Prioritizing Zones for Caribou Habitat Restoration in the Canada's Oil Sands Innovation Alliance (COSIA) Area. Version 3.0

Final Report – January 2020

Prepared for Canada's Oil Sands Innovation Alliance (COSIA)
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Preface

This report represents Version 3.0 of a project designed to prioritize townships for the restoration of seismic lines within caribou ranges in northeast Alberta. The study area occurs within the Canada's Oil Sands Innovation Alliance (COSIA) region. This is an iterative project that began with Version 1.0 in 2016 and Version 2.0 in 2017; throughout all project versions, it was recognized that this process is necessarily incremental, with new information and considerations incorporated over time. Therefore, while this report is a stand-alone product, Versions 1.0 (ABMI 2016) and 2.0 (ABMI 2017) can be referred to for further context.

Executive Summary

The objective of this project was to prioritize townships for the restoration of linear features within five caribou ranges in northeast Alberta: Cold Lake, East Side of the Athabasca River, Red Earth, Richardson, and West Side of the Athabasca River. In Versions 1.0 and 2.0, each township's priority was based on the potential increase of undisturbed caribou habitat that could be achieved through linear feature restoration, accounting for both the restoration cost and the potential for future resource development. Version 3.0 builds upon this work, introducing four additional objectives:

1. Incorporate caribou habitat value into township-level prioritization.
2. Integrate restoration with predicted future industrial disturbance, including both energy and forestry.
3. Consider decision-support guidance at multiple spatial scales, from regional, to township-level, to individual lines, to specific sites along individual lines, in consideration of operational restoration planning, logistics, and treatment requirements.
4. Include additional collaborators and stakeholders to broaden the scope of the analysis and ensure relevance of the project outcomes.

Not all parts of caribou range are equally important to caribou, therefore prioritizing seismic line restoration in areas of higher value habitat may have a greater conservation benefit. Caribou habitat value was included in the prioritization process through quantifying the intensity of caribou space use using Government of Alberta caribou GPS collar telemetry data. This approach guides restoration to areas in which caribou spend the majority of their time. While the federal Recovery Strategy considers all parts of caribou range to be critical habitat, prioritizing restoration in areas of high use provides the most immediate conservation benefit to caribou.

The overarching goal of this project is to provide a tool to help guide where to prioritize restoration to benefit caribou in a cost-effective manner while maintaining resource development on a shared landscape. Therefore, understanding where development is most likely to occur can reduce inefficient use of restoration funds and effort by guiding restoration away from areas likely to be developed, thus avoiding re-disturbance of lines following restoration. Previous versions of this project incorporated current and future industrial disturbance by precluding restoration within boundaries for operating, approved, applied for, and announced projects shown on the Government of Alberta's Oil Sands Information Portal (OSIP) website. Version 3.0 updates OSIP boundaries with more recent information,

and explicitly addresses the implications of forest harvest activities and scheduling on restoration. Given the inherent limitations of the data and assumptions used to develop this tool, it should be recognized that the tool is helpful to provide directional, not definitive, support to prioritize cost efficient caribou habitat restoration, and that it should not be used for other purposes such as prioritizing or restricting resource development. Furthermore, it is recognized that the location and timing of restoration will ultimately be driven by government policies and priorities.

To date, COSIA prioritization efforts have focussed at the township level, which addresses the need for operational economies of scale and creation of relatively large areas of biophysical intactness. However, effective and efficient restoration planning must also incorporate considerations at multiple spatial scales in order to meet the core indicators of success outlined in the *Provincial Restoration and Establishment Framework for Legacy Seismic lines in Alberta*. Prioritization guidance at the landscape, and alternatively sub-township, scale is therefore included in this iteration. This guidance includes – from broadest- to finest-scale – selecting among multiple high-priority townships (or groups of townships); ensuring access for restoration activities, aligning restoration with forestry activity; incorporating landscape factors influencing line treatment requirements such as community access, recreational off-highway vehicle (OHV) use, and soil moisture; and incorporating predator-prey dynamics into line treatment prescriptions.

To maximize the relevance and endorsement of the Prioritization 3.0 project outcomes, the technical work was guided by a multi-stakeholder advisory committee comprising COSIA and its member companies, other energy sector companies, forestry sector, Government of Alberta, and the research community.

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Introduction

Linear features, including seismic lines, pipelines, transmission lines, roads, railways, and trails are pervasive in Alberta's boreal forest. These features have been implicated as a primary factor leading to declines of boreal woodland caribou by increasing wolf use of caribou habitat (DeMars & Boutin 2018) as well as wolf hunting efficiency (Dickie et al. 2017). Seismic lines are by far the most numerous and widespread linear feature (ABMI 2017), and restoring seismic lines, with a primary goal of preventing wolf use of lines as travel corridors, is therefore a key action that can be taken to recover caribou (Environment Canada 2012; Government of Alberta 2017; AEP & ECCC 2019). However, given the extent of seismic lines – estimated at approximately 100,000 km within the Canada's Oil Sands Innovation Alliance (COSIA) area of interest (Figure 1) – it is necessary to prioritize areas to serve as starting points for restoration.

COSIA has previously retained with the Alberta Biodiversity Monitoring Institute (ABMI) to develop a method to prioritize townships within the COSIA area for restoration based on finding areas with high gain-in-undisturbed habitat for cost, termed bang-for-buck (ABMI 2016; hereafter Version 1.0). This version prioritized townships across the entire study area (all five caribou ranges), with the result being the majority of high priority townships being located in the Red Earth range. However, the federal Recovery Strategy for caribou (Environment Canada 2012) requires each range to be managed for the 65% undisturbed habitat threshold, therefore this method was refined in Version 2.0 (ABMI 2017) to develop an equal number of priority zones within each of the five caribou ranges: Cold Lake, East Side of the Athabasca River (ESAR), Red Earth, Richardson, and West Side of the Athabasca River (WSAR). This work has helped guide restoration projects conducted to date, particularly in the Cold Lake and ESAR ranges where over 1,200km of legacy seismic lines have been treated (RICC 2019).

However, from the outset, ABMI and COSIA have recognized that prioritization is necessarily an ongoing process, with additional considerations being incorporated in future iterations. Following the results of Versions 1.0 and 2.0, three new recommended modifications are addressed in this report (termed Version 3.0):

1. Differentiation of caribou habitat value within range boundaries. Caribou are not evenly distributed within their designated ranges. Home range fidelity, availability of biophysical resources, fire history, and anthropogenic disturbances may all influence caribou habitat value, and therefore space-use of individuals. Incorporating these differences in caribou habitat value within designated range boundaries can guide restoration toward areas caribou use more frequently, to more immediately benefit caribou populations.
2. Integrate and optimize restoration alongside multiple resource industries. Versions 1.0 and 2.0 explicitly considered future energy sector activity, but forestry is another major industrial land-use in the study area that may have implications for selecting priority restoration areas.
3. Considerations for prioritization at multiple spatial scales. Versions 1.0 and 2.0 focussed on prioritizing at the scale of the township because it is an operationally appropriate scale, enabling economies of scale and addressing caribou's need for relatively large areas of intactness. However, incorporating considerations at both broader and finer scales will improve the utility of decision-support provided by this project.

Additionally, a fourth key objective was to engage a broader cross-section of stakeholders to maximize the utility, application, and endorsement of the prioritization method being developed. This was primarily accomplished through the creation of an advisory committee comprising representatives from the energy, forestry, government, and research sectors. Feedback from this multi-sector group was sought and incorporated into the prioritization method throughout the process.

