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Boreal Caribou Habitat Restoration Monitoring Framework

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Executive Summary

Feedback received from stakeholders involved in existing and potential habitat restoration programs in Northeast British Columbia's (NE BC) boreal caribou ranges indicate there is a need for the development of a sampling design approach and monitoring protocol to enable consistent monitoring for restoration treatment effectiveness across the region. Currently there is no regulated system in place for monitoring or reporting of boreal caribou habitat restoration efforts. In collaboration with the BC Oil and Gas Research and Innovation Society (OGRIS), Golder Associates Ltd. (Golder) has developed this Boreal Caribou Habitat Restoration Monitoring Framework (the Framework) with the following objectives.

- To determine if restoration treatments are being implemented according to project requirements after one growing season.
- To provide a consistent approach to vegetation monitoring and monitoring protocols to enable the development of a regional dataset for tracking vegetation growth rates and / or the relative success of treatments at restoration treatment sites over time.
- To provide performance measures and recommended targets to determine if restoration treatments are meeting pre-determined recommended targets for native vegetation growth and access control after five, ten and fifteen year growing seasons.
- To provide guidance on monitoring timeline and frequency.
- To provide a regional monitoring framework that can be used to determine if restoration treatments are successful at accelerating the re-establishment of vegetation, that will in the long term achieve caribou habitat goals.

The Boreal Caribou Habitat Restoration Monitoring Framework describes the rationale and recommended protocols to monitor the effectiveness of boreal caribou habitat restoration treatments with consideration of both a Project-level scale and a NE BC restoration Program-level scale. Performance measures and recommended targets defined within the Framework are used to gauge the effectiveness of treatment measures applied over short term and long term periods.

Although recommendations are provided to support a rigorous monitoring program on the protocols and frequency of monitoring, reporting of results, and adaptive management approach, the reviewer is cautioned that these details are provided as a suggestion only based on previous restoration programs occurring outside of BC. The intended audience can use these recommendations in support of Project-level compliance monitoring or to understand restoration effectiveness at a broader spatial and temporal Program-level. The responsible authority should be contacted to clarify the use of these recommendations when a Project or Program-specific restoration monitoring plan is developed.

Study Limitations

Golder Associates Ltd. (Golder) has prepared this report in a manner consistent with the level of care and skill normally exercised by environmental professionals currently practicing under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this document. No warranty, expressed or implied, is made.

This report, including all text, data, tables, and figures contained herein, has been prepared by Golder for the exclusive use of the BC Oil and Gas Research and Innovation Society (OGRIS). It represents Golder's professional judgement based on the knowledge and information available at the time of completion.

This report is intended for boreal caribou habitat restoration monitoring on linear disturbances created by oil and gas development; reclamation monitoring for mining and forestry industries is beyond the current scope of the framework. It is anticipated that this document will be modified using an adaptive management approach as new information about habitat restoration techniques in boreal caribou ranges becomes available and changes to provincial and federal regulations are made.

Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. Golder accepts no responsibility for damages, if any suffered, by any third party as a result of decisions made or actions based on this report.

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1.0 INTRODUCTION

Boreal woodland caribou (*Rangifer tarandus caribou* pop. 14) is listed as 'Threatened' in Canada on Schedule 1 of the *Species at Risk Act* (SARA) (SARA 2015) and by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (COSEWIC 2015). In British Columbia (BC), boreal woodland caribou are listed as S2 ('Imperiled') by the BC Conservation Data Centre (CDC) and are on the provincial Red list (BC CDC 2015). The BC Conservation Framework ranks boreal woodland caribou as one of the highest conservation priorities (Conservation Framework Priority 1) under their goal to contribute to global efforts for species and ecosystem conservation (BC CDC 2015).

Boreal woodland caribou are the subject of recovery planning efforts underway by both the Province of BC and by the Government of Canada. The provincial *Implementation Plan for the Ongoing Management of Boreal Caribou (Rangifer tarandus caribou pop. 14) in British Columbia* was released in 2011 and outlined a plan to manage the size and impact of the industrial footprint (BC MoE 2011a). The federal *Recovery Strategy for the Woodland Caribou (Rangifer tarandus caribou), Boreal Population in Canada* (EC 2012) outlined that all boreal caribou populations are to be self-sustaining and have a minimum of 65% undisturbed habitat in their range (EC 2012).

To meet the undisturbed habitat target within boreal caribou ranges, the federal strategy (EC 2012) identifies coordinated actions to reclaim woodland caribou habitat as a step to meeting current and future caribou population objectives. Actions include restoring industrial landscape features such as roads, seismic lines, pipelines, cut-lines, and cleared areas in an effort to reduce landscape fragmentation and the changes in caribou population dynamics associated with changing predator-prey dynamics in highly fragmented landscapes.

Large-scale habitat restoration programs focused on linear features have yet to be initiated in northeast (NE) BC, but have been implemented in Alberta boreal caribou ranges since the mid-2000s (Golder 2012a). Monitoring of caribou habitat restoration programs to date has been voluntary, and results have mostly been shared through internal reports (Bentham and Coupal 2015). The Caribou Range Restoration Project, a quasi-formal committee established in Alberta in 2001 by the oil and gas industry and provincial government to focus on restoration of linear corridors in caribou ranges, produced an unpublished monitoring manual for collecting consistent revegetation data on linear corridors (CRRP 2007; Golder 2009). Other projects have voluntarily monitored the revegetation of linear features following the use of various restoration techniques (e.g., Golder 2010, 2012b; OSLI 2012a, 2012b; Nexen 2013) or have been required at a project scale to monitor under National Energy Board (NEB) regulations (e.g., NEB 2013a, 2013b, 2015; NGTL 2015). In addition, post-construction monitoring requirements have been included in BC provincial Environmental Assessment Certificates granted to several LNG pipelines operating in northern and mountain caribou ranges over the past two years (e.g., BC EAO 2014a, 2014b, 2014c).

As restoration plans are initiated in BC, a need has been identified to monitor the restoration implementation, as well as the effectiveness of restoration toolkit guidance (SCEK REMB Workshop 2014, pers. comm.). This framework is meant to provide a consistent approach to vegetation monitoring and monitoring protocols, to start to enable the development of a regional dataset for tracking vegetation growth rates and / or the relative success of treatments at restoration treatment sites over time. Performance measures are provided to be used to gauge the effectiveness of treatment measures expected over a 15 year period from implementation.

Although recommendations are provided to support a rigorous monitoring program through consistent protocol for data collection, frequency and timing of monitoring, reporting of results, and adaptive management approach, the reviewer is cautioned that these details are provided as a suggestion only based on previous restoration programs occurring outside of BC. The intended audience can use these recommendations in support of Project-level compliance monitoring or to understand restoration effectiveness at a broader spatial and temporal Program-level. The responsible authority should be contacted when a Project or Program-specific restoration monitoring plan is developed to clarify use of these recommendations.

1.1 Desired Outcome of Boreal Caribou Habitat Restoration

The focus of boreal caribou habitat restoration is to promote the timely re-establishment of native vegetation on disturbance features, while reducing or eliminating the benefits that linear disturbances provide to predators and their primary prey (Golder 2015a). The Canadian Association of Petroleum Producers (CAPP) defines functional restoration as “the outcome of a management action intended to mitigate one or more risks arising from an ecosystem disturbance. In contrast with ecological restoration, which aims to return an ecosystem to its pre-disturbance state, functional restoration takes a more targeted approach to disrupting particular ecological pathways, recognizing that achieving a pre-disturbance state may not be practicable in all cases (e.g., long recovery times that generate additional risk to important values, irreparable changes to processes, prohibitive costs)” (Wilson 2015).

The objective and end result of restoration and reclamation differ. Reclamation is defined by the BC Oil and Gas Commission (OGC) as “the process of restoring the surface area of a decommissioned wellsite, access road, and related facilities to pre-operational conditions as is technically and economically feasible” (BC OGC 2011). The objective of reclamation is to recover an area to a condition that is appropriate to surrounding land uses and conditions, not necessarily to mimic the pre-development conditions (Bowman and Baker 1998). Conversely, restoration is “the process of assisting with the recovery of an ecosystem that has been degraded, damaged or destroyed by re-establishing its structural characteristics, species composition, and ecological processes” (BC MoFLNRO 2015a). The intent of restoration is to recreate the conditions that existed prior to disturbance (Bowman and Baker 1998).

The desired outcome of boreal caribou habitat restoration is to create a restored landscape, where disturbed caribou range is returned to functional habitat that can support self-sustaining caribou populations. To achieve this desired outcome there are three, non-independent objectives of caribou habitat restoration:

1) controlling access into caribou habitat by humans and predators;

2) accelerating the rate of recovery of native vegetation; and

3) over the long term, providing habitat that supports the life processes of caribou populations and is used by caribou equally as much as undisturbed areas.

Reducing human and predator access and directly restoring caribou habitat are currently implemented using a variety of restoration treatment methods as outlined within the *Boreal Caribou Habitat Restoration Operational Toolkit for British Columbia* (Golder 2015a). These treatment methods include tree-felling/bending, site preparation techniques such as mounding, spreading of woody materials, and seedling planting. However, uncertainties exist on the effectiveness of the prescribed restoration treatment methods that require testing. To address these uncertainties, this restoration monitoring framework has been developed to test assumptions around whether the restoration toolkit guidance is leading to effective restoration, with restoration considered effective when the treatment program has succeeded in meeting the objectives of controlling access into caribou habitat by humans and predators, and accelerating the rate of recovery of native vegetation communities.

The following restoration effectiveness questions address the uncertainties which require testing as part of monitoring for restoration treatments.

Q1 Do restoration treatments accelerate native vegetation recovery?

a) Controlling for age, are trees (or woody vegetation) on treated sites taller compared to trees within natural vegetation re-establishment linear disturbance sites?

b) Controlling for age, do treated sites have a higher stem density of trees compared to trees within natural vegetation re-establishment linear disturbance sites?

c) Controlling for age, is vegetation cover greater on treated sites compared to natural vegetation re-establishment linear disturbance sites?

Q2 When applying access control measures, does treating a disturbed site reduce the probability of off-road vehicular use of a newly disturbed line?

Q3 When applying access control measures, does treating a disturbed site reduce the probability that a game trail becomes established along a newly disturbed line?

Q4 When controlling for site conditions and tree species, how does vegetation leader growth and tree height respond to each restoration treatment prescription as outlined within the Restoration Toolkit (Golder 2015a)?

Q5 Do restoration treatment areas provide habitat that is used by caribou, or provide areas around linear disturbances with increased caribou use relative to pre-treatment?

Q6 As restoration treatment areas increase in vegetation height and cover, are these treatment areas used less over time by predators (wolf, bear) and alternate prey species (deer, moose)?

Q7 On a large scale (caribou range), are Project-level restoration efforts cumulatively contributing towards increased functional caribou habitat?

Q8 Are restoration programs worth the financial investment or is natural revegetation just as effective over time at achieving increased functional caribou habitat?

The Boreal Caribou Habitat Restoration Monitoring Framework (hereafter Monitoring Framework) is intended to promote a consistent approach to the monitoring of restoration treatments along linear disturbances in NE BC in an effort to answer the above questions Q1 to Q4. To achieve this, the Monitoring Framework is laid out to provide consistent protocols for vegetation monitoring methods, data collection, timelines, and recommended targets. Validation monitoring is required to address Q5 to Q8. To achieve validation monitoring in the context of caribou habitat restoration there will be a required assessment of wildlife responses to habitat restoration. Assessing wildlife responses is outside of the scope for this Monitoring Framework as this assessment requires a separate study design. However, this Monitoring Framework guidance on vegetation response and the results of restoration effectiveness monitoring can be used in combination with wildlife monitoring data, to determine if the desired outcome for caribou habitat restoration is achieved (Figure 1).

