type

Much like the results from the distance from the edge variable, the species richness does not seem to vary between treatment types (Figure 19).

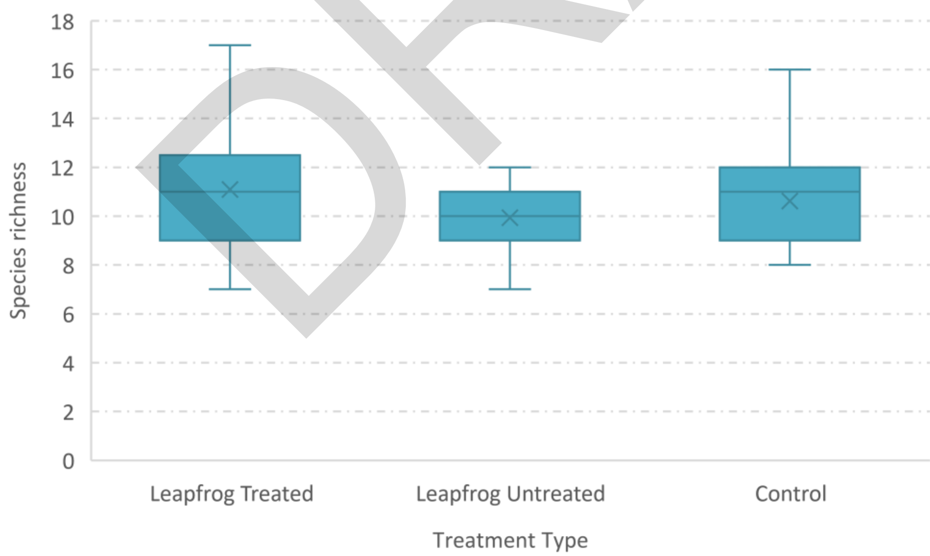


Figure 19. Species richness by treatment type

OTHER FACTORS INFLUENCING VEGETATION

Further analysis was conducted to help parse out some of the data and to identify other potential factors. Two ecosite types were noted in the plot surveys and both were found at least once in all treatment types and distance from the edge groupings. The variability in trees per hectare seems to indicate that although there are differences in the amounts of trees per hectare based on the ecosite type (bogs showing a higher average), this would likely not influence our observations about treatment type or distance from the edge (Figure 20).

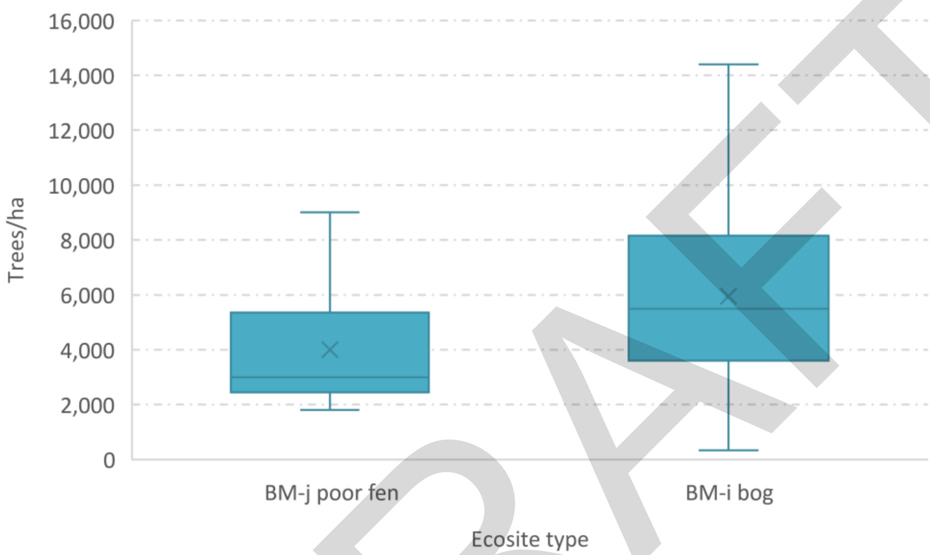


Figure 20. Total trees per hectare by ecosite type

We also wanted to see if adjacent stand heights influenced the results and affected observed trees per hectare across treatment types. Figure 21 shows no obvious trends in trees per hectare across treatment types with different adjacent tree heights (low, moderate, high).