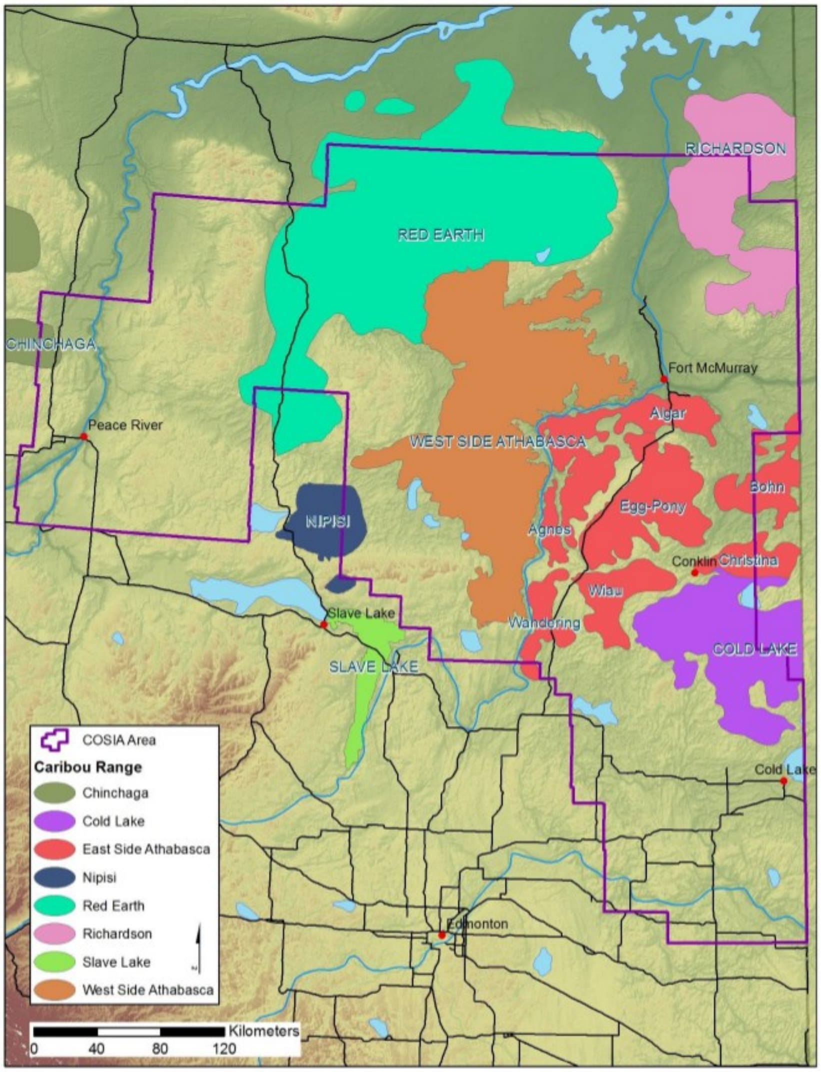

Figure 1. The COSIA area of interest for development of priority restoration zones, showing the COSIA boundary and caribou ranges considered for analyses (those with > 75% inside the area of interest; does not include Slave Lake, Nipisi, or Chinchaga ranges, or the two isolated segments of the Red Earth range to the northwest).

Incorporating Caribou Habitat Value into Township Prioritization

A key addition to Prioritization 3.0 was incorporating caribou habitat value into the method, in order to differentiate and prioritize areas of greater importance to caribou. Although the federal Recovery Strategy (Environment Canada 2012) indicates that all areas within caribou range are critical habitat, prioritization of high-use areas will provide the most immediate conservation benefit to caribou. A variety of metrics to represent caribou habitat quality were considered, each differing in their complexity, tractability, and data availability (Appendix 1: Caribou Habitat Value Metrics). Ultimately, caribou space-use was the metric chosen for caribou habitat value. Caribou space use was determined using telemetry data from individual GPS-collared caribou. The critical assumption to this metric is that the sample of GPS-collared caribou is representative of each range's population; if an area of high use happened to not have any collars deployed in it, then it would not appear to be a high-value area for caribou. However, the distribution of caribou fecal samples obtained through independent surveys visually aligns with the distribution of GPS-collar locations (T. Hegel, personal communication), suggesting the sample of collared animals is reasonably representative of the population at the range level (but see a discussion of the ESAR herds in the Methods section below). Finally, although GPS collars were only deployed on females, this is the critical demographic to capture for conservation matters, because caribou population growth is largely determined by recruitment and adult female survivorship (DeCesare et al. 2012a).

Methods

Township-level restoration potential was calculated in the same manner as Versions 1.0 and 2.0 (ABMI 2016, ABMI 2016), that is, the potential gain in undisturbed habitat through restoration of seismic lines, divided by the density of seismic lines within a township (hereafter termed "bang-for-buck"), both including and excluding forest fire disturbances. Throughout this report, only conventional, legacy seismic lines are considered, while low-impact seismic lines are omitted from all analyses. Therefore, for brevity, the term "seismic lines" can hereafter be interpreted as referring to conventional seismic lines only. Human footprint was updated to 2017 ABMI Human Footprint data (ABMI 2019). Fire perimeters were also updated up to 2019 (Government of Alberta 2019a).

Areas within current energy sector project boundaries from the Government of Alberta's Oil Sands Information Portal (OSIP) website were not considered as candidates for restoration (see Limitations, Uncertainties, and Next Steps of this report for a discussion on limitations of the OSIP boundaries). These boundaries were updated to the most recent version of these data, 2016 OSIP project boundaries (Government of Alberta 2019b). For all analyses, areas within 2016 OSIP operating, approved, applied for, and announced project boundaries were not considered to be available for restoration. In the "announced" category, only projects that appeared on the Alberta Energy Regulator (AER) Scheme Approval Map Viewer or had a proposed Terms of Reference for an Environmental Impact Assessment submitted to the Government of Alberta were included in this analysis. If a township was partly overlapped by an OSIP project boundary, only the portion of the township outside the OSIP boundary was considered available for restoration. It is important to note that project statuses and geographical boundaries change frequently as industrial activities are carried out. Therefore, defining current project areas using OSIP boundaries has spatial and temporal limitations that are important to consider (see Limitations, Uncertainties, and Next Steps for a discussion on the limitations of OSIP boundaries).

To incorporate caribou habitat value into the prioritization, telemetry data from GPS-collared caribou in each of the 5 ranges in the COSIA area of interest were used to develop range-level layers of caribou space use. GPS collar deployment began in different years for each range, and for all ranges includes collar data up to 2019. Deployment began in WSAR in 1998, followed by ESAR (2008), Richardson (2009), Red Earth (2011), and Cold Lake (2012). Although GPS data from WSAR extends over a longer monitoring period than the other ranges, many individuals collared more recently (post-2010) use the same areas that were used in the earlier portion of the dataset. The more recent collaring efforts in WSAR have made the telemetry database more representative by deploying collars in previously underrepresented parts of the range.