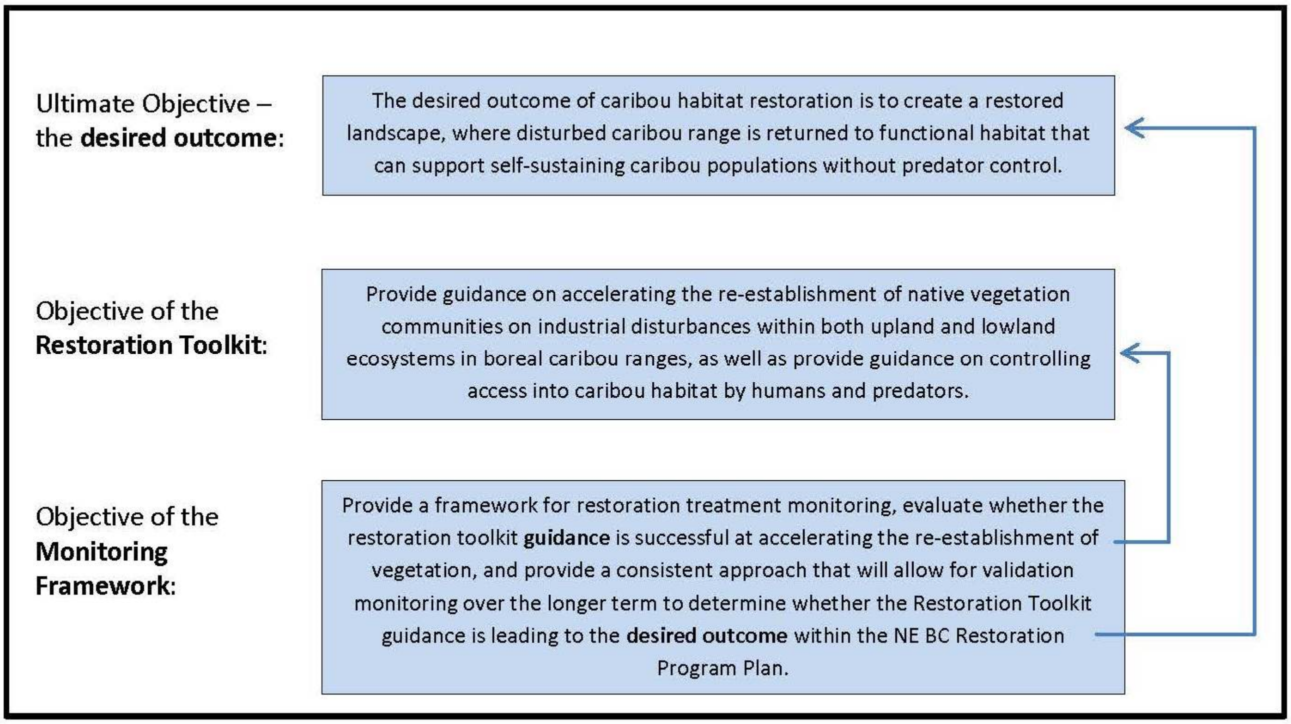

Figure 1: Desired Outcome of Caribou Habitat Restoration, the Restoration Toolkit, and the Restoration Monitoring Framework.

2.0 HABITAT RESTORATION MONITORING

Monitoring has been defined as the "measurement of environmental characteristics over an extended period of time to determine status or trends in some aspect of environmental quality" (Suter 1993, pg. 505). Monitoring habitat restoration treatments and programs can be considered the "feedback loop" to ensure compliance to the commitments made by proponents, to measure effectiveness of restoration treatments, to measure and detect long-term environmental changes, and to help decision-makers check on their assumptions and assess whether observed changes dictate a change in process or policy (McWilliams 2002; Noon 2003).

For the purposes of habitat restoration, monitoring can be separated into three categories (McWilliams 2002; Woodward and Hollar 2011):

- Compliance Monitoring: to determine if the steps of a restoration program are being implemented according to the requirements of permit conditions (by a proponent to report to a responsible authority);
- Effectiveness Monitoring: to determine if the restoration treatments are having the desired increased rate of response in native vegetation growth (height and vegetation cover) and access control; and
- Validation Monitoring: to determine if assumptions underlying habitat restoration are accurate and leading to the desired habitat objectives for boreal woodland caribou.

Within this Monitoring Framework, it is anticipated that monitoring will be completed at two levels; the Project level and the Program level. Project-level restoration monitoring is suggested to fulfill compliance monitoring on a project by project basis. Program-level restoration monitoring will require the use and analysis of data collected from cumulative Project-level monitoring programs over a broad spatial and temporal scale to determine restoration treatment effectiveness. Monitoring data collected under the guidance of this Monitoring Framework could be used in combination with wildlife monitoring data to cover validation monitoring (Table 1). Validation monitoring is necessary to determine if restoration treatments are meeting the desired outcome of habitat restoration.

Table 1: Objectives of Caribou Habitat Restoration Monitoring at the Project and Program levels

	Monitoring Category	Objective[1]
Project-level	Compliance	To determine if restoration treatments are being implemented according to project requirements after one and up to five growing seasons.
Program-level	Effectiveness	To determine if restoration treatments are meeting pre-determined recommended targets for native vegetation growth and access control after five, ten and fifteen year growing seasons.
Program-level + Wildlife monitoring[1]	Validation	To determine if restoration treatments are accelerating the natural revegetation process by providing habitat that can support self-sustaining caribou populations without predator control, thereby making the Program restoration treatments worthwhile to achieve caribou habitat goals.[1]

1 The Monitoring Framework is focused on monitoring both planted and natural ingress of native vegetation response to restoration treatments, not wildlife response to restoration treatments. A wildlife monitoring study design is beyond the scope of this Monitoring Framework. Concurrent wildlife monitoring should be on-going during habitat restoration programs to address Validation Monitoring Q5 to Q8.

To meet the objectives of the Monitoring Framework for compliance and effectiveness monitoring (Table 1), the Monitoring Framework provides the following:

- recommended targets for vegetation performance following the 1st, 5th, 10th and 15th growing seasons (Section 2.2) to assess the establishment of vegetation and the effectiveness of restoration treatments versus paired reference (naturally re-establishing) sites (Section 3 and 4);
- a consistent approach to vegetation monitoring to enable the development of a regional dataset for effectiveness testing of restoration treatments on vegetation growth rates and / or the relative success of treatments at restoration treatment sites at a NE BC Program Level (Section 4); and
- guidance on monitoring timeline and frequency (Section 3.6 and 4.2).

2.1 Quantifying Restoration Success

The BC Ministry of Forests recommends a minimum of five growing seasons elapse after seedling establishment in a BWBS zone prior to completing a free growing assessment (BC MoF 2000), with a 'free growing stand' defined in the Forest and Range Practices Act as "a stand of healthy trees of a commercially valuable species, the growth of which is not impeded by competition from plants, shrubs, or other trees" (BC MoFLNRO 2015b, pg. 32). Although the revegetation of linear disturbances (both treated and with natural revegetation recovery) within caribou habitat can occur on sites that previously contained non-commercially valuable species, the principle should remain the same. As such, identifying performance measures with quantifiable targets for restoration success have considered consistency with the number of trees in natural vegetation communities with considerations of site differences between the moisture and nutrient regimes within upland, treed-lowland and transitional sites, as well as results from west-central Alberta on restoration monitoring 9 to 13 years post treatment (Golder 2015b). As linear disturbances vary in their light levels, type of disturbance and soil conditions, forestry cutblock regeneration standards have not been used.

Performance measures and recommended targets have been grouped by restoration units based on moisture characteristics. The "Upland" site type was restricted to moisture regimes ranging from submesic to xeric, "Transitional" site type are mesic moisture regimes, and the "Lowland" site type was restricted to moisture regimes ranging from subhygric to subhydric, including treed bogs and fens. Targets are not provided for non-treed wetlands, as non-treed wetlands are not currently a focus for caribou habitat restoration treatments.

The Monitoring Framework is intended to provide guidance on targets that should be achieved throughout a restoration program, and is focused on ensuring a treated area has native vegetation growth that exceeds the rate of natural native vegetation recovery; as well as meeting access control targets. Recommended targets are provided for the first and fifth growing seasons (Table 2) to ensure the restoration treatments are functioning in the desired manner to meet compliance and in the short term provide an indication that native vegetation is establishing and growing. Recommended targets are provided for the 10th and 15th growing seasons (Table 3) to assess if restoration treatments are more effective than natural revegetation and if they are starting to lead to ecosystem characteristics similar to adjacent stands.

However, a high degree of variability is expected for different sites and tree species to demonstrate a trajectory towards achieving the recommended performance measures. When quantifying success, consideration must be made for the treatment design and variable site characteristics, with results stratified accordingly. Variability stems primarily from the following characteristics:

- type, width, orientation, and age of disturbance;
- Biogeoclimatic Ecosystem Classification (BEC) zone and site series;
- depth to water table (van Rensen et al., 2015);
- nutrients;
- seedling species planted;
- site preparation;
- planting techniques;
- on-going natural disturbances (e.g. snow and wildfire); and
- on-going human disturbances and level of soil compaction.

2.2 Recommended Performance Measures

Recommended performance measures are used to determine whether restoration treatments are on track to meet the objectives for restoration, and are provided for the first 15 year period following treatment implementation. Habitat restoration will be evaluated based on absolute measures of restoration treatment performance of vegetation at treatment plots and the performance of access control measures. Tables 2 and 3 provide recommended indicators and target values by restoration unit for the first five year period after restoration treatments have been implemented (Table 2), and for longer-term monitoring at years 10 and 15 (Table 3). Recommended targets have been identified for particular variables because there are many factors that influence the ability for revegetation to occur, both known (e.g. slope, aspect, moisture and nutrient regimes, light availability (van Rensen et al. 2015) and unknown (e.g. unpredictable weather events). These targets are preliminary, based on literature and information available from restoration studies in other regions (e.g., Golder 2015b, NGTL 2014). Performance indicators and recommended targets for longer-term monitoring (10 years and greater) should be compared to adjacent undisturbed stands to assess the relative response of the treatment, while considering stand type as a function of age since disturbance (e.g., black spruce seedling growth should be compared to black spruce stands, lodgepole pine seedling growth should be compared to lodgepole pine stands). As restoration is implemented and monitoring data is evaluated from restoration projects in NE BC, these targets should be revisited. Statistical inferences can be made using the standard metrics when treatment plots are compared to paired reference plots on the same linear disturbance with similar factors (occur within the same restoration unit, time since disturbance, type of disturbance, depth to water, access) influencing the ability for revegetation to occur.

To meet vegetation re-establishment objectives, vegetation on disturbances should mimic the adjacent stand type in community composition. The following indicators are used to assess revegetation progress:

- density of targeted tree species including planted seedlings and natural seedling ingress;

- percent cover of targeted tree species;
- leader growth by tree species;
- growth and vigour of targeted vegetation including seedlings; and
- presence of invasive / non-native plant species, as a measure of competition.

The following recommended targets are used to assess access control:

- presence and level of ATV tracks; and
- presence and level of game trails.

An additional metric to monitor effectiveness of restoration treatments is line-of-sight (Table 3). Line-of-sight management is typically required to be implemented every 200 to 500 m on linear features to decrease caribou visibility to predators, thereby increasing the effectiveness of a restoration treatment by limiting potential predation (BC MoE 2011b; BC MoFLNRO 2013a, 2013b). The recommended target used to assess line-of-sight management will be percent cover of vegetation screens, measured using a Robel pole.