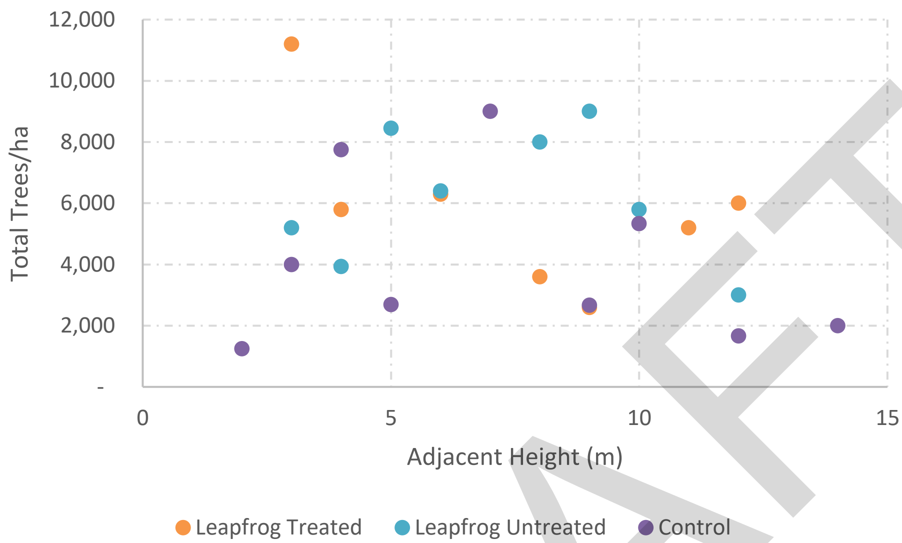


Figure 21. Total trees per hectare by treatment type and adjacent tree height

UAS SURVEY

To answer the research questions about vegetation response from the edge and the difference between treatment types, we looked several variables using the UAS and GIS derived data:

- Vegetation/ha
- Maximum height (m)
- Mean height (m)

To determine each of those variables is influenced on legacy seismic lines under different treatment conditions, several factors were considered:

- Distance from treatment edge
- Treatment type

Using the results from the UAS imagery and the GIS analysis, all the above variables and factors are considered to help answer the research questions. The distance from the treatment edge and the treatment type factors are directly linked to the research questions and as such are the focus of the analysis.

Analysis of the UAS data was conducted over several iterations. The data used for the final analysis removed height points at zero metres captured by the UAS and where vegetation with heights greater than two metres were removed. The zero-height data was removed because those data points could include objects that might not be vegetation such as water, rocks, coarse woody material, or other. Vegetation with heights greater than two metres was removed because on the ground surveys showed no growth above two metres on the seismic lines, there were vegetation points getting pulled in from the edges of the seismic lines.

DISTANCE FROM THE TREATMENT EDGE VEGETATION EFFECTS ON UNTREATED LEAPFROG LINE

Polygons were created for each of the treatment segments on the Leapfrog line. Each segment is roughly 100 m long. To increase the accuracy of the analysis, each of the treatment segments was divided into four segments of roughly 25 m in length. Those segments are then roughly between 0-25 metres or 25-50 metres from the edge of the treatment on either side. For example, in Figure 22 you can see treated segments in blue and untreated segments in yellow. One treatment and one untreated segment are left uncoloured to show imagery (mosaic RGB) of the treatment type.

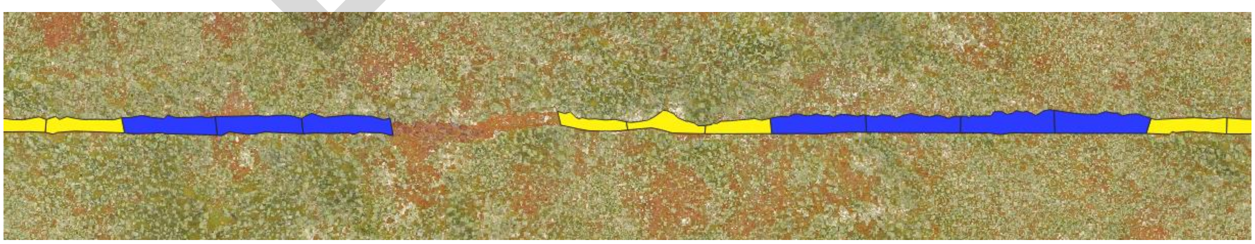


Figure 22. Image of Leapfrog line with colourized 25 m segments of treated (blue) and untreated (yellow)