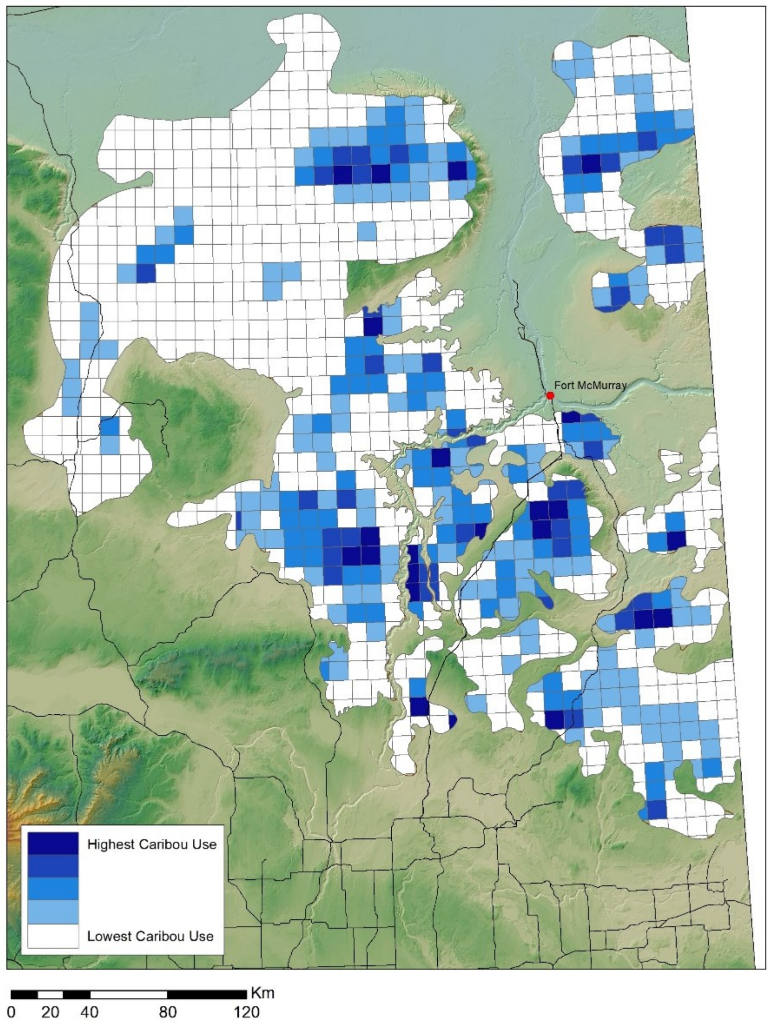

Figure 2. Distribution of caribou-use index at the township level, based on telemetry data from GPS-collared caribou. This map does not provide information regarding other aspects of the prioritization process, and instead focusses on how caribou habitat value will be incorporated into that process.

For each individual caribou, a "utilization distribution" (*i.e.* the probability of use across an individual's home range) was developed in R (R Core team 2019) using the package "adehabitatHR" (Calenge 2006). The smoothing parameter for each individual utilization distribution was calculated using the reference method (Calenge 2006). The utilization distribution captures an individual's intensity of space-use, which is critical for guiding restoration to areas more frequently used by caribou. The individual utilization distributions were averaged across all individuals in a range to create a range-level index of caribou use. This measure is a metric of what parts of each caribou range are used more or less intensively by the local population. The average index of caribou use was then calculated for each township in the study area, and subsequently standardized within each range by dividing each township's index value with the maximum value within the same caribou range. For ESAR, this standardization was performed for each of the 7 herds, to account for the uneven distribution of GPS collars across herds. Thus, the caribou-use index is range-specific, and falls between 0-1, with the most highly used township in each range (or each herd in the case of ESAR) receiving an index value of 1 (Figure 2).

Following the method used in Prioritization 2.0 (ABMI 2017), each township's "Bang-for-Buck" was calculated as its potential gain-in-undisturbed habitat achieved through linear restoration, divided by its density of seismic lines (a proxy for restoration cost). The Bang-for-Buck for each township was then multiplied by the township's normalized Resource Valuation Layer (RVL), which is a modelled estimate of potential future resource value (see Limitations, Uncertainties, and Next Steps for a discussion of RVL), in order to divert restoration effort away from areas more likely to be developed in the near future. Normalized RVL was calculated for each township as ($1 – RVL/RVL_{max}$), such that all township RVL_{norm} scores are between 0-1. Thus, lower RVL_{norm} scores represent high-resource-value townships, such that the RVL-adjusted bang-for-buck scores are decreased.

The township-level caribou-use index was combined with the RVL-adjusted bang-for-buck by multiplying the RVL-adjusted Bang-for-Buck score by the caribou-use index for each township. Priority zones were developed with the the resulting output. Following the township-level scoring according to each of the above three options, priority Zones 1-5 were created by grouping townships into quintiles for each range, following the prioritization methodology from versions 1.0 and 2.0, such that each zone is approximately 1/5 of the total range area. Two other options were considered for incorporating the metric of caribou use, however this option places the most weight on areas used by caribou. See Appendix 2: Alternative Weightings and Sensitivity Analysis for a discussion of the alternate weighting schemes, and the sensitivity of results to this decision.

Following the creation of priority restoration zones, the overall habitat disturbance state was estimated following hypothetical restoration of successive zones and evaluated against the 35% disturbance target (Environment Canada 2012). These results are presented for scenarios excluding fire, including fire, and also considering restoration of all temporary features in contrast to restoration of only seismic lines. Temporary features include seismic lines, forestry harvest areas, vegetated roads/trails, pipelines, transmission lines, borrow-pits, dugouts, sumps, and rural industrial sites (termed "semi-permanent features" in Version 2.0; see Table 3 in ABMI 2017 for additional details).

The 35% disturbance target (Environment Canada 2012) is derived using a 30m resolution landcover layer. In contrast, ABMI's 2017 human footprint layer is of a higher resolution, and thus identifies smaller features such as seismic lines. Compared to ECCC's landcover layer (ECCC 2019), ABMI's human footprint layer shows a higher level of disturbance for a given parcel of land than that used to develop the 35% disturbance target. Therefore, following the method used in Version 2.0 (ABMI 2017), ABMI disturbance estimates were calibrated to ECCC disturbance estimates at the township level for each range; calibration results are available in Appendix 3: Disturbance Calibration Results. All results are presented using both ABMI and ECCC-calibrated disturbance states.

Results and Discussion

The restoration priority zones are presented in Figure 3. When excluding fire, restoring only seismic lines in zone 1 achieves the 35% target for Richardson, and restoring only seismic lines in zones 1-3 achieves the target for Red Earth, while none of the other ranges reaches this level (Table 1). Using ECCC-calibrated disturbance levels, WSAR and Cold Lake approach the 35% threshold following restoration of only seismic lines in all five zones (Final calibrated disturbance levels of 36.5% and 39.5, respectively). The full results of zone-by-zone restoration of only seismic lines on total disturbance levels in each range are presented in Table 1. These results are comparable to the zone-by-zone results from Version 2.0, in terms of the decrease in disturbance as restoration progresses through zones, as well as the number of ranges reaching the 35% disturbance threshold.

As demonstrated in Versions 1.0 and 2.0, including fire disturbances <40 years old (Environment Canada 2012) greatly increases the levels of disturbed habitat observed, such that none of the ranges reach the 35% disturbance threshold even after restoring all five zones, including when using ECCC-calibrated disturbance results (Table 2). These existing fires <40 years old will, by ECCC definition, recover as they reach age 40 and no longer be considered disturbed. However, new fires will continue to occur into the future. Therefore, results are presented both including and excluding fires to provide an approximate assessment of the potential effect of fire disturbance in meeting habitat disturbance targets, even though the exact amount and spatial distribution of future fires will be different from what is observed today.

Restoring all temporary footprint types dramatically improves the disturbance state of all caribou ranges, particularly when fire is excluded (Table 3, Table 4). This scenario is the most optimistic, under which all five caribou ranges meet the 35% disturbance target, even using uncalibrated disturbance. This scenario is also operationally relevant, as current approaches to restoration treat all linear features within a project area, whether classified as legacy seismic or not. However, when fire is considered, only WSAR reaches the 35% disturbance target, using either calibrated or uncalibrated disturbance values. Additional discussion on the other footprint types, particularly the role of forestry in restoration planning, is provided in the Multi-Scale Prioritization and Operational Guidance section.