Table 2: Recommended Evaluation Criteria, Indicators and Targets for 1st and 5th Growing Seasons

Restoration Objective	Restoration Unit	Evaluation Criteria	Indicator	1st Growing Season [1]	5th Growing Season[1]
Vegetation Establishment	Upland and Transitional	• Density of live seedlings (stems/ha) of planted seedlings and naturally regenerating seedlings (i.e., from seed ingress or suckering) • Percent cover of live seedlings • Vigour of live seedlings • Vegetation community composition including percent cover and species present: • Conifer • Deciduous tree • Palatable shrub • Non-palatable shrub • Herb/graminoid • Non-vascular (mosses and lichens) • Introduced (non-native, weed, invasive	% of surviving planted or naturally re-established seedlings	At least 70% of seedlings/ ha surviving (when seedlings planted in winter[2, 3, 4]); at least 90% of seedlings/ha surviving (when seedlings planted in summer [4, 5]) *Identify any immediate issues such as seedling mortality due to poor seedling stock or desiccation; poor seed germination, and improperly placed or spread access control treatment implementation*	At least 50% of seedlings/ha surviving. Tree seedlings (planted and/or natural regeneration) demonstrate sustained growth trends (seedling height and leader growth) between 1st and 5th monitoring periods.
			Percent cover of targeted vegetation (conifer)	> 80% of surviving seedlings in treatment plot are considered well spaced. [6] *Identify any immediate issues with invasive species*	> 80% of surviving seedlings in treatment plot are considered well spaced.[6] Treatment and reference plots mimic adjacent stand type in community composition.[7]
			Evidence of chlorosis	No evidence of chlorosis *Identify any immediate issues such as seedling color or freeze desiccation*	No evidence of chlorosis.
			Density of targeted vegetation	Target of 1,200 stems/ha, with minimum 840 stems/ha from winter planting and 1080 stems/ha for summer planting (based on 70% and 90% survival, respectively) [8, 9]	Live seedling density of 1600-2,000 stems/ha (combined planted seedlings and/or natural regeneration) on sites not mounded. Live seedling density of 800-1,400 stems/ha (combined planted seedlings and /or natural regeneration) on mounded sites (dependent on mound density).[8]

Restoration Objective	Restoration Unit	Evaluation Criteria	Indicator	1st Growing Season [1]	5th Growing Season[1]
	Lowland-Treed	• Density of live seedlings (stems/ha) of planted seedlings and naturally regenerating seedlings (i.e., from seed ingress or suckering) • Percent cover of live seedlings • Vigour of live seedlings • Vegetation community composition, including percent cover and species present: • Conifer • Deciduous tree • Palatable shrub • Non-palatable shrub • Herb/graminoid • Non-vascular (mosses and lichens) • Introduced (non-native, weed, invasive	% of surviving planted or naturally re-established seedlings	At least 70% of seedlings/ ha surviving (when seedlings planted in winter[2, 3, 4]); at least 90% of seedlings/ha surviving (when seedlings planted in summer [4, 5]) *Identify any immediate issues such as seedling mortality due to poor seedling stock or desiccation; poor seed germination, and improperly placed or spread access control treatment implementation*	At least 50% of seedlings/ha surviving. Tree seedlings (planted and/or natural regeneration) demonstrate sustained growth trends (seedling height and leader growth) between 1st and 5th monitoring periods.
			Percent cover of targeted vegetation (conifer)	> 80% of surviving seedlings in treatment plot are considered well spaced [6] *Identify any immediate issues with invasive species*	Natural vegetation is regenerating, including at least 2 characteristic species (vascular and/or non-vascular; e.g., *Carex* sp. and Spagnum moss sp.)[10] as indicators of healthy vegetation treed-lowland community. No restricted weeds or invasive species such as cattails or reed grass.[9] > 80% of surviving seedlings in treatment plot are considered well spaced.[6]
			Evidence of chlorosis	No evidence of chlorosis	No evidence of chlorosis.
			Density of targeted vegetation	Target of 1,200 stems/ha, with minimum 840 stems/ha from winter planting project and 1080 stems/ha for summer planting projects (based on 70% and 90% survival, respectively) [8, 9]	Minimum 2,000 stems/ha (due to both planted and natural ingress).[8]

Restoration Objective	Restoration Unit	Evaluation Criteria	Indicator	1st Growing Season [1]	5th Growing Season[1]
Access Control	All	Evidence and level of vehicular use will be measured using subjective criteria ratings for evidence of access, type of access, and level of access[9]	Evidence of access: • yes/no Motorized access type: • ATV • truck • other Access level: • absent • low (tracks/ trail evident but difficult to discern or appear to be infrequently used) • high (tracks/ trails appear to be well used; vegetation is trampled down; bare ground may be visible from frequent use)	Access controls demonstrate human access along the linear disturbance is prevented and/or limited to low levels. No evidence of motorized access where access control measures are installed.	Access controls demonstrate human access along the linear disturbance is prevented and/or limited to low levels within 5 years following treatment. No evidence of motorized access where access control measures are installed. In areas where high human use was/is evident at 1st growing season, is rated absent or low at 5th growing season. Success of habitat restoration targets, specifically sustained growth trends, is a good indicator that human access is not inhibiting habitat restoration.

1 Note that this is average targets, and results will vary by site variability and treatment type.
2 Cenovus 2013
3 MEG 2014
4 Golder 2015b
5 Golder 2012c
6 The “well spaced” measurement is used to determine the consistency of regeneration of tree seedlings on a site. For example, target species are considered “well spaced” if they are present approximately every 2 m at a density of 2500 stems/ha. Distance between 'well-spaced' seedlings is directly related to the target density which can vary by vegetation community. See Diagram 2 in Golder 2015a for an example illustrating well-spaced seedlings on a restoration treatment plot.
7 “mimic” = species composition and structure are similar to the adjacent undisturbed vegetation community, with consideration of stand age on the disturbance versus stand age and subsequent structure within the adjacent stand.
8 Golder 2015a
9 OSLI 2012a
10 NGTL 2014

Table 3: Recommended Indicators and Targets for 10th and 15th Growing Seasons

Restoration Objective	Restoration Unit	Indicator	10th Growing Season [1]	15th Growing Season[1]
Vegetation Establishment	Upland and Transitional	Percent cover of targeted vegetation[2]	Should mimic[3] the naturally revegetating reference plots in percent cover and species composition.	Should mimic[3] the adjacent undisturbed stand type in density, percent cover, and species composition.
		Density of targeted vegetation[2]	Should mimic[3] the naturally revegetating reference plots in density and species composition.	Should mimic[3] the adjacent undisturbed stand type in species composition. Controlling for age, treated plots expected to have higher stem density of trees compared to naturally revegetating reference plots.
		Height and leader growth of targeted vegetation[2]	Evidence of consistent height growth, significantly greater than the height growth pattern of tree species on reference plots.[4] Mean height of planted tree species should be at or approaching 50 cm, with height of natural ingress targeted vegetation of 18 cm.[4] Leader growth on planted trees at or approaching 4 cm.[4] Leader growth on natural ingress targeted vegetation approaching 3 cm.[4]	Evidence of consistent height growth to mimic[3] height growth pattern and tree species on adjacent undisturbed stand type. Treated plots should be at or approaching 1.5 m heights, depending on tree species, as compared to upland naturally revegetating reference plots which are expected to reach 1 m height.[4]
	Lowland-Treed	Density of targeted vegetation[2]	Should mimic[3] the naturally revegetating reference plots in percent cover, density, and species composition.	Should mimic[3] the adjacent undisturbed stand type in percent cover, density, and species composition. Controlling for age, treated plots expected to have higher stem density of trees compared to naturally revegetating reference plots.
		Height and leader growth of targeted vegetation[2]	Evidence of consistent height and leader growth, significantly greater than the height growth pattern of tree species on reference plots. [4] Mean height of planted tree species should be at or approaching 50 cm, with height of natural ingress targeted vegetation of 18 cm.[4] Leader growth on planted trees at or approaching 6 cm.[4] Leader growth on natural ingress targeted vegetation	Evidence of consistent height growth to mimic[3] height growth pattern of tree species in adjacent undisturbed stand. Treated plots should be at or approaching 1.4 m heights, depending on tree species, as compared to lowland naturally revegetating reference plots which are expected to reach 1 m height.[4]

Restoration Objective	Restoration Unit	Indicator	10th Growing Season [1]	15th Growing Season[1]
			approaching 3 cm.[4]	
Access Control	All		Less than 50% of treatment plots have human and predator access (based on evidence of a trail) as compared to reference plots.[4]	Less than 35% of treatment plots have human and predator access (based on evidence of a trail) as compared to reference plots. [4]
Line of Sight	All		Limited to < 500 m along linear disturbance.[5]	Limited to < 500 m along linear disturbance. [5]

1 Note that this is average targets, and results will vary by site and by tree species, with targets on upland and lowland seedling (planted and natural ingress) height and leader growth based on actual data at 10 years and trajectories built from the Little Smoky 9-13 year post restoration treatment monitoring study (Golder 2015b)

2 Note that “targeted vegetation” is focused on native trees and shrubs to address restoration objective of providing caribou habitat in the long term and reducing predator access and line of sight on linear features in the near term.

3 “mimic” = species composition and structure are similar to the adjacent undisturbed vegetation community, with consideration of stand age on the disturbance versus stand age and subsequent structure within the adjacent stand. For example, dominant and subdominant tree species should be similar between the treatment plot and the adjacent undisturbed vegetation – community.

4 Golder 2015b

5 BC MoE 2011b

3.0 HABITAT RESTORATION MONITORING: PROJECT LEVEL

3.1 Project-level Restoration Monitoring Objectives

Project-level restoration monitoring is recommended to fulfill compliance monitoring on a project by project basis. Monitoring would occur on treatment plots with paired reference plots. Data collected at treatment plots is compared to recommended targets in the short term (up to year 5 post treatment, and/or depending on permit conditions in consultation with the responsible authority), while data collected at both treatment and paired reference plots would be used to support effectiveness monitoring analyses at the broader spatial and temporal (10 and 15 years post treatment) scale within Program-level monitoring (Section 4.0).

Project-level restoration monitoring collects and analyzes indicator data to specifically compare the characteristics of a treated area to the recommended targets described in Table 2. The objective of Project-level monitoring is two-fold:

1) allows the responsible authority to confirm that restoration treatments have been implemented and to assess the establishment of vegetation as required under permit conditions (compliance monitoring); and

2) allows the proponent and responsible authority to compare planted vegetation at treatment plots to naturally established native vegetation at paired reference plots [located along the same disturbance and within the same restoration unit] in the short term to inform remedial actions.

The outcomes of Project-level restoration monitoring are that permit conditions for restoration treatments and monitoring are met, and confirmation is made that vegetation (both natural ingress of species plus any planting treatments) on disturbed sites is growing.

3.2 Sampling Design

Each Project-level monitoring plan needs to monitor a representative percentage of restoration treatment area, using a paired design of treatment and reference plots. Treatment plots are the sampling sites designated to be monitored, established at specific locations within a treated area. Reference plots are the sampling sites designated to be monitored within a paired design to treatment plots to compare the vegetation re-establishment and trajectories between treated and natural ingress areas. Reference plots should be established on untreated gaps of linear disturbances in a restoration project area (refer to Figure 3). To account for type of disturbance, width, orientation, and age of disturbance, treatment plots should be paired with a reference plot on the same linear disturbance. To account for site type variability in biogeoclimatic zone and site series, treated and reference plot comparisons should be restricted to a particular site series unit to reduce the amount of variability in the data that could be attributed to differing vegetation growth patterns. To account for variability in site characteristics and for the purposes of monitoring, three 'restoration units' will be used to group site series into upland, treed lowland or transitional (Appendix A).

3.2.1 Number of Monitoring Plots

The number of monitoring plots to be established for a particular project's restoration plan should be determined in consultation between the proponent and the responsible authority, with a recommendation of one paired plot per linear kilometer of treatment. The number of plots established should consider the size of the restoration project, the number of BEC zone or subzones within the treated area, the number of restoration units, and the number of restoration treatment types implemented. Plots should be established for each treatment type (e.g., mounding with planting, tree-felling, plant with no site preparation, etc.), and equally distributed within each restoration unit (upland, transitional and lowland).

3.2.2 Selection of Plot Location

The location of restoration monitoring plots should be determined by reviewing the restoration area. Using a Geographic Information System (GIS), a systematic plot design should be developed, meeting the project specific requirement for number of plots. If there is more than one BEC zone or subzone in the treated area, plot numbers should be equally distributed by percentage of length or disturbance area in each BEC zone or subzone. Plots should be a minimum of 500 m apart. Multiple plots can be established on the same disturbance feature if, for example, treatment is only occurring every 500 m. For every restoration treatment plot, a reference plot will need to be established on the same linear disturbance (controlling for type of disturbance, time since disturbance, width, orientation), within the same BEC zone or subzone, and the same restoration unit (upland, lowland, transitional). Field crews should conduct a preliminary fly-over of selected sites to assess access for field visits, and revise the monitoring plot locations as required.

3.2.3 Plot Establishment

Monitoring plots should be established at the time of restoration treatment implementation, within treatment areas at least 25 m in length along a linear disturbance. Monitoring plots can either be a singular 3.99 m radii circular plots (approximately 50 m^2) for linear disturbances > 8 m wide (Figure 2a) or a monitoring plot can be comprised of three subplots of 1.78 m fixed radii circular plots (10 m^2 each) located off centre line within a 25 m length of linear disturbance < 8 m in width (Figure 2b) (OSLI 2012b; BC MoFLNRO 2015b). For treatment sites that have been site-prepped with mounding, an average of 6 mounds should be captured within the singular plot, or between the three subplots, to ensure an adequate number of trees to monitor are captured. The center of each vegetation monitoring plot should be marked with 1.5 m height PVC pipe (approximately 1 " diameter) and a wooden stake. An aluminum tag affixed to the wooden stake should include the plot name and number, date of establishment, company name, and crew initials (Pickard et al. 2013). Planted seedlings should be flagged or marked for identification for long term monitoring (Golder 2015b). Each monitoring plot will consist of both a treated plot and a paired reference (disturbed) plot along the same linear disturbance, within the same restoration unit (Figure 3).

A 30 - 50 cm soil pit will be established on the disturbed portion of the line, 2 - 5 m from the boundary of the treatment monitoring plot. Two BEC zone field calls will be made for the adjacent stands, at least 15 m away from each side of the treatment monitoring plot edge (Figures 2a and 2b).