The UAS and GIS derived data show similar results between segments closer to the treatment edge as those further away for mean height of vegetation (*Figure 23*). Given previous research on treatment edges we expect that in future years that areas closer to the edges will experience more growth, as seed dispersal becomes more prominent (Harper, et al., 2005).

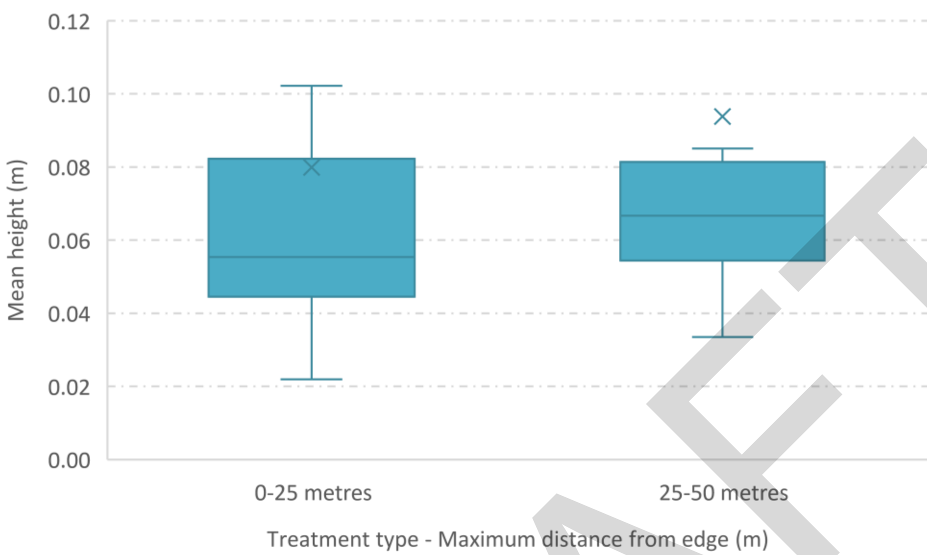


Figure 23. Mean height (m) of vegetation by maximum distance from treatment edge

The results between the segment types were not statistically significant. (*Figure 24*). Again, with more growth seasons worth of observations, we expect to see higher vegetation heights close to the treatment edge, especially when seed dispersal becomes more prevalent.

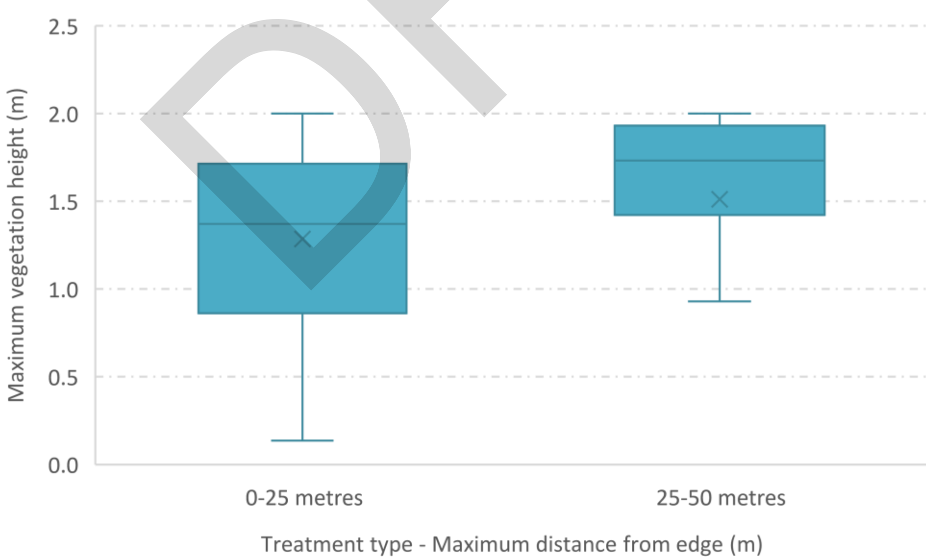


Figure 24. Maximum height (m) of vegetation by maximum distance from treatment edge

The vegetation count per hectare observations from the UAS and GIS analysis also shows no real difference between segments closer to the edge and those further from the edge (*Figure 25*).