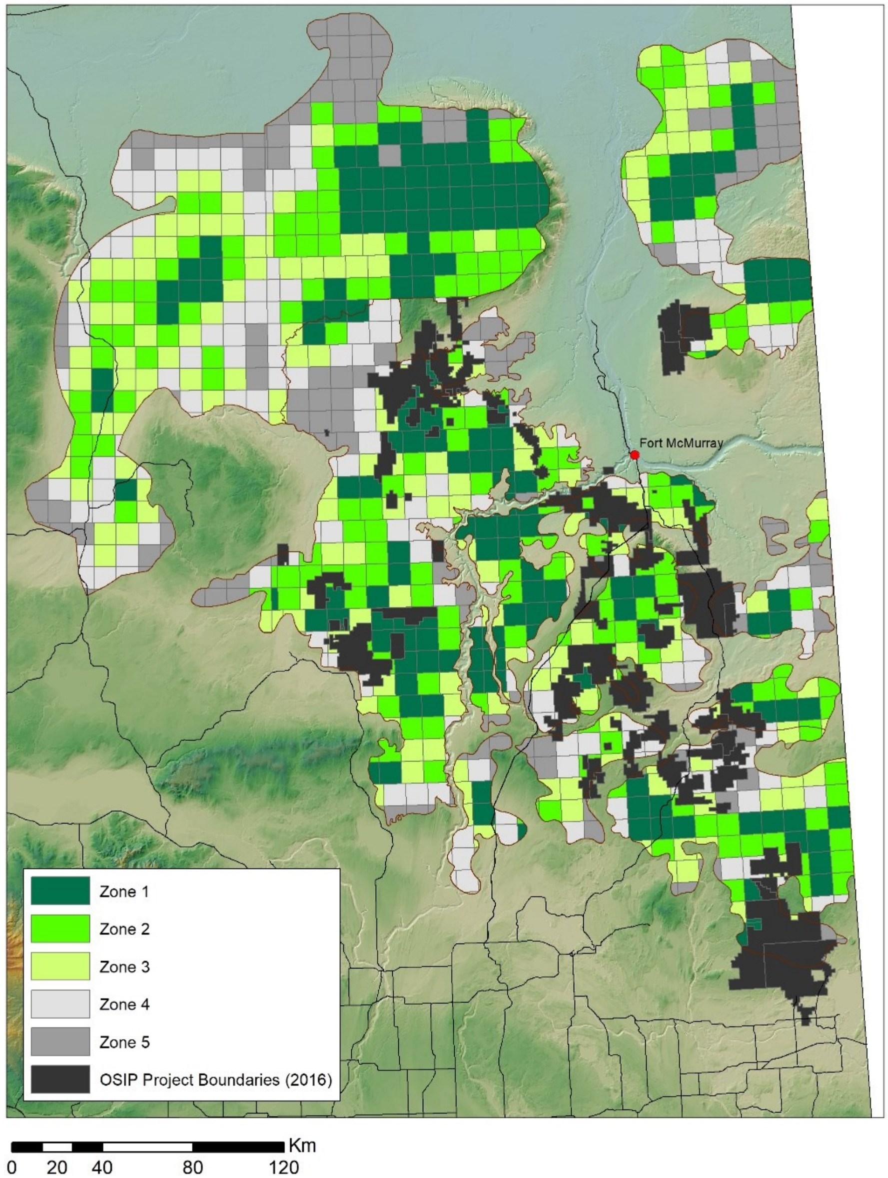

Figure 3. Restoration Priority zones incorporating cost-efficiency, potential future resource value, and caribou space use. Townships are ranked into priority zones for restoration, with Zone 1 being highest priority and Zone 5 (dark grey) the lowest. Any area within 2016 OSIP boundaries (operating, approved, applied for, and announced projects), are considered non-candidate areas for restoration (black).

Table 1. The change in percent (%) disturbance (excluding fire) as restoration progresses from Zone 1 through 5 resulting from restoring seismic lines only, reporting both ABMI 2017 and ECCC-calibrated disturbance levels. Any area within 2016 OSIP boundaries (operating, approved, applied for, and announced projects, buffered by 500m), are considered disturbed.

	% Disturbance Remaining (Excluding Fire)											
	Current % Disturbed		Zone 1 Restored		Zones 1-2 Restored		Zones 1-3 Restored		Zones 1-4 Restored		Zones 1-5 Restored	
Range	**ABMI**	**ECCC**	**ABMI**	**ECCC**	**ABMI**	**ECCC**	**ABMI**	**ECCC**	**ABMI**	**ECCC**	**ABMI**	**ECCC**
Red Earth	68.0	47.1	57.3	39.2	46.1	31.1	35.4	23.2	26.2	16.5	22.8	14.0
Richardson	35.9	22.8	31.2	18.6	27.0	14.9	22.4	10.8	18.5	7.4	18.4	7.2
WSAR	85.5	69.8	76.7	61.8	67.8	53.6	60.6	47.0	53.8	40.9	49.1	36.5
ESAR	88.6	77.3	79.9	68.3	71.1	59.2	66.3	54.3	60.8	48.6	59.0	46.8
Cold Lake	86.8	72.3	76.7	61.4	67.6	51.4	61.7	44.9	58.0	41.0	56.7	39.5

Table 2. The change in percent (%) disturbance (including fire) as restoration progresses from Zone 1 through 5 resulting from restoring seismic lines only, reporting both ABMI 2017 and ECCC-calibrated disturbance levels. Any area within 2016 OSIP boundaries (operating, approved, applied for, and announced projects, buffered by 500m), are considered disturbed.

	% Disturbance Remaining (Including Fire)											
	Current % Disturbed		Zone 1 Restored		Zones 1-2 Restored		Zones 1-3 Restored		Zones 1-4 Restored		Zones 1-5 Restored	
Range	**ABMI**	**ECCC**	**ABMI**	**ECCC**	**ABMI**	**ECCC**	**ABMI**	**ECCC**	**ABMI**	**ECCC**	**ABMI**	**ECCC**
Red Earth	81.3	72.2	77.3	69.3	70.9	64.7	64.7	60.3	58.4	55.7	55.3	53.5
Richardson	90.6	87.8	89.1	85.9	87.6	84.1	87.1	83.5	85.0	81.1	84.9	80.9
WSAR	87.2	68.9	79.4	62.3	71.2	55.3	64.8	49.8	58.7	44.6	54.9	41.3
ESAR	90.9	82.1	82.8	73.8	78.7	69.7	75.1	66.1	71.7	62.7	70.6	61.5
Cold Lake	92.7	86.0	85.9	78.7	80.5	73.0	77.5	69.8	75.7	67.9	74.9	67.1

Table 3. The change in percent (%) disturbance (excluding fire) as restoration progresses from Zone 1 through 5 resulting from restoring seismic lines and temporary features, reporting both ABMI 2017 and ECCC-calibrated disturbance levels. Any area within 2016 OSIP boundaries (operating, approved, applied for, and announced projects, buffered by 500m), are considered disturbed.

	% Disturbance Remaining (Excluding Fire, Including Restoring Temporary Features)											
	Current % Disturbed		Zone 1 Restored		Zones 1-2 Restored		Zones 1-3 Restored		Zones 1-4 Restored		Zones 1-5 Restored	
Range	**ABMI**	**ECCC**	**ABMI**	**ECCC**	**ABMI**	**ECCC**	**ABMI**	**ECCC**	**ABMI**	**ECCC**	**ABMI**	**ECCC**
Red Earth	68.0	47.1	56.1	38.4	41.5	27.7	26.0	16.4	13.4	7.1	8.8	3.8
Richardson	35.9	22.8	30.1	17.7	24.4	12.5	18.4	7.2	8.2	0.0	6.7	0.0
WSAR	85.5	69.8	72.2	57.6	57.8	44.5	45.7	33.4	33.8	22.5	24.6	14.2
ESAR	88.6	77.3	71.7	59.9	57.9	45.6	45.5	32.9	33.0	19.9	27.1	13.9
Cold Lake	86.8	72.3	71.5	55.6	56.6	39.4	46.9	28.8	38.4	19.6	34.7	15.5

Table 4. The change in percent (%) disturbance (including fire) as restoration progresses from Zone 1 through 5 resulting from restoring seismic lines and temporary features, reporting both ABMI 2017 and ECCC-calibrated disturbance levels. Any area within 2016 OSIP boundaries (operating, approved, applied for, and announced projects, buffered by 500m), are considered disturbed.