An equivalent number of reference plots, as paired plots to treatment plots, should be established by the proponent following the same methods as the treatment plots. Reference plots should be established on untreated sections of a treated line within the same restoration unit as the treated plot (Figure 3).

Standardized plot information is to be collected at the time of plot establishment, and recorded on the Plot Establishment Datasheet (Appendix B) at each monitoring treatment and paired reference plot. A diagram illustrating the placement of the vegetation monitoring treatment and reference plots relative to the linear disturbance feature and other significant landmarks should be drawn on the datasheet.

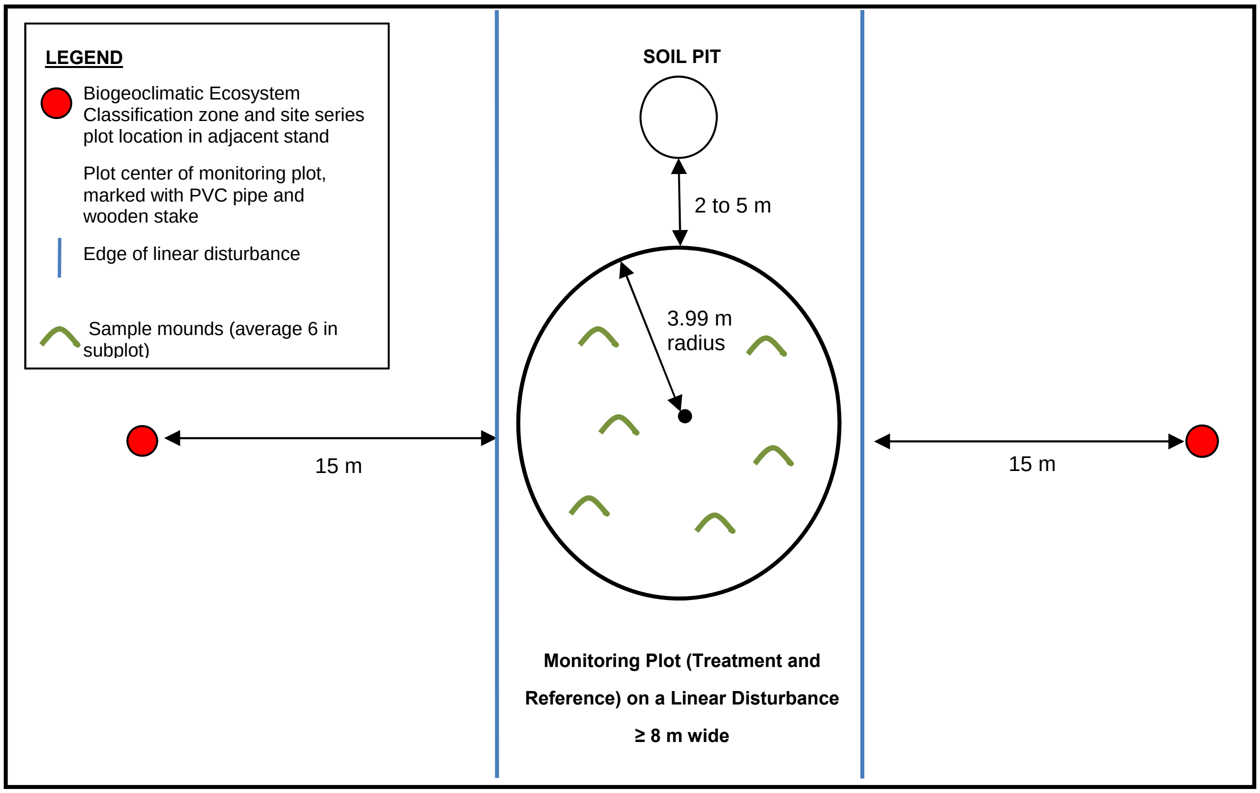

Figure 2A: Restoration Monitoring Sample Plot Layout on Linear Disturbances > 8 m wide

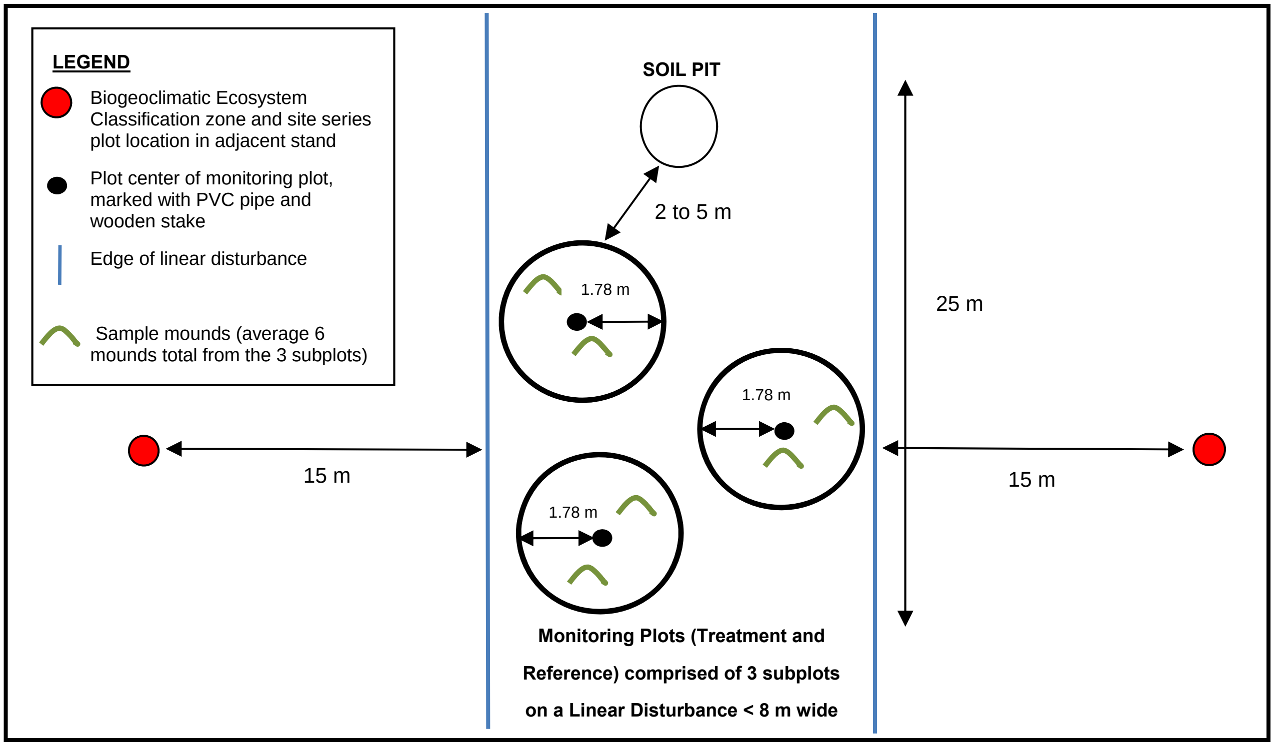

Figure 2B: Restoration Monitoring Sample Plot Layout on Linear Disturbances < 8 m wide

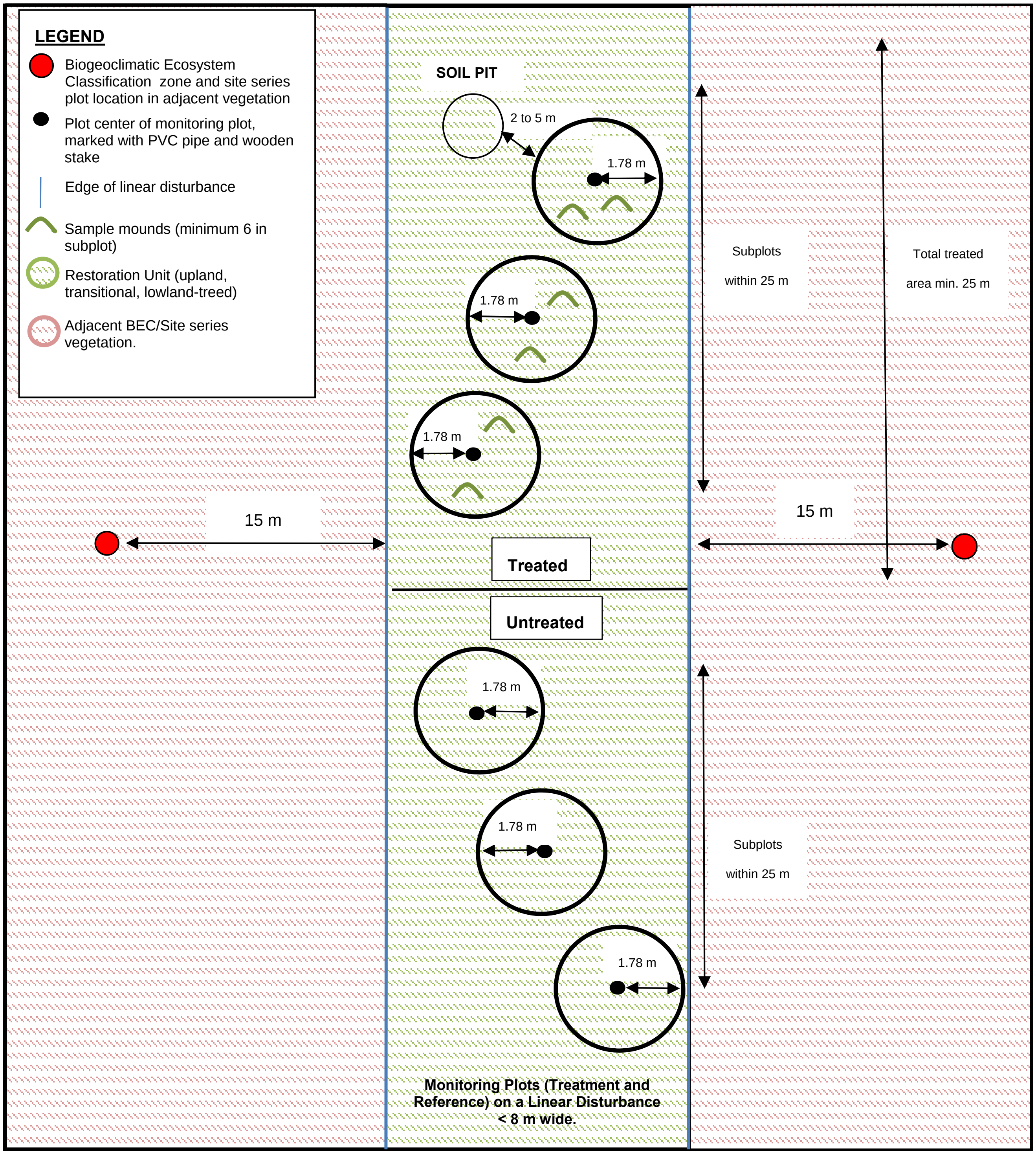

Figure 3: Paired Treatment and Reference Plot Layout on a Linear Disturbance < 8 m wide

3.2.4 Field Procedures

Field crews will collect data following at least the first and up to the fifth growing season after restoration treatments are implemented. Field crews should consist of two people, at least one of which is a Qualified Environmental Professional (QEP), defined as someone familiar with local vegetation, silviculture techniques and seedling planting, and the restoration treatment types and their objectives. A health and safety plan should be discussed with all survey crew members prior to the survey's commencement.

Crews will travel by truck, ATV, or helicopter to the site vicinity. To avoid disturbing the progress of restoration treatments and altering monitoring results, crews should only access the monitoring treatment and reference plots by foot.

The following field equipment should be taken to plot establishment and monitoring visits:

- large measuring tape;
- PVC pipe (1.5 m lengths, approximately 1 " diameter);
- heavy hammer;
- aluminum tags;
- stakes;
- flagging tape;
- pencils and permanent markers;
- compass;
- clinometer;
- GPS unit;
- camera;
- datasheets;
- soil auger;
- robel poles;
- vegetation ID book/reference cards; and,
- appropriate permits and site passes, as needed.

Once at the monitoring site, crews should collect all relevant data described on the Ground Monitoring Datasheets (Appendix C), including photos (Appendix D), using data collection protocols provided in Appendix E. At the end of each day, GPS data should be downloaded and a Quality Assurance/Quality Control (QA/QC) review should be conducted on all datasheets. Each datasheet should be passed to a crew member other than the person who recorded the data. This person checks for errors, omissions, or legibility concerns. Datasheets are then corrected in consultation with the recorder of the data, and the QA/QC person initials the datasheet(s) in the designated box. Datasheets should be scanned into a digital filing system and raw data entered into an electronic database at the end of each monitoring session. Alternatively, data can be collected and maintained using an electronic device (e.g., iPad). Care should be given to ensure adequate QA/QC procedures are carried forward during electronic data collection to understand what changes were made when and by whom, and also that back-up procedures are in place.