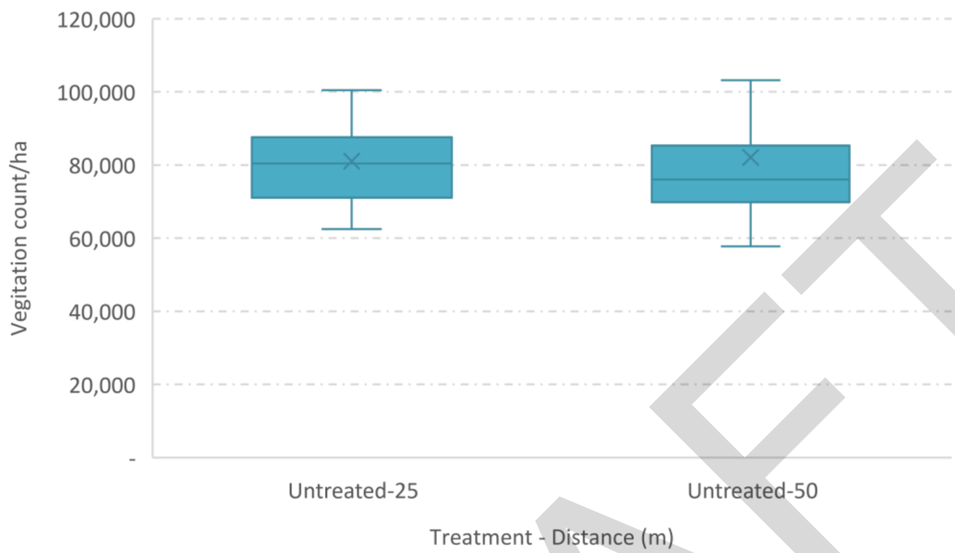


Figure 25. Vegetation count per hectare by maximum distance from treatment edge

TREATMENT TYPE EFFECTS

Using data collected by the UAS and analyzed by Silvacom, we were able to compare vegetation heights and counts for the different treatment types. We compare segments on the Leapfrog line that were treated, those on the Leapfrog line that were untreated, and the control lines. The average height of vegetation on treated portions of the Leapfrog line are higher than those on the untreated portions, which are higher than the average on the control lines (*Figure 26*).

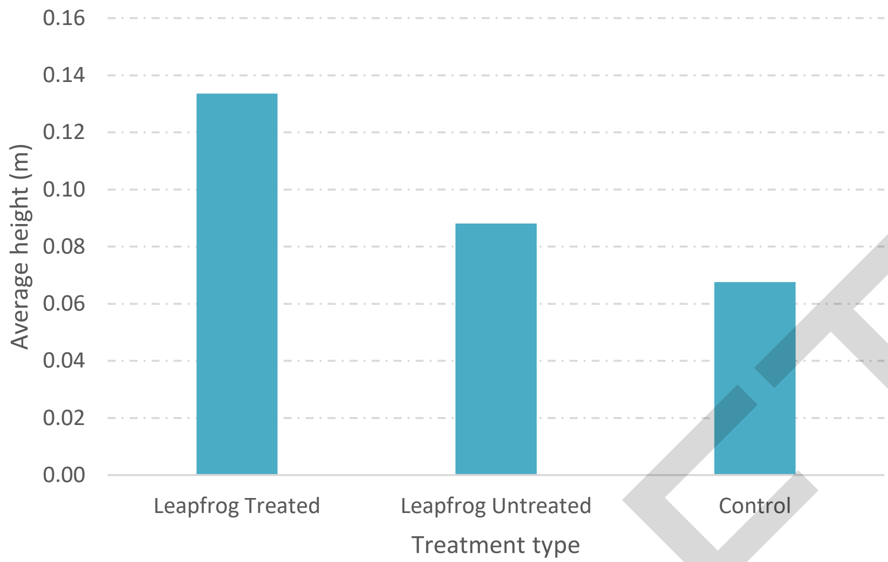


Figure 26. Average height of vegetation by treatment type

Average vegetation count per hectare shows the same trend as the average height did when comparing the treatment types. The portions of the Leapfrog line that were treated exhibit higher counts of vegetation than those on untreated portions which are higher than the control lines (*Figure 27*).