	% Disturbance Remaining (Including Fire, and Restoring Temporary Features)											
	Current % Disturbed		Zone 1 Restored		Zones 1-2 Restored		Zones 1-3 Restored		Zones 1-4 Restored		Zones 1-5 Restored	
Range	**ABMI**	**ECCC**	**ABMI**	**ECCC**	**ABMI**	**ECCC**	**ABMI**	**ECCC**	**ABMI**	**ECCC**	**ABMI**	**ECCC**
Red Earth	81.3	72.2	76.8	68.9	68.2	62.8	59.0	56.2	49.9	49.7	45.7	46.7
Richardson	90.6	87.8	88.6	85.3	86.0	82.3	85.0	81.1	77.9	72.7	77.0	71.7
WSAR	87.2	68.9	75.3	58.8	61.9	47.4	51.0	38.0	40.1	28.7	32.6	22.2
ESAR	90.9	82.1	77.6	68.6	69.7	60.7	62.3	53.1	55.0	45.8	51.1	41.9
Cold Lake	92.7	86.0	81.8	74.4	71.6	63.6	66.3	58.0	61.2	52.5	58.7	50.0

Multi-Scale Prioritization and Operational Guidance

Townships are an operationally convenient unit for restoration prioritization, due largely to the high cost and logistical difficulties of deploying people and equipment to remote areas to conduct restoration. Further, caribou require large, contiguous areas, and as such restoring reasonably large areas such as townships is more ecologically relevant than restoring individual disparate lines. However, it was recognized in Version 1.0 that township-level zonation is appropriate for coarse-filter, strategic planning, and that comprehensive decision-support requires considerations at both broader and finer spatial scales.

Version 1.0 highlighted the need for within-township assessments as follows: "Planning systems for a finer spatial scale are desirable in order to account for matters such as 1) unpredictable natural regeneration success in the boreal, 2) spatial relationships between different habitat types such as upland mixed woods, creeks and drainages, and bog and fen complexes, 3) appropriate silvicultural prescriptions at the feature scale, and 4) prioritization at the feature scale based on knowledge of predator and prey responses to treatment and regeneration status" (ABMI 2016). In addition to these fine-scale considerations, a regional perspective is also required for maximizing the value of decision support. This includes guidance around restoring large contiguous tracts of caribou habitat, logistical considerations such as the availability of access for conducting restoration, and how to integrate restoration with ongoing forestry.

These multi-scale factors – as well as the township-level factors discussed above – directly address the core indicators of success outlined in the draft Provincial Restoration and Establishment Framework for Legacy Seismic lines in Alberta (hereafter the "Restoration Framework"; Government of Alberta 2018):

- Restoration programs and locations have been selected based on relevance to woodland caribou and contribute to efforts to restore large tracts of woodland caribou habitat.
- Where advanced regeneration is not evident, treatments have addressed site limiting factors and have established appropriate trees based on the adjacent habitat.
- Where advanced regeneration is already present and to the degree feasible, this advanced regeneration has been protected.
- The treatments limit human and predator movement on the landscape.

These considerations range from the regional-level, to the project- or township-level, to the individual line- or site-level. Considerations at each spatial scale are demonstrated below with an example from the Cold Lake range (Figure 4), and potential data sources and additional resources for addressing each consideration are provided where available.

Regional-Level Considerations

The first indicator of success – restoring contiguous areas important to caribou – is partially addressed through the inclusion of caribou habitat use in the township-level prioritization detailed above. However, a single high-priority township on its own does not constitute a large contiguous area for caribou. Given that a primary goal of linear restoration is to reduce wolf predation by limiting wolf use of lines, the ecologically relevant scale for restoring "large tracts" of caribou habitat is the scale of a wolf pack territory, at least 500-1000km^2 (Spangenberg et al. 2019); this translates to areas comprising ≥ 5-10 townships. In the Cold Lake example, two primary candidate areas for restoration are apparent (Figure 4): a western section around the Clyde Lake Provincial Recreation Area (PRA), and a central section extending westward from the completed LiDEA restoration project. The Clyde Lake area is intensively used by caribou (Figure 2) and reasonably large and compact. The area comprises six Zone 1 townships (*i.e.* ~600km^2, on the order of a wolf pack territory size), and is used as an example below.

Related to the importance of large contiguous areas is the presence of any designated protected areas such as provincial or national parks. Such protected areas may or may not be highly used by caribou, but they do represent areas with near-zero probability of future development, providing considerable certainty that restoration efforts would not be disturbed in the future. Specific land-use designations allow different levels of infrastructure, so this should be evaluated in addition to their presence.

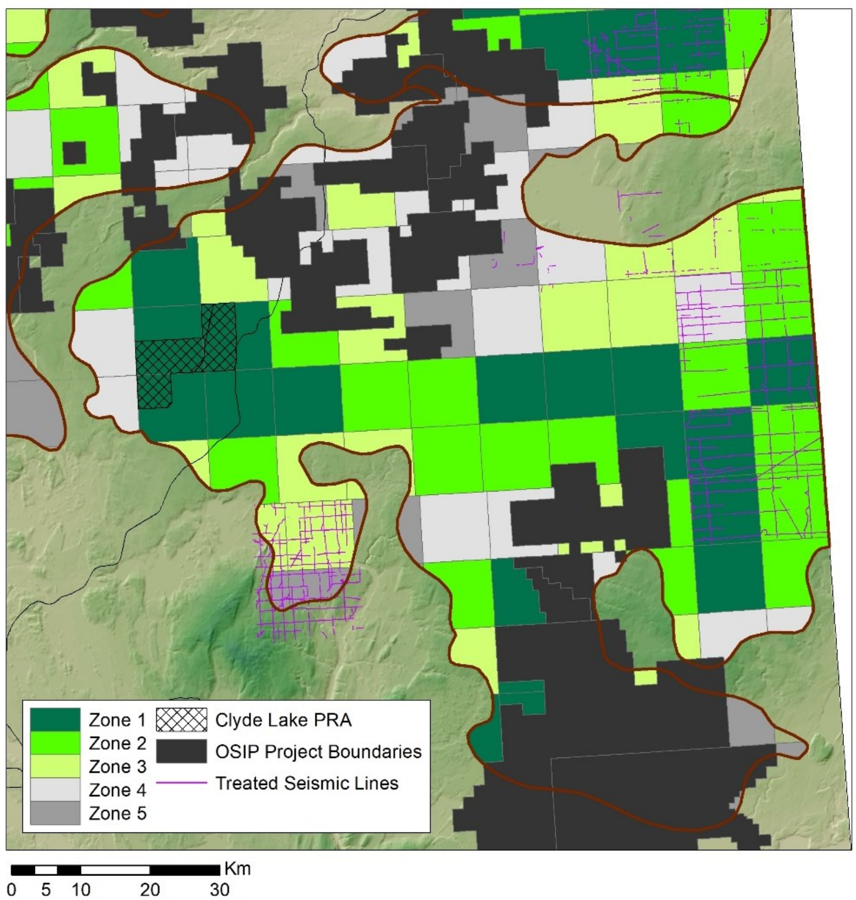

Figure 4. Priority restoration zones and important land-use features in the Cold Lake caribou range. Townships are ranked into priority zones for restoration, with Zone 1 being highest priority and Zone 5 (dark grey) the lowest. Any area within 2016 OSIP boundaries (operating, approved, applied for, and announced projects), are considered non-candidate areas for restoration (black).