3.3 Data Collection

The following variables are to be collected at all treatment and paired reference plots following the standardized protocols provided in Appendix E:

- disturbance metrics: type of disturbance (e.g., legacy seismic, Low Impact Seismic, pipeline Right-of-Way [ROW], hydro ROW, winter-only access road, year-round access road, etc.), approximate age of disturbance (age of trees present is age of disturbance is unknown);
- BEC zone, subzone, and site series, with variant and phase where applicable (BC MoFR and BC MoE 2010);
- slope and aspect;
- vegetation community type and presence / percent cover on the disturbance, including trees, palatable and non-palatable shrubs, lichen and moss, forbs, grasses, nonvascular plants, and non-native invasive or weed species;
- height, percent cover and density of targeted vegetation by strata, including trees, palatable and non-palatable shrubs, lichen and moss, forbs, grasses, and nonvascular plants;
- percent cover and density of non-living matter, including water, mineral soil, cobbles and stone (> 2 mm in diameter), bedrock, decaying wood (>10 cm thick), and organic matter (organic layers > 2 cm thickness over gravels, cobbles, stones or bedrock; decaying wood <10 cm thick; animal droppings) (BC MoFR and BC MoE 2010);
- tree canopy attributes adjacent to linear disturbance being monitored;
- number, survival, growth and vigour of planted seedlings (treatment plots only);
- soil moisture regime (code 0 – 8 for very xeric to hydric following BC MoFR and BC MoE 2010);
- nutrient regime (code A – F, indicating available nutrient supply as very poor to saline following BC MoFR and BC MoE 2010);
- surface organic matter thickness;
- line of sight distance class;
- percent sightability, measured using a robel pole 5 m from plot center;

- incidental wildlife sign;
- presence and estimated amount of off-road vehicle use and width of trails;
- presence/absence of game trails (and if applicable, width of trails); and
- climate and severe weather summaries for time period since last monitoring session (e.g., winter snow patterns, wildfires).

Standardized protocols for collecting the above variables are described and referenced in Appendix E. Appendix C provides a datasheet to use for data collection in the field.

In addition to collecting monitoring data for analysis of performance measures, photographs are an effective, qualitative means of documenting the state of a site through time, and can help validate results when they are repeated at each assessment (Woodward and Hollar 2011). Photographs should be taken at approximately the same place (i.e., the plot center) and in all four cardinal directions during every monitoring event (OSLI 2012b; Appendix D).

All wildlife species of concern/interest encountered while at, and while traveling to and from, monitoring plot locations will be recorded as incidental observations. Incidental observations should be submitted to the BC Ministry of Environment Ecosystem Branch's Incidental Observations of Wildlife database (http://www.env.gov.bc.ca/wildlife/wsi/incidental_obs.htm).

3.4 Data Analysis

The data collected in each monitoring year required by permit conditions should be analyzed after field work is completed. No advanced statistical analysis is recommended within Project-level monitoring. Data from treatment monitoring plots should be evaluated for each recommended target. Results from the treatment plot data should be compared with the recommended targets presented in Table 2 to report how the treatment sites compare to the expected recommended targets. Where expected targets have not been met, remedial actions should be discussed with the responsible authority.

3.5 Data Management

The Procedures for Environmental Mitigation (BC MoE 2014a, 2014b) recommend data be submitted and stored for future monitoring. The responsible authority should be contacted when a Project-specific restoration monitoring plan is developed to clarify data submission requirements, as requirements related to restoration monitoring and data submissions is likely to evolve over time.

The responsible authority should consider the following when reviewing Project-level restoration treatment plans and data submission requirements.

- Restoration treatment plans should include an associated monitoring plan which specifies monitoring schedule, number and location of treatment and reference plots to be established, naming convention for treatment and reference plots, type of treatments being implemented, possible remedial actions if targets are not achieved, and data submission schedule.

- Data should be submitted to the responsible authority, and include:
  - a .csv file summarizing data from the raw datasheets, with each plot as a row (defined as either treatment or reference plot, naming convention to link paired plots) and data fields as the columns; and
  - a GIS shapefile showing the location of treatment and reference plots.

3.6 Monitoring Frequency

It is anticipated that for Project-level monitoring, that paired treatment and reference plots are established after one growing season of restoration treatment implementation, and revisited within the first 5 years (or for the timeline directed by permit conditions) to determine seedling survival rate and any opportunities to adjust treatments based on site conditions and early response of vegetation. Monitoring after the first complete growing season will identify any immediate issues such as seedling mortality due to poor seedling stock or desiccation; poor seed germination, and improperly placed or spread access control treatment implementation. Monitoring between the first and fifth complete growing season will identify issues such as relatively poor seedling growth or chlorosis, and should indicate any site condition related issues not related to poor seedling stock or improperly placed access control. By the end of the fifth growing season, introduced and naturally re-established vegetation should be growing according to the site conditions, and early monitoring results should indicate whether the recommended targets are, or will be, achieved over time. If not, remedial measures may be required (Section 3.7).

3.7 Remedial Actions

This Monitoring Framework has been developed such that Project-level data collection at monitoring plots can be compared to the recommended targets in Table 2 after each monitoring event. If data analyses demonstrate a degree of uncertainty as to whether the vegetation reestablishment will achieve the recommended targets, the proponent and appropriate authority will need to discuss remedial action options, or revising the targets, if they are deemed infeasible.

In certain situations, there may be a need to monitor both treatment and reference plots between scheduled monitoring periods (e.g. after the 2nd or 3rd growing season) or for an additional time period (e.g. up until after the 6th growing season) if vegetation establishment is uncertain. In other cases, it may be more appropriate to wait to determine appropriate actions until after the subsequent monitoring session (e.g. if there was one bad fire season). Reference plots can be used to inform site-specific conditions that may influence the selection, intensity, and duration of remedial actions.

Suggested remedial actions for restoration treatment sites if recommended targets are not achieved are summarized in Table 4.

Table 4: Remedial Actions for Restoration Treatment Sites

Restoration Objective	Indicator	Remedial Actions[1]
Revegetation	% of surviving planted or naturally re-established seedlings	■ If planted seedling mortality occurs, assess and correct factors leading to mortality (e.g., due to poor seedling stock, winter planting storage or planting temperatures). Replace seedlings that have died, as required. ■ If seedlings (planted or natural regeneration) are damaged due to human access, assess and modify access control measures and plant seedlings to maintain desired seedling density targets, as required. ■ If seedlings (planted or natural regenerations) are damaged due to disease, plant seedlings to replace those that have died, as required. ■ If establishment and growth of planted seedlings are impeded by wet site conditions (e.g., flooding and ingress of invasive species such as cattails), modification of surface drainage patterns may be implemented to facilitate near-surface water flow.
	Vigour of planted or naturally re-established seedlings	■ If seedling vigour (planted or naturally re-established) is impeded by competition from surrounding vegetation, such as grasses, implement manual vegetation control to reduce competition pressure and plant seedlings to maintain desired seedling density targets, as required.
	Percent cover and density of targeted vegetation[2]	■ If natural revegetation of desired vegetation is impeded, plant desired species to facilitate natural revegetation of trees and shrubs. ■ If prohibitively noxious or noxious weed species occur on the disturbance feature, implement manual control measures, as required to manage weed populations.

1 Remedial actions will be site specific and dependent on vegetation community type (upland, lowland, transitional). Proponents and responsible authority should discuss options and expectations prior to undertaking remedial actions.

2 Note that “targeted vegetation” is focused on native trees and shrubs to address restoration objective of establishing caribou habitat, reducing predator access and line of sight on disturbance features.

4.0 HABITAT RESTORATION MONITORING: PROGRAM LEVEL

4.1 Program-Level Restoration Monitoring Objectives

Program-level restoration monitoring is intended to gather data from a large cross-set of Project-level monitoring programs, conducted by a number of habitat restoration practitioners, thus increasing the sample size for restoration treatment effectiveness monitoring. Program-level restoration monitoring compares treatment plots with both reference plots as well as to the adjacent undisturbed vegetation community to assess the value – both ecological and economic- of implementing restoration treatments. Program-level restoration monitoring is intended to support updates to best management practices, policies, and legislation (BC MoE 2014b). The objective of Program-level restoration monitoring is to answer specific questions and assumptions around habitat restoration. The following questions can be answered:

Q1 Do restoration treatments accelerate native vegetation recovery?

a) Controlling for age, are trees (or woody vegetation) on treated sites taller compared to trees within natural vegetation re-establishment linear disturbance sites?

b) Controlling for age, do treated sites have a higher stem density of trees compared to trees within natural vegetation re-establishment linear disturbance sites?

c) Controlling for age, is vegetation cover greater on treated sites compared to natural vegetation re-establishment linear disturbance sites?

Q2 When applying access control measures, does treating a disturbed site reduce the probability of off-road vehicular use of a newly disturbed line?

Q3 When applying access control measures, does treating a disturbed site reduce the probability that a game trail becomes established along a newly disturbed line?

Q4 When controlling for site conditions and tree species, how does vegetation leader growth and tree height respond to each restoration treatment prescription as outlined within the Restoration Toolkit (Golder 2015a)?

4.2 Sampling Design, Timeline and Frequency

Program-level monitoring incorporates data from both treatment plots and paired reference plots collected from individual Project-level monitoring programs. As such, the plot locations (Section 3.2.2) and plot establishment procedures (3.2.3) will have been determined through the Project-level monitoring events.

Program-level monitoring should not be implemented until at least the 10th growing season following implementation of restoration treatments and monitoring during Project-level restoration plans. Although a 5 year gap in monitoring may be insufficient to document wildlife response to a restoring landscape, it is sufficient for monitoring the vegetation response to restoration treatment. By the fifth year after treatment, the vegetation (planted and naturally re-established) is expected to be on a trajectory that, unless re-disturbed, will continue into the future. Monitoring at the 10th and 15th growing season is a final check and a way to gather long-term vegetation growth data and access data that has, to date, been lacking in caribou habitat restoration programs.

Monitoring that occurs following the 10th growing season is expected to use both aerial and ground-based sampling protocols. Monitoring should be completed at the end of the growing season between mid-August and mid-September during the leaf-on period. Access to monitoring plots needs to consider not damaging the restoration treatment or natural revegetation of the area. As such, access will likely be by foot or air. If access to a monitoring plot location is densely vegetated to the point where access would cause damage to established vegetation or negatively impact an access control measure, aerial remote sensing methods to gather monitoring data should be employed (Section 4.2.2).

To meet the objectives of the habitat restoration Monitoring Framework, an overall sampling design for long-term plots needs to be established. The required number of paired treatment and reference plots within the region is going to be dependent on the variability expected for the measurable targets in the boreal ecosystem of NE BC (Section 4.2.1). It is a valid assumption that not all treatment and reference plots will remain undisturbed through time, thus, it is recommended that more plots than likely needed for comparison purposes are established.

4.2.1 Power Analysis to Inform Program-level Sampling Design

Currently, there are no region-specific data to inform sampling intensity for linear disturbance restoration (number of plots) however, recent restoration monitoring work conducted in the Little Smoky boreal caribou range (upper foothills ecosystem) of west-central Alberta can provide an estimate of the sample size needed to provide statistically valid results from the Monitoring Framework.

Treated linear disturbance features were sampled for both planted and natural ingress vegetation in 2015 and compared to naturally revegetating reference plots (sampled in 2008; Golder 2009) where vegetation had been naturally re-establishing for more than 20 years (Golder 2015c). Multiple regression analysis was used to analyze the effect of four predictor variables on average black spruce seedling height and the stem density measured at 82 linear disturbance plots within the Little Smoky caribou range in the foothills of Alberta. The four predictor variables included in the regression models were: percentage shrub cover at sample plot, site type (Alberta ecosites grouped to either upland or treed-wetland), time since disturbance or treatment occurred, and seismic line condition (either reference or treated).

A post-hoc power analysis using G*Power (Faul et al. 2007) was conducted to determine the overall power of a regression analysis used on the Little Smoky data and to inform decisions on the minimum number of plots needed at the Program-level in NE BC. Results from the power analysis indicated that in order for a multiple regression analysis to achieve a statistical power level of 0.95 at an alpha level of 0.05, a minimum of 16 treatment plots with a paired reference plot would need to be sampled for seedling height and a sample size of 45 would be required for stem density.