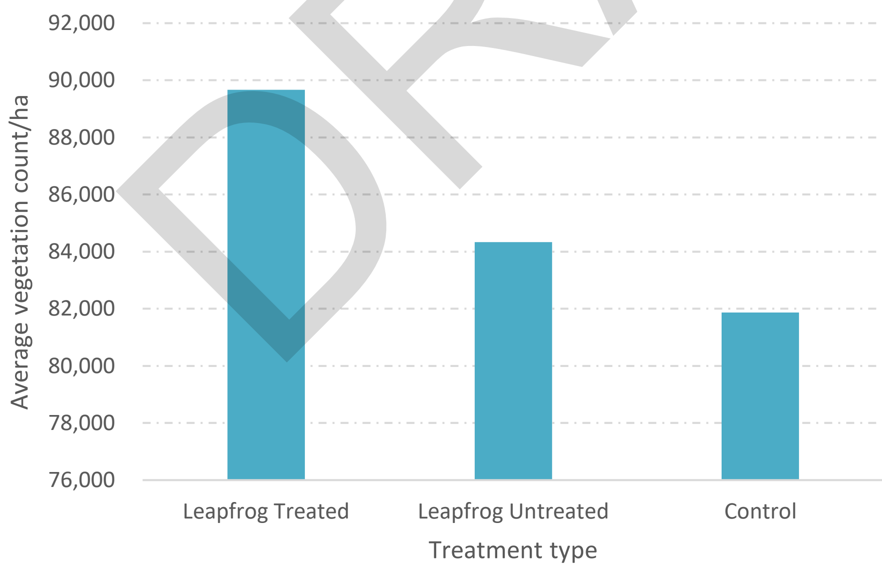


Figure 27. Average vegetation count per hectare by treatment type

DISCUSSION

VEGETATION RESPONSE MOVING AWAY FROM TREATMENT EDGE ON UNTREATED PORTIONS

Both the ground plot surveys and the UAS derived data provided results about the vegetation characteristics of the legacy seismic lines surveyed in the project. The plot surveys revealed a difference in the total trees per hectare on untreated portions of the Leapfrog line as the plots moved away from the treatment edge. Like the total number of trees, the maximum height of trees appears to decline as the distance from the edge gets larger. No difference in total species richness was seen during the field monitoring.

The UAS derived data on the other hand show similar results between segments closer to the treatment edge as those further away for mean height of vegetation. No statistically significant difference appears between the two segments when looking at maximum height of vegetation in those segments. The vegetation count per hectare observations from the UAS also shows no statistically significant difference between segments closer to the edge and those further from the edge.

The literature suggests effects on vegetation, soil process and structure, seed and pollen dispersal, and other processes on or near the edges of disturbance (Dabros, Hammond, Pinzon, Pinno, & Langor, 2017) (Harper, et al., 2005). Research on the effects of the type of edge (in between treated and untreated portions of a Leapfrog line) are not as well understood. However, based on the cited literature and the preliminary ground survey results, the vegetation response at the treatment edge appears to be present. Although this result is not statistically significant, the expectation is that as more growing seasons pass, the results will be more evident. With the advanced imagery products collected during the UAS survey, there is potential to further analyze the data looking at other factors and conditions.

VEGETATION RESPONSE DIFFERENCE BETWEEN TREATMENT TYPES

Plot survey data indicates that the number of trees per hectare appears to be higher in both treated and untreated portions of the Leapfrog line relative to the control lines. The maximum height of conifer trees appears to have the inverse relationship, where the control lines exhibit higher maximum heights than the Leapfrog plots. Much like the results from the distance from the edge variable, the species richness does not seem to vary between treatment types.