Project-Level Considerations – Access & Logistics

Primary considerations at the project scale relate to site access, currently and in the future. Access opportunities and restrictions to conduct restoration has a significant impact on project cost. Therefore, selecting sites with reasonable access is an important cost-control measure. Access is continually changing, so there may be opportunities to align the timing of restoration with future access in areas that currently have none; this is particularly true with access created for forest harvest, which follows a relatively well-defined schedule (see Integrating Forestry and Restoration section below).

The corollary to this is that legacy seismic lines themselves may serve as important access routes to other seismic lines that require restoration, and there is a risk that a given restoration project may strand more remote lines, necessitating re-disturbance of lines to reach more remote areas in the future. Examining the potential for this type of line stranding is therefore an important component of operational planning in a specific area. In the provided Clyde Lake example (Figure 5), Highway 881 provides continued access to adjacent areas to the northeast and south, and a railway running parallel to the highway may also provide access. Lower-priority (*i.e.* Zone 2) areas to the west and east do not have any permanent access features such as roads or railways, but pipeline networks extend into these Zone 2 townships. Although use of the pipelines and railway for restoration access depends on available space and potential crossing issues, there is a relatively low risk of line stranding should restoration proceed in the Zone 1 townships around the Clyde Lake PRA. There may be opportunities to restore temporary features within this area while seismic restoration occurs, for example the extensive pipeline network. Therefore, any operational planning for this region should investigate the lifespan of these features, to determine whether there is a possibility for restoring them, and over what time frame.

In addition to access for future restoration, seismic lines may provide access for ongoing work by other industrial operators. For example, where winter access is common, seismic lines may partly be used by other industrial users to access operating sites, as well as during site reclamation. Therefore, whenever seismic line restoration is being considered in an area, considering and engaging with other industrial operations is critical to prevent potential land access conflicts.

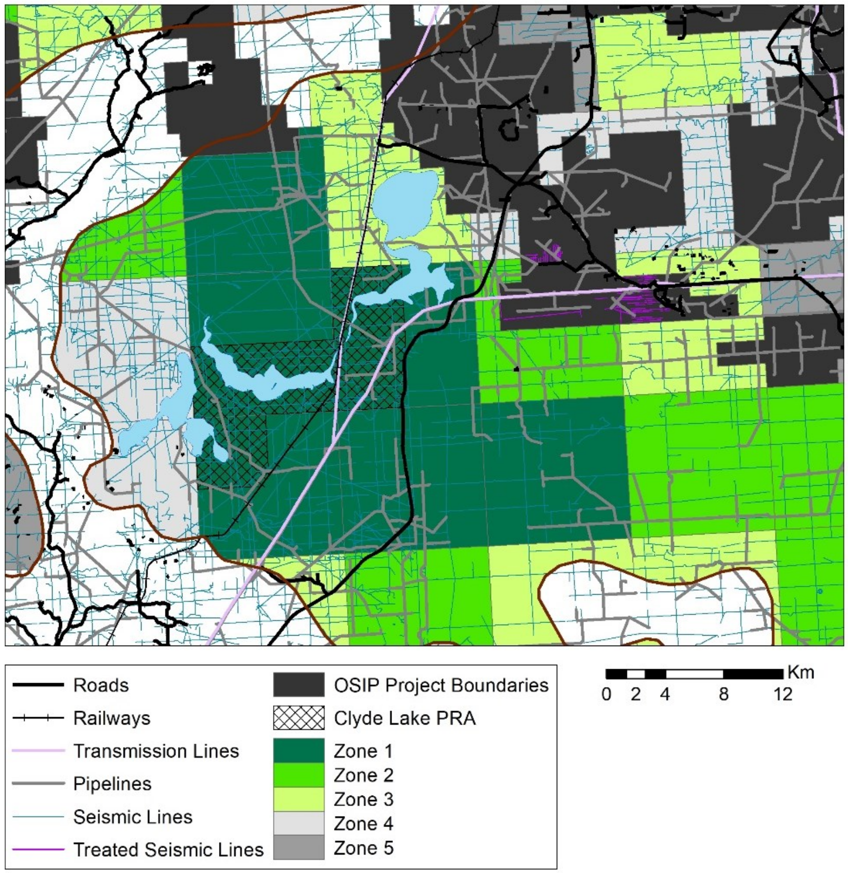

Figure 5. Potential restoration area within the Cold Lake caribou range, centred on the Clyde Lake PRA, depicting priority zones, seismic lines, access features, and major land uses. Townships are ranked into priority zones for restoration, with Zone 1 being highest priority and Zone 5 (dark grey) the lowest. Any area within 2016 OSIP boundaries (operating, approved, applied for, and announced projects), are considered non-candidate areas for restoration (black).

Integrating Forestry and Restoration

Caribou habitat restoration prioritization has previously taken into consideration current and potential energy development via the inclusion of OSIP boundaries and the Resource Valuation Layer (ABMI 2016; ABMI 2017). However, the energy sector operates on a shared working landscape with other resource industries, in particular the forestry industry. While forestry within high-value caribou habitat (*i.e.* peatlands) in caribou ranges is limited by the lack of merchantable timber in these areas, timber harvest may occur in upland sites adjacent to these peatlands. Additionally, forestry companies are responsible for restoring legacy seismic lines that fall within harvest areas (AAF 2018). Therefore, there exists a possibility to align linear feature restoration in peatlands adjacent to timber harvest while forestry access is in place.

Timber harvest schedules within caribou ranges are currently slated for development under the Draft *Agreement for the Conservation and Recovery of the Woodland Caribou in Alberta* between Alberta and

Canada (AEP & ECCC 2019), as alternatives to the typical 20-year Spatial Harvest Sequence created by Forest Management Agreement (FMA) holders. The goal of these amended plans is to develop "Sequencing Units" that aggregate forest harvest in both time and space to reduce the extent and duration of harvest footprint and associated disturbance buffers. This includes harvesting areas as close as possible to each other to minimize buffered disturbance, and completely harvesting each Sequencing Unit within a 10-year time window, then not entered again until the next forestry rotation many decades later. Conducting linear restoration while this temporary access is in place is a potentially significant cost-saving measure; additionally, some equipment for line treatment may already be in place, for example in coniferous harvest blocks that require mechanical site preparation as part of silvicultural treatments following harvest. AEP & ECCC (2019) provides the following schedule for developing the alternative timber harvest sequences for ranges in the COSIA study area:

- Cold Lake – 2019-2020 (ongoing as part of the range planning process)
- ESAR – 2020-2022
- WSAR, Richardson, Red Earth – 2021-2023

Given that the revised timber harvest sequences within caribou ranges have not yet been developed, it is not possible at this time to provide spatially explicit guidance around how or where to integrate restoration with forest harvest. However, forestry planning to date suggests that opportunities for combining forest harvest and linear restoration are most likely to exist in areas adjacent to core caribou home ranges (*i.e.* the highest-use areas in Figure 2). The FMA holder in the area, Alberta-Pacific Forest Industries has already deferred harvest for a 20-year period within many of the high-value caribou areas in the region (Al-Pac 2015), in order to create a spatiotemporal window of opportunity for government-led range planning to occur. However, these deferrals necessarily limit the potential for combined harvest and restoration in much of Restoration Zone 1. Furthermore, development of the alternative sequence for the Cold Lake range has indicated that high-value caribou areas may be avoided in the earlier parts of the 100-year planning window (T. Hegel, personal communication.). While this approach is important for minimizing new disturbance in high-value caribou habitat, it may be unhelpful for guiding short-term restoration efforts toward the highest-use caribou areas. Nevertheless, if access is being removed from a given near-term sequencing unit in 10 years, then it may still be more efficient and cost-effective for restoration to be prioritized in such units while access is in place, recognizing that restoration within and adjacent to these near-term sequencing units will only represent a small portion of the total restoration effort required for caribou recovery.