A separate power analysis was performed to provide guidance on the sample size required to answer Q4 in section 2.0: When controlling for site conditions and tree species, how does vegetation leader growth and tree height respond to each restoration treatment prescription as outlined within the Restoration Toolkit (Golder 2015a)? Leader height measurements for black spruce and lodgepole pine seedlings from the Little Smoky restoration program were compared to age of seedlings using a multiple regression analysis. Seedling leader height was averaged within each linear disturbance sampled and then compared to the average age of the seedlings measured. Time since disturbance or treatment occurred, ecosite [restoration unit], and percentage of shrub cover present at sample plot were all included as additional explanatory variables in the regression model. To determine sample size needed, a separate regression and power analysis was run for each species (i.e., black spruce and lodgepole pine). Results indicated that in order to achieve a power of 0.95 at an alpha level of 0.95, a total of 42 paired plots measuring black spruce leader height and 18 paired plots measuring lodgepole pine seedlings would be required.

In order to confidently answer questions concerning the efficacy of restoration treatment on seedling height and stem density, it is recommended to establish paired reference and treatment plots, at least 500 m apart from each other, in a restoration program area, on a minimum of 45 linear disturbance sites throughout a Program-level monitoring area. The monitored portion of the Program's area should be evenly distributed over the entire treatment area and in all restoration unit types (upland, lowland, transitional) so that monitoring results are representative of the disturbance features in area. The number of monitoring plots should be increased for each restoration treatment type. For example, if three treatment types are implemented, a total of 135 paired treatment-reference plots should be evenly distributed within restoration unit types over the Program-level restoration monitoring area.

It is important to conduct a power analysis relevant to NE BC and the restoration treatments that will be employed in this region to continually inform the appropriate sample size. Sample size should be revisited after two years of Project-level monitoring data is collected from this region. At that point, the appropriate variation from this ecosystem can be captured in a power analysis, which can then inform a sampling size for reference plots needed to conduct trend analyses over time. Future versions of this Monitoring Framework should be updated appropriately.

4.2.2 Field Procedures

Ground Methods for Treatment and Reference Plots, Year 10 and 15

Treatment and reference plots that are accessible by ground following the 10^{th} and 15^{th} growing season after treatment should be revisited, only if access will not be detrimental to the vegetation re-establishment of the site. Crews should follow the field procedures described in Section 3.2.4 and use the datasheets in Appendices B and C. All monitoring should be conducted by a QEP.

Aerial methods for Treatment and Reference Plots, Year 10 and 15

If restoration treatments have been successful, many of the treatment and reference plots will be inaccessible by ground methods by the 10^{th} or 15^{th} growing season, in which case aerial methods of monitoring will need to be employed. The variables collected using aerial monitoring will include:

- vegetation height (m);
- stem density (stem/ha);
- ground cover (%);
- evidence of human or wildlife access;

- age since disturbance;
- BEC unit classification for adjacent stand; and
- depth to water table (collected from alternate datasets or derived from wetlands mapping).

However, it is possible that as technological and mapping developments over the next 10 years improve, that additional variables such as line of sight may be achievable. As this is a living document, it is recommended that Section 4.2.2 be updated over time.

Current trial programs that include long-term monitoring of restoration treatments focus on remote sensing using PURVIEW soft copy mapping, in combination with using Light Detection and Ranging (LiDAR) remote sensing technology, as an effective method of aerial monitoring restoration treatment and reference plots. Remote sensing mapping with LiDAR accurately maps and classifies vegetation, including vegetation species and height. An alternative method of aerial monitoring is 360 overflight and photo mapping, which allows linear features to be flown while capturing still photo images that can be viewed on desktop. This method requires the use LiDAR to create a digital elevation model (DEM) to determine vegetation heights. Field verification for more precise data may be required. Whichever remote sensing technology is selected, care should be given to ensure high quality images are obtained from drone or fixed-wing aircraft with GPS reference.

4.3 Data Collection

The variables that need to be collected from the treatment and reference plots are outlined in Section 3.3. Appendix C provides a datasheet to use for ground-based monitoring data collection in the field, and Appendix D provides a photo log datasheet. A datasheet has not yet been created for aerial monitoring after 10 or 15 growing seasons, as described in Section 4.2.2. Future versions of this Framework should include datasheets appropriate to the remote sensing technology of the time.

4.4 Data Analysis

Data collected from cumulative Project-level monitoring for treatment and paired reference plots should be combined, stratified by restoration unit (upland/lowland-treed/transitional) and treatment type, and a mean and standard error for each measurable target determined.

Analyses examining tree seedling height and growth for treated areas compared to reference areas will help to answer Program-level restoration questions. Mixed effects regression models for total height and leader growth and tree height-age trajectory models should be performed. These trajectories provide a basis for comparing the time it takes to reach a specific height threshold, which provides insight into the trajectory of the treatment options.

A mixed-effects regression model can be used to analyze the relationship between seedling type (i.e., planted or natural ingress), as well as environmental factors on: (a) seedling height and (b) leader height for treated sites. Tests for normality should be conducted prior to running models. Explanatory variables for the model may include seedling type, site type (i.e., upland vs lowland vs transitional), depth to water from ground surface, and percent cover of competitive species (grass, shrubs).

Height-age trajectory models provide a means for evaluating relative amount of time (i.e., years) that it will take a seedling to reach specific height thresholds. As these predicted height – age trajectory models are based entirely from modelling the annual incremental change in leader growth and applying that model to the mean leader growth present at the current age of the trees to predict height, these models are not intended to be used in the same manner as traditional site index curves or growth intercept models. However, these models can be compared to provincial subregion-based site index curves to assess if the predicted height – age trajectory models are in line with the standard approach (i.e., were not grossly under or overestimating the height – age trajectory). Heights of > 1.5 m, 1.5 to 3 m, and > 5 m could be used as thresholds in the models, as research by both Dickie (2015) and Finnegan et al. (2014) has shown that once vegetation reaches certain heights on seismic lines, the vegetation either slows down predators and/or acts as a deterrent to both human and predator use (seasonal variations).

4.5 Data Management

Data collected as part of each Project-level monitoring program should be submitted to the responsible authority for the restoration monitoring plan, as described in Section 3.5. The responsible authority will house the data and either have analyses conducted on the data, or upon request, provide it to proponents, consultants, or other government authorities who require the data to conduct analyses of the restoration treatments or programs in the region. Some data may be kept confidential depending on permit conditions and agreements between proponents and the responsible authority.

As a condition of receiving the data, summary reports should be submitted to the responsible authority. Reports prepared as required under Program-level monitoring should include a comparison between treatment versus reference plot data. Any statistical analyses should be clearly described, and related statistics script (e.g. for R code) should be included in the report. Shapefiles and associated figures should also be submitted.

4.6 Adaptive Management

Although previous habitat restoration program results have informed the recommended targets outlined in Section 2.2, the lack of long-term habitat restoration monitoring in Canada has led to a degree of uncertainty regarding the long-term success of restoration treatments. Habitat restoration is a relatively new science, and thus projects to date have been implemented with a large number of assumptions. The development of restoration techniques (Golder 2015a) and methods of data collection for short and long-term monitoring (this Monitoring Framework) are informed by projects in Alberta, and neither have been sufficiently tested because restoration programs, with the exception of the Little Smoky restoration project (Golder 2015b), are all less than 10 years old. Monitoring projects in BC will be established to help address uncertainty and inform future regulations, measurable targets, and remedial actions specific to this province.

Adaptive management "provides flexibility to identify and implement new mitigation measures or to modify existing ones during the life of a project" (CEAA 2013) and can "increase the probability of achieving mitigation commitments" (BC MoE 2014b, pg. 48). Adaptive management requires an investigation into the underlying cause(s), site conditions, and other ecological factors that may be affecting restoration. Adaptive management recognizes that some site limitations cannot be addressed without major site impacts that could negate the efforts, and thus restoration targets may need to be adjusted.

Adaptive management at the Program-level will require an investigation of the treatment results in both the short and long term to assess whether implementation of treatments are more effective at accelerating vegetation re-establishment on linear disturbance features compared to natural revegetation processes (based on comparison with reference plots). An assessment of whether treatment recommendations need to be modified to be more effective to meet trajectories faster may be required. In addition, the ecological benefit to caribou can be assessed at a range/regional level. These results could inform whether changes need to be made to habitat restoration practices or permit conditions.

5.0 SUMMARY

Implementing this Monitoring Framework will result in a consistent approach by industry operators, consultants and regulators, making it easier to compare results of restoration treatments as compared to reference sites. As monitoring data becomes available over time within the region, the consistent approach for plot design and data collection protocols will provide an opportunity to evaluate restoration treatment effectiveness over a larger spatial and temporal scale. Caribou habitat restoration efforts will benefit if monitoring data is shared amongst regulators and industry operators, ensuring greater statistical power in the results and a wider breadth of variables encompassed in analyses and reports.

A consistent approach to monitoring and a collaborative approach to data sharing and analysis will help inform regulator decisions about restoration requirements with treatments being evaluated for effectiveness against performance measures. Regulators benefit from restoration monitoring because the data and subsequent analyses can help inform if the restoration toolkit guidance on restoration treatments are effectively meeting habitat restoration objectives, can reduce uncertainty associated with treatment and mitigation measures, and can apprise whether permit conditions are sufficient to meet the requirements set by the existing policies and management plans (BC MoE 2014b).

Habitat restoration programs are costly and there is a time lag associated with potential benefit to caribou habitat recovery given the timeline for trees to grow. Industry proponents benefit from monitoring their restoration efforts because they can assess if their restoration treatments are effective and what the associated costs are with treatment effectiveness versus measures to minimize disturbance or enhance natural recovery, thereby informing future project planning and restoration plans. In addition, monitoring may be a condition of a permit approval; hence, a benefit of monitoring is that a proponent fulfills permit requirements.

As caribou habitat restoration monitoring has been limited to date, this Monitoring Framework should be treated as a living document, and should be reviewed and revised based on the accumulation and analysis of monitoring data in BC boreal caribou habitat types. It is expected that monitoring results will provide a feedback loop to subsequent restoration plans and treatment methods. As this Monitoring Framework is focused on compliance and effectiveness monitoring for native vegetation response to restoration treatments, wildlife response to those restoration treatments has not been captured. Validation monitoring, encompassing both vegetation and wildlife response to habitat restoration treatments, is necessary to measure if the desired outcome of caribou habitat restoration is achieved over time in British Columbia.

6.0 LITERATURE CITED

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APPENDIX A

Restoration Units Separated by BEC Zone

Restoration Unit[1]	BEC Unit	Site Series Code	Site Series Name	Soil Moisture Regime	Soil Nutrient Regime
Upland	Dry Cool Boreal White and Black Spruce (BWBSdk)	102	Pl – Kinnikinnick – Lingonberry	xeric to subxeric	very poor to poor
		103	SwPl – Soopolallie – Toadflax	submesic	poor to rich
	Graham Wet Cool Boreal White and Black Spruce (BWBSwk2)	102	Pl – Lingonberry – Reindeer lichen	xeric to subxeric	very poor to medium
		103	SwPl – Soopolallie – Wildrye	submesic	poor to rich
	Kledo Wet Cool Boreal White and Black Spruce (BWBSwk3)	102	Pl – Crowberry – Lingonberry	xeric to subxeric	very poor to medium
		103	Sb – Huckleberry – Lingonberry	submesic to subhygric	very poor to poor
	Moist Cool Boreal White and Black Spruce (BWBSmk)	102	Pl – Kinnikinnick – Lingonberry	xeric to subxeric	very poor to medium
		103	SwPl – Soopolallie – Wildrye	submesic to mesic	medium to rich
	Moist Warm Boreal White and Black Spruce (BWBSmw)	102	Pl – Kinnikinnick – Lingonberry	xeric to subxeric	very poor to medium
		103	SwPl – Soopolallie – Wildrye	submesic	poor to medium
	Murray Wet Cool Boreal White and Black Spruce (BWBSwk1)	102	Pl – Lingonberry – Reindeer lichen	xeric to subxeric	very poor to medium
		103	SwPl – Soopolallie – Showy aster	submesic	poor to rich
Transitional	Dry Cool Boreal White and Black Spruce (BWBSdk)	101a	Sw – Soopolallie – Step moss, mesic phase	submesic to mesic	medium to rich
		104a	Sb – Labrador tea – Step moss, freely drained phase	submesic to mesic	very poor to poor
	Graham Wet Cool Boreal White and Black Spruce (BWBSwk2)	101	SwBl – Huckleberry – Feathermoss	submesic to mesic	poor to medium
		104	Sb – Huckleberry – Lingonberry	submesic to hygric	very poor to poor
	Kledo Wet Cool Boreal White and Black Spruce (BWBSwk3)	101	SwBl – Huckleberry – Feathermoss	submesic to mesic	medium to rich
	Moist Cool Boreal White and Black Spruce (BWBSmk)	101	Sw – Lingonberry – Step moss	submesic to mesic	medium to rich
		104a	Sb – Labrador tea – Step moss, freely drained phase	submesic to mesic	very poor to poor