The UAS derived data indicates that the average height of vegetation on treated portions of the Leapfrog line are higher than those on the untreated portions, which are higher than the average on the control lines. Average vegetation count per hectare shows the same trend as the average height did when comparing the treatment types. The portions of the Leapfrog line that were treated exhibit higher counts of vegetation than those on untreated portions which are higher than the control lines.

Treated portions of the Leapfrog line exhibit more vegetation response than the untreated portions. The untreated portions of the Leapfrog line appear to exhibit higher vegetation response than the control lines.

USE OF UAS LINEAR RESTORATION SURVEYS

Ventus produced a number of products which helped the analysis for the project and provided additional context for the ground plot surveys. Imagery, like that derived from the Ventus UAS captured, could be achieved by airplanes, helicopters, or satelites, however, the cost associated with those technologies is prohibitive. This type of imagery allows for multiple growing seasons of potential data collection and creates an efficient opportunity to re-fly these areas. The technology lets us compare images and results in the future, get differentials in height over time, look at seedling health with the multispectral images and more. The *Provincial Restoration and Establishment Framework for Legacy Seismic Lines in Alberta* was designed to accommodate ground-based survival assessments and both ground-based and aerial establishment surveys (The Framework) (Government of Alberta, 2017). The Framework discusses establishement monitoring at years 2-5 post treatment and overall tree stocking, coverage, tree height and absence of human access trails at years 8-10 giving a long timeline of opportunities to conduct surveys and understand the trends associated with treatments. As the effects of the treatments become more evident and trees grow in, access will become more difficult and using UAS technologies will be beneficial to capture the required monitoring results.

Other opportunities exist to use the UAS imagery beyond the scope of this project. As an example, using the multi-spectral imagery, species identification and richness can be studied. This would provide more information about the treatment types, the distance from the edges of treatment, and offer more context to the overall results. Heights along the lines can be diluted because certain types of shrubs and forbs being captured by the UAV cameras. Some of that vegetation is not likely to grow much beyond current heights. Finding trees and shrubs that would be expected to grow taller is important in identifying restoration potential of the lines.

The following pages in this section are included to illustrate a few examples of the information and images provided by Ventus following their field operations.

Figure 28. Screen capture of the fly through of the Leapfrog line (1)

Figure 29. Screen capture of the fly through of the Leapfrog line (2)

Figure 30. Screen capture of the fly through of the control/research line (1)

Figure 31. Screen capture of the fly through of the control/research line (2)