The opportunities for restoration efficiency – and value to caribou – created by pairing restoration adjacent to harvest areas will be highly dependent on the distribution of harvest cutblocks, caribou use, and seismic lines. Therefore, no general conclusions or single rule-set can capture this variability, and opportunities for coordinated restoration will need to be assessed on a case-by-case basis. Importantly, this type of coordination requires bilateral consideration. Not only should restoration planning consider scheduled forestry activity, but also development of alternative timber harvest schedules within caribou range must consider opportunities for restoration of priority areas.

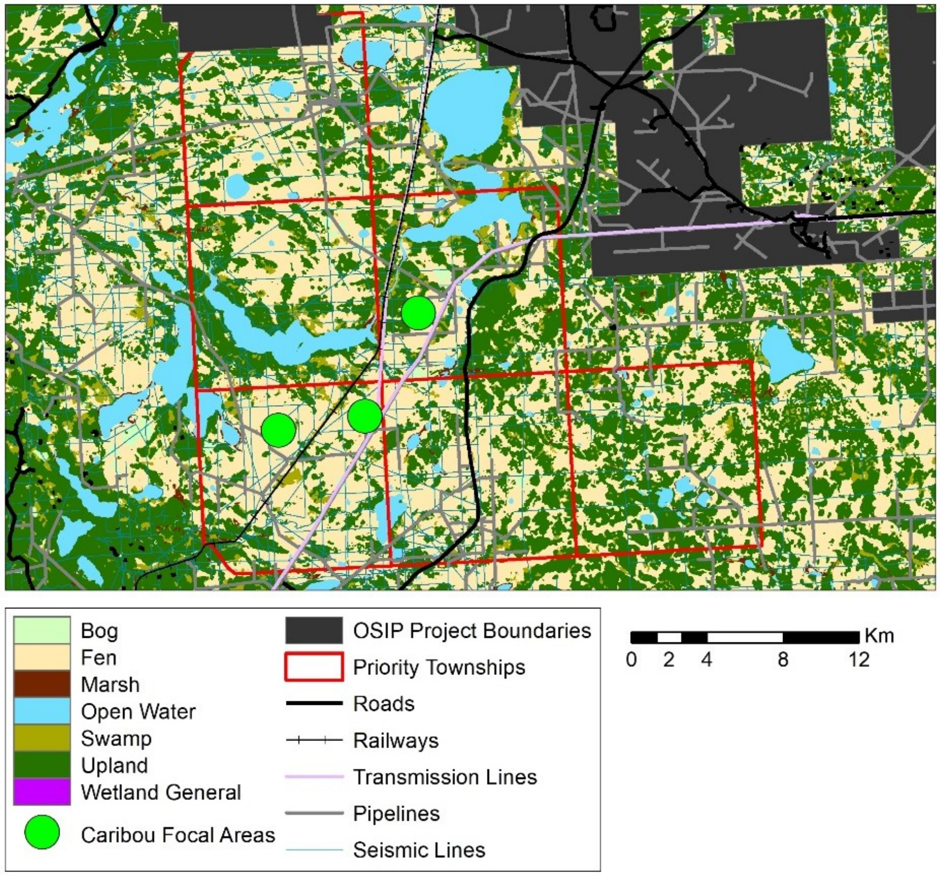

Figure 6. Potential restoration area within the Cold Lake caribou range, centred on Clyde Lake, depicting landcover and localized areas of high caribou use. Any area within 2016 OSIP boundaries (operating, approved, applied for, and announced projects), are considered non-candidate areas for restoration (black).

Line/Site Specific Considerations – Regeneration & Predator-Prey Ecology

The need for guidance around line-specific or site-scale decisions ultimately stems from the fact that not all lines are created equal. Ecosite, soil moisture, line width, proximity to roads, proximity to development, and fire history all influence the degree of natural regeneration that will occur on legacy seismic lines (Filicetti and Nielsen 2018, van Rensen et al. 2015, Hornseth et al. 2018, Filicetti et al. 2019). Most site-limiting factors must be ground-truthed in the field, but a desktop analysis may provide some insight into the levels of restoration effort required. While each of these factors can influence vegetation recovery, they act through different mechanisms, and therefore require different treatments; *i.e.* "treatments [address] site limiting factors" (Government of Alberta 2018). A variety of restoration treatments have been implemented to date in Alberta and British Columbia, and include measures to establish trees as well as line-blocking techniques to prevent recreational motorized human access (*i.e.* OHVs) to regenerating lines (Pyper et al. 2014; Pyper and Broadley 2019; Golder 2015; Government of Alberta 2018).

In the example here, seismic lines intersecting permanent roads (*e.g.* highway 881), the railway, and the pipeline/transmission utility corridor running between these two features would be expected to have high levels of recreational OHV use, and therefore increased treatment requirements for soil decompaction and line-blocking (Figure 5). The creation of the Clyde Lake Provincial Recreation Area may also influence the amount of recreational motorized access in the region, further highlighting the need for access management planning as part of caribou range planning and/or regional land-use planning, but this is beyond the scope of this project. Soil moisture may be assessed using Wet Areas Mapping (White et al. 2012), if the restoration area falls within coverage of this dataset. In the Clyde Lake area, wet areas mapping only covers a portion of the priority restoration area, but it indicates very wet areas throughout (not shown). Therefore, advanced natural regeneration of lines is unlikely in many areas, and creation of microsites via mounding may be required.

Beyond site-limiting factors, considering caribou ecology and predator-prey dynamics should also play a role in determining appropriate treatment types or intensities. While predators may exist throughout a restoration program area, in terms of caribou ecology, the largest risk to caribou occurs where upland areas transition into large peat complexes that are highly used by caribou (James et al. 2004; DeMars & Boutin 2018). Due to the skewed distribution of caribou use (Figure 8), Priority Zone 1 covers a large range of caribou use, with a handful of townships - and localized areas within them - receiving extremely intense use. These focal caribou-use areas should be highlighted in operational plans for additional line-blocking measures to functionally restore lines and potentially create a more immediate reduction in predator use of these important caribou areas. Functional restoration measures include line-blocking via stem bending, intensive mounding, spreading logs or other woody debris, creating berms, or installing fencing. Although replacing mounding/planting with intensive line blocking in these areas may be more cost-effective, restoration flexibility is limited by the Restoration Framework, which outlines specific numeric targets for seedling survival (2,500-5,000 stems/ha, depending on ecosite), and does not provide an option for line-blocking-only treatments in some high caribou-use areas. Ideally, reducing movement efficiency can also be combined with reforestation treatments. In the Clyde Lake area, three peatland complexes show particularly high levels of caribou use (Figure 6); lines in these areas are candidates for intensive line-blocking, particularly at transition zones between peat complexes and adjacent upland areas.

A Silviculture Toolkit with visual resources on how and where to apply different site treatments is available at www.360tours.cosia.ca. Data sources for desktop analysis of line characteristics and site conditions outlined above are presented in Figure 7 and Table 5.