Restoration Unit	BEC Unit	Site Series Code	Site Series Name	Soil Moisture Regime	Soil Nutrient Regime
	Moist Warm Boreal White and Black Spruce (BWBSmw)	101	Sw – Trailing raspberry – Step moss	submesic to subhygric	medium to rich
		104	Sb – Lingonberry – Step moss	submesic to hygric	very poor to poor
	Murray Wet Cool Boreal White and Black Spruce (BWBSwk1)	101	SwBl – Huckleberry – Feathermoss	submesic to mesic	poor to medium
		104	Sb – Huckleberry – Lingonberry	submesic to subhygric	very poor to poor
Lowland	Dry Cool Boreal White and Black Spruce (BWBSdk)	101b	Sw – Soopolallie – Step moss, subhygric phase	subhygric	medium
		104b	Sb – Labrador tea – Step moss, imperfectly/poorly drained phase	subhygric to hygric	very poor to poor
		110	Sw – Currant – Horsetail	subhygric to hygric	medium to rich
		111	Sw – Mountain alder – Horsetail	subhygric to hygric	very rich
		112 (Fm02)	AcbSw – Mountain alder – Dogwood	subhygric to hygric	very rich
	Graham Wet Cool Boreal White and Black Spruce (BWBSwk2)	110	Sw – Currant – Bluebells	mesic to subhygric	medium to rich
		111	Sw – Currant – Horsetail	subhygric to hygric	medium to rich
	Kledo Wet Cool Boreal White and Black Spruce (BWBSwk3)	110	Sw – Currant – Horsetail	subhygric to hygric	medium to rich
		111	Sb – Horsetail – Stepmoss	hygric	very poor to poor
	Moist Cool Boreal White and Black Spruce (BWBSmk)	110	Sw – Currant – Horsetail	subhygric to hygric	medium to rich
		111	Sw – Mountain alder – Horsetail	subhygric to hygric	rich to very rich
		104b	Sb – Labrador tea – Step moss, imperfectly/poorly drained phase	subhygric to hygric	very poor to poor
		112 (Fm02)	AcbSw – Mountain alder – Dogwood	subhygric to hygric	rich to very rich

Restoration Unit	BEC Unit	Site Series Code	Site Series Name	Soil Moisture Regime	Soil Nutrient Regime
	Moist Warm Boreal White and Black Spruce (BWBSmw)	110	Sw – Oak fern – Sarsaparilla	mesic to subhygric	rich
		111	Sw – Currant – Horsetail	subhygric to hygric	medium to rich
		112 (Fm02)	AcbSw – Mountain alder – Dogwood	subhygric to hygric	rich to very rich
	Murray Wet Cool Boreal White and Black Spruce (BWBSwk1)	110	Sw – Currant–Horsetail	mesic to hygric	medium to rich
		111	Sb – Lingonberry-Horsetail	submesic to subhygric	very poor to poor
	Boreal White and Black Spruce (BWBS)	Wb	Wetland bog	hygric to subhydric	very poor to poor
	Boreal White and Black Spruce (BWBS)	Wf	Wetland fen	subhydric	poor to medium

Source: DeLong, C., A. Banner, W. H. MacKenzie, B. J. Rogers, and B. Kaytor. 2011. A Field Guide to Ecosystem Identification for the Boreal White and Black Spruce Zone of British Columbia. B.C. Ministry of Forests and Range, Forest Science Program, Victoria, B.C. Land Management Handbook. No. 65. Available at: www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh65.htm. Accessed December 2015.

[1] Note that for Restoration Unit monitoring purposes, site units have been grouped according to their relative soil moisture regimes using Delong et al.'s (2011) edatopic grids as a guide. Dry (Xeric-Submesic) is considered Upland Restoration Unit, Fresh (Mesic) a Transitional Restoration Unit, and Moist (subhygric-subhydric) a Lowland Restoration Unit. Treed bogs and fens are grouped within the Lowland Restoration Unit.

APPENDIX B

Treatment and Reference Plot Establishment Datasheet

Habitat Restoration Monitoring Plot Establishment

General Plot Information								
Project No.	Plot ID	Date (dd/mmm/yy)		Company		Crew Initials	QAQC initials	
Plot Type		Plot Center Coordinates						
☐ Treatment ☐ Reference		Datum	UTM E		UTM N	UTM Zone		
		☐ NAD 27 ☐ NAD 83						
Plot center staked?	Disturbance boundary staked?	Plot Markers				Plot Photos		
Y/ N	Y / N	Flagging tape Y/ N		Aluminum tags Y / N				
General Location Description								
General Location Drawing (include plot markers, adjacent habitat features, disturbances, etc)								
BEC Zone/ Subzone/ Site Series	BEC Site Series Name	General Vegetation Classification						
		☐ Upland_Pine ☐ Upland_Decid. ☐ Upland_Spruce ☐ Wetland_Sb-Lt ☐ Other___						
Slope (%)	Aspect (°)	Mesoslope Position				Elevation (m)		
		CR -crest UP -upper MD -middle LW -lower TO -toe DP -depression LV -level GU -gully						
Disturbances		Soil Information						
Human		Soil Org. Depth (cm)	Mottles / Gley (depth)	Surface/Effective Texture		Soil Class	Drainage	
Fire / snow			Y / N cm					
Wildlife		Moisture Regime						
Notes		0-very xeric 1-xeric 2-subxeric 3-submesic 4-mesic 5-subhygric 6-hygric 7-subhygric 8-hydric						
		Nutrient Regime						
		A - very poor B - poor C - medium D - rich E - very rich F - saline						

Linear Feature Information						
Type of Linear Disturbance					Comments	
☐ Seismic line ☐ Cutline ☐ Trail ☐ Pipeline ☐ Transmission line ☐ Road ☐ Other						
Line Width (m)	Line Age Class (years)		Line-of-Site Distance Class (m)			Line Orientation
	☐ <5 ☐ 5-10 ☐ 10-20 ☐ 20-40		☐ <50 ☐ 50 - 200 ☐ 200 - 500 ☐ > 500			
Robel	Height (cm)	Bearing	Photo #	Adjacent Site Series /Tree Canopy Attributes	Adjacent (NE)	Adjacent (SW)
1				BEC zone/ subzone/ site series		
2				Overstory / Understory canopy		
Evidence of Line Use by Humans				Evidence of Line Use by Wildlife		
☐ none ☐ ATV ☐ Truck ☐ Heavy Machinery ☐ Other__________				☐ none ☐ scat(s) ☐ track(s) ☐ game trail(s) ☐ nest(s) ☐ other:_______		
Notes re. human evidence of line use, including estimated amount of use:				Notes re. wildlife evidence of line use, including estimated amount of use:		

Surface Substrate - % cover of non-living matter; adds to 100% within plot

Water		Mineral Soil		Cobbles & Stones		Bedrock		Decaying Wood		Organic Matter	

Treatment Plot Information

Treatment Type	Stocking Density	Stock type (of planted species)	Year of Treatment	Plot Radius

Species	Planted (P) / Nat. Regen (N)	Ht (cm)	Leader Growth (cm) 1st / 2nd / 3rd year #	rcd (cm)*^	age^	Species	Planted (P) / Nat. Regen (N)	Ht (cm)	Leader Growth (cm) 1st / 2nd / 3rd year #	rcd (cm)*^	age^

1st year refers to the current year; 2nd year refers to one year since time of data collection; 3rd year refers to 2 years from time of data collection

* root collar diameter; ^ recorded only for tallest individual of each species

Vegetation Cover - within plot

Tree/ Tall Shrub [T] (1.5 - 4.9 m)	Shrub [S] (<1.5 m)	Forb [F]	Graminoid [G]	Bryophyte [B]	Lichen [L]
+ 1 2 3 4 5 6 7 8	+ 1 2 3 4 5 6 7 8	+ 1 2 3 4 5 6 7 8	+ 1 2 3 4 5 6 7 8	+ 1 2 3 4 5 6 7 8	+ 1 2 3 4 5 6 7 8

Dominant and Co-dominant Plant Species

Species	Strata	Cover Class	Species	Strata	Cover Class
	T S F G B L	+ 1 2 3 4 5 6 7 8		T S F G B L	+ 1 2 3 4 5 6 7 8
	T S F G B L	+ 1 2 3 4 5 6 7 8		T S F G B L	+ 1 2 3 4 5 6 7 8
	T S F G B L	+ 1 2 3 4 5 6 7 8		T S F G B L	+ 1 2 3 4 5 6 7 8
	T S F G B L	+ 1 2 3 4 5 6 7 8		T S F G B L	+ 1 2 3 4 5 6 7 8
	T S F G B L	+ 1 2 3 4 5 6 7 8		T S F G B L	+ 1 2 3 4 5 6 7 8
	T S F G B L	+ 1 2 3 4 5 6 7 8		T S F G B L	+ 1 2 3 4 5 6 7 8
	T S F G B L	+ 1 2 3 4 5 6 7 8		T S F G B L	+ 1 2 3 4 5 6 7 8
	T S F G B L	+ 1 2 3 4 5 6 7 8		T S F G B L	+ 1 2 3 4 5 6 7 8
	T S F G B L	+ 1 2 3 4 5 6 7 8		T S F G B L	+ 1 2 3 4 5 6 7 8
	T S F G B L	+ 1 2 3 4 5 6 7 8		T S F G B L	+ 1 2 3 4 5 6 7 8

Incidental Wildlife Observations

	Species	Sign	Notes / Comments
1			
2			
3			
4			
5			

Comments / Notes

Cover classes: + [<1%], 1 [1-2%], 2 [>2-5%], 3 [>5-10%], 4 [>10-25%], 5 [>25-50%], 6 [>50-75%], 7 [>75-95%], 8 [>95-100%].

APPENDIX C

Ground-based Restoration Monitoring: Field Datasheet

Ground-based Habitat Restoration Monitoring Survey

General Plot Information

Project No.	Plot/Waypoint ID	Plot Type	Crew Initials	Field QA/QC	Plot Photos	Date (dd/mmm/yy)
		☐ Treatment ☐ Reference				/ /

BEC Zone/ Subzone/ Site Series	BEC Site Series Name	General Vegetation Classification
		☐ Upland_Pine ☐ Upland_Decid. ☐ Upland_Spruce ☐ Wetland_Sb-Lt ☐ Other_____

Slope (%)	Aspect (°)	Mesoslope position	Site Location Description
		CR -crest UP -upper MD -middle LW -lower TO -toe DP -depression LV -level GU -gully	

Location Coordinates		Soil Information				
Datum	☐ NAD27 ☐ NAD83	Soil Org. Depth (cm)	Mottles / Gley (depth)	Surface/Effective Texture	Soil Class	Drainage
UTM E *			Y / N cm			
UTM N *		Moisture Regime				
UTM Zone		0-very xeric 1-xeric 2-subxeric 3-submesic 4-mesic 5-subhygric 6-hygric 7-subhygric 8-hydric				
Location Notes		Nutrient Regime				
		A - very poor B - poor C - medium D - rich E - very rich F - saline				

Linear Feature Information

Line Width (m)	Line Age Class (years)	Line-of-Site Distance Class (m)	Line Orientation
	☐<5 ☐ 5-10 ☐10-20 ☐ 20-40	☐ <50 ☐ 50 - 200 ☐ 200 - 500 ☐ > 500	

Robel	Height (cm)	Bearing	Photo #	Adjacent Site Series/ Tree Canopy Attributes	Adjacent (NE)	Adjacent (SW)
1				BEC zone/subzone/site series		
2				Overstory/ Understory canopy		

Evidence of Line Use by Humans	Evidence of Line Use by Wildlife
☐ none ☐ ATV ☐ Truck ☐ Heavy Machinery ☐ Other__________	☐ none ☐ scat(s) ☐ track(s) ☐ game trail(s) ☐ nest(s) ☐ other:_______
Notes re. human evidence of line use, including estimated amount of use	**Notes re. wildlife evidence of line use, including estimated amount of use**