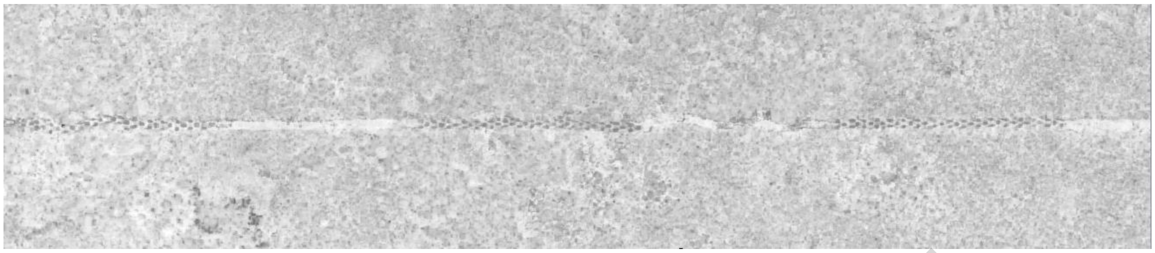


Figure 32. Normalized difference vegetation index (NDVI) image of Leapfrog line

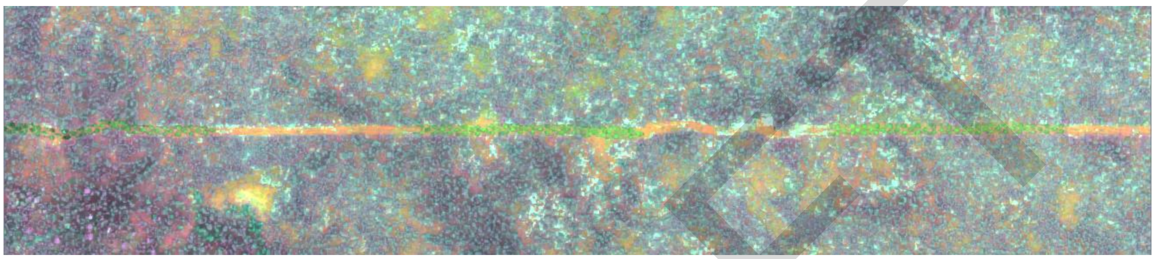


Figure 33. 4-band image of Leapfrog line

Figure 34. Mosaic Red-Green-Blue (RGB) image of Leapfrog line

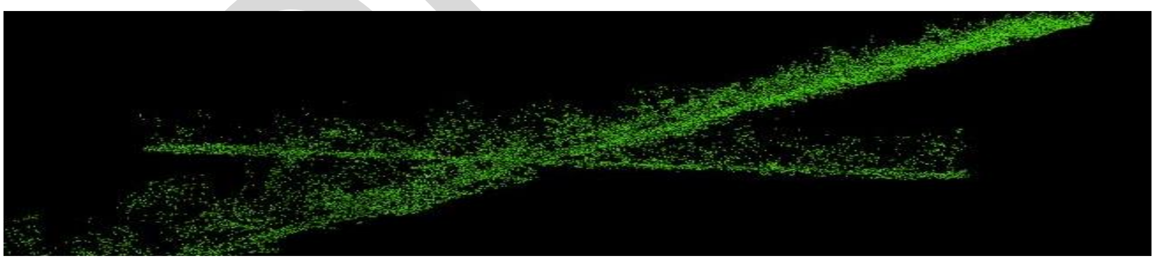


Figure 35. Point cloud of Leapfrog line

CONCLUSIONS AND RECOMMENDATIONS

The goal of this project is to address key knowledge gaps in the effectiveness of the Leapfrog linear restoration treatments in achieving restoration goals of caribou habitat restoration and reduced predation risk. This research will benefit both industry and government (who is embracing linear restoration as part of caribou range planning), as they seek innovative and cost-effective solutions for restoring caribou habitat. This report outlines two key questions to be answered with the field work and analysis for this project and they are as follows:

- Is there a vegetation response on the untreated portions of Leapfrog lines and how does it compare to non-treated/control lines?
- Is vegetation response different between untreated and treated segments of the Leapfrog line and is there reduction in the response further from treatment edge?

Preliminary results from this project indicate vegetative response on untreated portions of the Leapfrog line and that response appears to diminish as you move away from the edge of treatment. Furthermore, untreated portions of the Leapfrog line exhibit promising vegetation responses relative to areas left untreated. The Leapfrog treatment technique appears to help return the legacy seismic lines to a trajectory in line with the surrounding forest.

In order to further address knowledge gaps surrounding the Leapfrog technique, studies would need to occur in different areas of restoration, at larger scales, reviewing treatment segment lengths, and with more growing seasons worth of data. Extra research means implementing the Leapfrog restoration technique at other sites in order to study all these variables.

The UAS imagery and other products from Ventus provide additional context for the ground plot surveys and give more data to work with. UAS imagery improves the ability to monitor multiple growing seasons worth of data collection, creating an efficient opportunity to re-fly these areas. The technology allows us to compare images and results with more resolution at a more cost effective level. As trees grow in, access becomes more difficult and using UAS technologies will be beneficial to capture the required monitoring results. The ability to do targeted high-resolution samples is the most significant benefit from a UAS based survey.

Further to the UAS vegetation height and count potential illustrated in this report, there exist opportunities to analyze the imagery to look at species types and determine site vegetation richness. Additional results derived from that type of analysis could offer more context to results.

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 (Environment Canada , 2012) (Environment Canada, 2014). Pursuant to the objectives of the federal recovery strategies, the Government of Alberta released a Draft Provincial Woodland Caribou Range Plan (December 2017) (Government of Alberta, 2017) 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 (Government of Alberta, 2017).

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* (Government of Alberta, 2017). Using UAS in cmobination with ground plot surveys increases the resolution of the monitoring results and allows for more coverage of the treatment area.

With those goals in mind, having the most efficient techniques available will be necessary. The costs associated with legacy seismic line restoration are high and any opportunity to generate the desired outcomes while saving money should be pursued. Government approval would go a long way in securing a much more efficient means to an end for caribou habitat restoration.

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