Surface Substrate - % cover of non-living matter; adds to 100% within plot

Water		Mineral Soil		Cobbles & Stones		Bedrock		Decaying Wood		Organic Matter	

Treatment Plot

Species	Planted (P) / Nat. Regen (N)	Ht (cm)	Leader Growth (cm) 1st / 2nd / 3rd Year #	rcd (cm)*^	age^	Species	Planted (P) / Nat. Regen (N)	Ht (cm)	Leader Growth (cm) 1st / 2nd / 3rd Year #	rcd (cm)*^	age^
			/ /						/ /		
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1st year refers to the current year; 2nd year refers to one year since time of data collection; 3rd year refers to 2 years from time of data collection

* root collar diameter; ^ recorded only for tallest individual of each species

Vegetation Percent Cover - average within plot

Tree/Tall Shrub [T] (1.5 - 4.9 m)	Shrub [S] (<1.5 m)	Forb [F]	Graminoid [G]	Bryophyte [B]	Lichen [L]
+ 1 2 3 4 5 6 7 8	+ 1 2 3 4 5 6 7 8	+ 1 2 3 4 5 6 7 8	+ 1 2 3 4 5 6 7 8	+ 1 2 3 4 5 6 7 8	+ 1 2 3 4 5 6 7 8

Percent Cover of Invasive/Non-Native Species	Description of Invasive/Non-Native Species	Description of Soil Litter Layers
+ 1 2 3 4 5 6 7 8		L F H O

Vegetation Density - average within plot

Tree/Tall Shrub [T] (1.5 - 4.9 m)	Shrub [S] (<1.5 m)	Forb [F] - description of distribution	Graminoid [G] - description of distribution	Bryophyte [B] - desciption of distribution	Lichen [L] - description of distribution
Low Med High Dense	Low Med High Dense				

Planted and Naturally Re-established Seedlings - average within treatment plot

Mounded	Season Planted	% Survival	Vigour
Y / N	Winter / Summer	# of live seedlings: _______ # of dead seedlings:______	0 - dead 1 - poor 2 - fair 3 - good 4 - excellent

Dominant and Co-dominant Plant Species

Species	Strata	Cover Class	Species	Strata	Cover Class
	T S F G B L	+ 1 2 3 4 5 6 7 8		T S F G B L	+ 1 2 3 4 5 6 7 8
	T S F G B L	+ 1 2 3 4 5 6 7 8		T S F G B L	+ 1 2 3 4 5 6 7 8
	T S F G B L	+ 1 2 3 4 5 6 7 8		T S F G B L	+ 1 2 3 4 5 6 7 8
	T S F G B L	+ 1 2 3 4 5 6 7 8		T S F G B L	+ 1 2 3 4 5 6 7 8
	T S F G B L	+ 1 2 3 4 5 6 7 8		T S F G B L	+ 1 2 3 4 5 6 7 8
	T S F G B L	+ 1 2 3 4 5 6 7 8		T S F G B L	+ 1 2 3 4 5 6 7 8
	T S F G B L	+ 1 2 3 4 5 6 7 8		T S F G B L	+ 1 2 3 4 5 6 7 8
	T S F G B L	+ 1 2 3 4 5 6 7 8		T S F G B L	+ 1 2 3 4 5 6 7 8
	T S F G B L	+ 1 2 3 4 5 6 7 8		T S F G B L	+ 1 2 3 4 5 6 7 8
	T S F G B L	+ 1 2 3 4 5 6 7 8		T S F G B L	+ 1 2 3 4 5 6 7 8

Incidental Wildlife Observations

	Species	Sign	Notes / Comments
1			
2			
3			
4			
5			

Comments / Notes

Cover classes: + [<1%], 1 [1-2%], 2 [>2-5%], 3 [>5-10%], 4 [>10-25%], 5 [>25-50%], 6 [>50-75%], 7 [>75-95%], 8 [>95-100%].

APPENDIX D

Ground-based Restoration Monitoring: Photo Log Datasheet

Photo Log
Ground-based Habitat Restoration Monitoring Survey

Project No.: **Date:** **UTM Zone:**

Plot ID	Plot Type	Camera	Photo No.	Direction	Photo Description	UTM E	UTM N	Gen. Veg Class	BEC Site Series

APPENDIX E

Data Collection Protocols and References

Table 1: Measurable Target Data Collection Procedures

Measurable Target	Description of data collection method	Reference
BEC zone, subzone, site series	Describe the Biogeoclimactic zone, subzone, and site series of the plot using the Ministry of Forests and Range maps and regional field guide to site identification and interpretation for terrestrial zones (available online), and the Wetlands of British Columbia to describe wetland ecosystems.	BC MoFLNRO 2011; MacKenzie and Moran 2004
Slope	Record percent slope gradient using a clinometer.	BC MoFR and BC MoE 2010 (Section 1 page 25)
Aspect	Record orientation of slope relative to true north, using a compass.	BC MoFR and BC MoE 2010 (Section 1 page 25)
Mesoslope position	Record the position of plot relative to localized catchment area using codes, where: • CR = crest • UP = upper slope • MB = middle slope • LW = lower slope • TO = toe • DP = depression • LV = level • GU = gully	BC MoFR and BC MoE 2010 (Figure 1.3, Section 1 page 25-26)
Elevation	Determine in the field using an altimeter or GPS at plot center. Record in meters.	BC MoFR and BC MoE 2010 (Section 1 page 25)
Soil Organic depth	Record the depth of the upper and lower boundaries of the organic layer (in centimetres) at plot center.	BC MoFR and BC MoE 2010 (Section 2, page 28)
Mottles/gley depth	Describe whether there is iron oxidation in the soil and if so, measure the depth at plot center.	BC MoFR and BC MoE 2010 (Section 2 page 45)
Soil surface/effective texture	Describe the texture of the soil within the A horizon using soil classification codes in the Canada Soil Information System.	Expert Committee on Soil Survey 1982
Soil class	Use the Canadian System of Soil Classification codes for soil order, great groups, and subgroups.	BC MoFR and BC MoE 2010 (Section 2 page 14 and Sections 9.17 and 9.18)
Drainage Class	Assess the speed and extent of water removal from the soil in growing season conditions using Drainage class codes, where: • x = very rapidly drained • r = rapidly drained • w = well drained • m = moderately well drained • i = imperfectly drained • p = poorly drained • v = very poorly drained	BC MoFR and BC MoE 2010 (Table 2.16, Section 2 page 22)
Soil moisture regime	Assess the soil moisture based on environmental factors, soil properties and indicator plants. Use code system 0 to 8, where: • 0 = very xeric • 1 = xeric • 2 = subxeric • 3 = submesic • 4 = mesic • 5 = subhygric • 6 = hygric • 7 = subhydric • 8 = hydric	BC MoFR and BC MoE 2010 (Table 1.1., Section 1 page 13)

Measurable Target	Description of data collection method	Reference
Nutrient regime	Assess the nutrient regime based on environmental factors, soil properties, and indicator plants. Use code system A to F, where: • A = very poor • B = poor • C = medium • D = rich • E = very rich • F = saline	BC MoFR and BC MoE 2010 (Table 1.2, Section 1 page 15)
Type of disturbance	Describe the type of linear disturbance, i.e., seismic line, cutline, trail, pipeline, transmission line, road, other.	n/a
Line/trail width	Record the width of each linear disturbance by measuring a straight line from one distinguishable linear edge to another at plot centre. As a general rule, edges can be determined to start at the first mature tree (DBH > 10 cm) from the disturbed area. Record measurement of the linear disturbance in meters.	Oberg 2001
Age of line	Approximate age based on vegetation regrowth (refer to age of trees in treatment /reference plot) or known age based on disturbance marker such as a seismic tag; use age categories of < 5 years, 5 - 10 years, 10 - 20 years, 20 - 40 years, and > 40 years.	To estimate using age of trees in plots: BC MoFLRNO 2015a (Figure 4.15)
Line orientation	Record the orientation that the linear disturbance runs using a compass (in degrees).	n/a
Line of sight distance	Estimate distance that observer can visually see down the linear disturbance (both directions) with bare eye (in meters). One observer stands at plot center while other field crew member walks down line until observer can no longer see them. Classify distances as < 50 m, 50 – 200 m, 200 – 500 m, and > 500 m.	Switalski and Nelson 2011
Average height and vertical density of standing vegetation	Using robel poles, this measurement method can determine amount of standing vegetation remaining on an area after use, and can be interpreted as the hiding cover for wildlife. This method can be used to monitor height and vertical density of standing vegetation over large areas quickly. Place the robel pole 5 m from the plot center in the middle of the line along each orientation of the linear disturbance (e.g. 90 degrees and 270 degrees if that is the orientation of the line). Observer crouches so their eye level is at 1 m, to visually assess the band on the pole that is at the top of the vegetation, and records the height. Two measurements should be taken (in centimeters) and an average recorded (in meters) for each orientation of the linear disturbance (Robel 1 and Robel 2).	Robel et al. 1970
Evidence of human line use	Assess whether there has been evidence of human use on the linear disturbance. If so, add information about whether it is motorized or foot traffic. Assess access level using the following categories: absent, low (tracks/ trail evident but difficult to discern or appear to be used infrequently), or high (tracks / trail evident and appear to be well used; vegetation is trampled, and bare ground may be visible).	NGTL 2014
Evidence of game trail	Assess linear disturbance for evidence of wildlife game trail. Game trail is defined as wildlife walking on a trail that is embedded in a path on the ground due to animals walking the same route for many years. Assess access level using the following categories: • absent • low: tracks/ trail evident but difficult to discern or appear to be used infrequently • high: tracks / trail evident and appear to be well used; vegetation is trampled, and bare ground may be visible.	BC MoFR and BC MoE 2010 (Section 5, Table 5.11)

Measurable Target	Description of data collection method	Reference
Wildlife sign	Search the area and record any sign of scat, tracks, trails, tunnels, nests/beds/burrows/dens, signs on compacted or foraged vegetation, and wildlife remains.	Numerous references for determining wildlife signs, e.g. Elbroch 2003
Percent cover of non-living and organic matter	Record the proportion of ground surface covered by each substrate class of non-living and organic matter (water, mineral soil, cobbles and stones, bedrock, decaying wood, and organic matter); needs to add up to 100% within plot. See Figure 3.2 in BC MoFR and BC MoE 2010 for visual estimation of foliage coverage.	BC MoFR and BC MoE 2010 (Figure 3.2)
Height of trees in treatment/reference plots	Measure and record total height of individual trees in centimetres, by measuring the length of the tree along the stem from high side ground. Record by tree species type.	BC MoFLRNO 2015a (page 86)
Root collar diameter (rcd) of trees in treatment/reference plots	Measure diameter of the stem 1 cm below cotyledon nodes and below any obvious swelling. An average of two measurements should be taken for each tree located within the treatment/reference plot.	BC MoFLNRO 2014
Age of trees in treatment/ reference plots	Count the number of whorls present on coniferous trees present within the plot. Record age by species type.	BC MoFLRNO 2015a (Figure 4.15)
Leader growth (cm)	Measure height of leader for current year, one year prior to data collection and two years prior to data collection. Measurement should be made from the point of germination to the top of the terminal bud of the dominant leader. Record leader growth by tree species type.	BC MoFLRNO 2015b (page 86).
Percent cover of vegetation and invasive/non-native species in treatment/reference plot	Record percentage of the ground surface covered within plot when the crowns are projected vertically, for each vegetation type: Tree/Tall shrub, shrub, forb, graminoid, bryophyte, lichen. See Figure 3.2 in BC MoFR and BC MoE 2010 for visual estimation of foliage coverage.	BC MoFR and BC MoE 2010 (Section 3 page 8 - 10; Figure 3.2)
Density of vegetation in treatment/reference plot	Density class determined through a fixed plot area, using classifications: • low: 1 – 1000 stems/ha • medium: 1,001 - 2000 stems/ha • high: 2,001 - 5000 stems/ha • dense: > 5,000 stems/ha.	AESRD 2015
Soil litter layers description	Dig a soil pit and record the average depths of the L, F, and H soil horizons (in centimeters).	BC MoFR and BC MoE 2010 (Section 2, page 25-28; Table 2.20)
Survival of planted seedlings	Record the number of live and dead seedlings within the plot, where live = “trees have enough foliage to keep them alive (live cambium is present), and are rooted into the ground” and dead = “trees are obviously dead, or roots are separated from the ground”.	BC MoFLNRO 2015a (Table 4.2)
Vigour of planted seedlings	Describe general condition of seedlings using classification system 0 to 4, where: • 0 = dead • 1 = poor; yellow • 2 = fair; pale green • 3 = good; green • 4 = excellent; dark green	BC MoFR and BC MoE 2010; Haase 2008

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