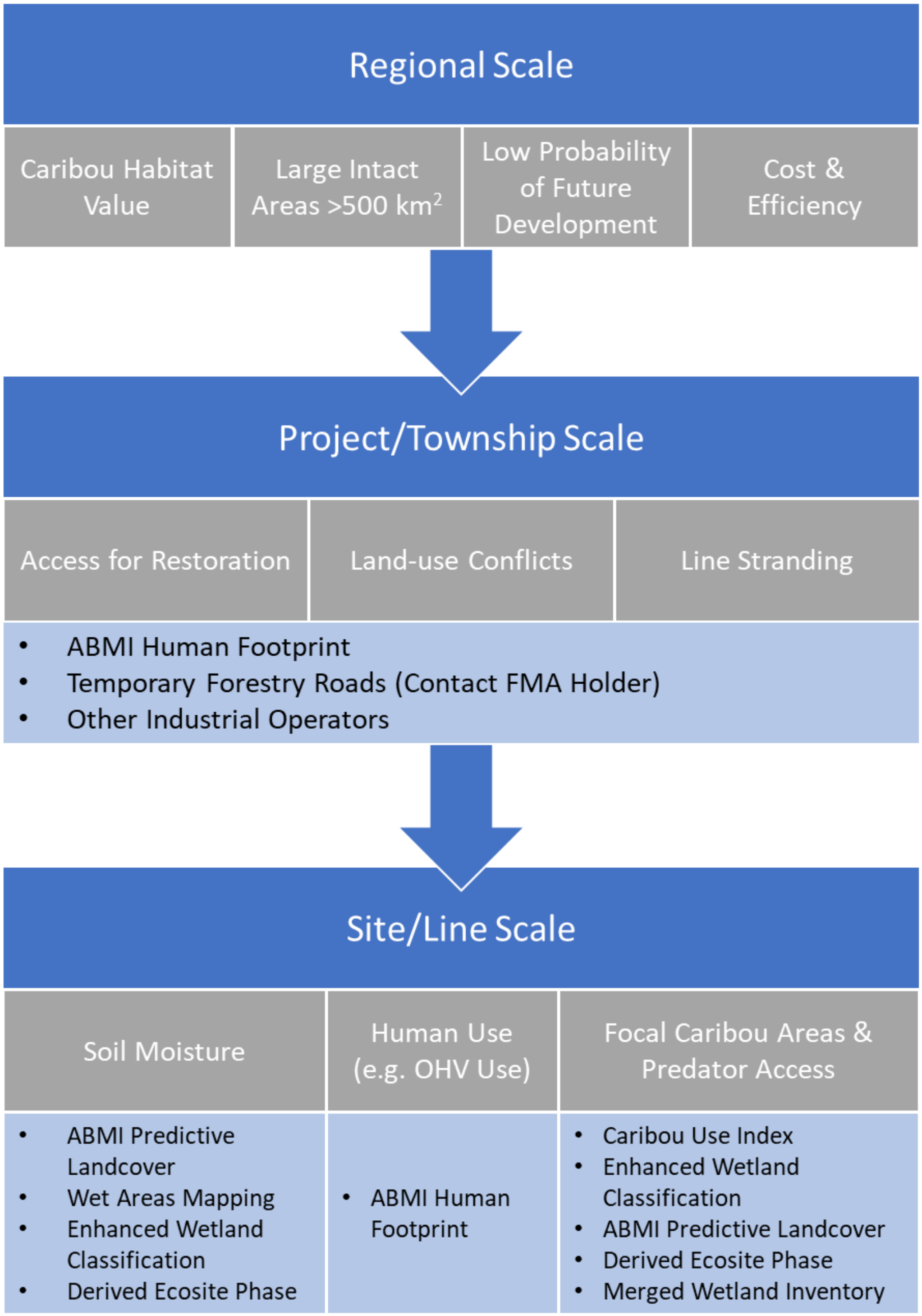

Figure 7. Multi-scale restoration considerations and key data sources for decision-support.

Table 5. Potential data sources for multi-scale restoration decision-support.

Dataset	Consideration(s) Addressed	Comments, Advantages, and Limitations
ABMI Human Footprint	Access for Restoration Line Stranding Recreational Human Use	Most comprehensive dataset available. Publicly available province-wide. Updated every 1-2 years. Does not include all temporary features such as for temporary forestry roads. Due to a data-sharing issue, current version does not include pipelines. Pipeline layer available from AER until issue is resolved.
Temporary Forestry Roads	Access for Restoration Line Stranding	Contact FMA holder or other forestry operators for availability.
ABMI Predictive Landcover	Soil Moisture Focal Caribou Areas (Peatland Complexes)	Publicly available province-wide (DeLancey et al. 2019). Simplified landcover categories, and soil moisture is not directly estimated. Wet Areas Mapping or Enhanced Wetland Classification are preferred if available.
Enhanced Wetland Classification (EWC)	Soil Moisture Focal Caribou Areas (Peatland Complexes)	Developed by Ducks Unlimited Canada (DUC) in collaboration with forest industry partners. Not available in all areas. Contact DUC for information.
Alberta Merged Wetland Inventory	Focal Caribou Areas (Peatland Complexes)	Wetland inventory maintained by the Government of Alberta, created by merging 35 wetland inventories into a single layer with province-wide coverage.
Derived Ecosite Phase	Soil Moisture Focal Caribou Areas (Peatland Complexes)	Predicted ecosite layer developed by the Government of Alberta, based on Alberta Vegetation Inventory and Light Detection and Ranging (LiDAR)-derived datasets. Available from Government of Alberta.
Wet Areas Mapping (WAM)	Soil Moisture	Not available in all areas. Available from Government of Alberta.

Limitations, Uncertainties, and Next Steps

Caribou Habitat Value

The principal addition of Version 3.0 is incorporating caribou habitat value into the prioritization process, in the form of areas of high caribou space use. As other caribou habitat layers are developed by the research community there may be opportunities to refine this method using more detailed metrics, such as demographic habitat quality (DeCesare et al. 2014) that directly estimates determinates of caribou fitness across the landscape. A key difference between caribou space use and metrics based on spatial modelling (Appendix 1: Caribou Habitat Value Metrics) is that the latter will also place value on areas of potential high-value caribou habitat that is not currently being used, but may be used by caribou in the future. Such an approach would likely distribute high priority townships more extensively throughout caribou ranges, which has long-term value given that caribou will likely shift their range use over time in unpredictable ways, for example due to future fires that may occur in current high-use areas. The disadvantage to a more extensive approach that also prioritizes potential caribou habitat is that caribou are declining right now, and restoring elsewhere in areas with an uncertain amount of future caribou use does not address this.

OSIP Project Boundaries

OSIP boundaries allow a transparent definition of current disturbance in which to define areas that are not candidates for restoration. However, like most data, OSIP project boundaries contain spatial and temporal discrepancies that must be considered when interpreting or applying the results of this work. These limitations include frequent adjustments to project boundaries and changes in project statuses since publication of OSIP boundaries. As an example of project status changes, two projects classified as "Suspended" by OSIP and omitted from this analysis were recently acquired by CNRL and appear on the AER Scheme Approval Map Viewer, which is based on Oil Sands Conservation Act (OSCA) approved scheme boundaries (*i.e.* "Project Areas"). Additionally, there are potentially large differences between OSIP boundaries and commercial footprint. For example, the Cenovus Foster Creek OSIP boundary is 5 times larger than the commercial footprint, even when a 500-metre buffer is applied. Note that Foster Creek is the oldest commercial steam assisted gravity drainage project in Alberta, so this is not an artifact of an early development stage. Although the Foster Creek example may not be typical, there is variation between projects in the difference between commercial footprint and the project boundary. To address these discrepancies, COSIA will undertake work in 2020 to update project boundary data and understand how to best represent current and future commercial footprints; this work will inform numerous programs, including restoration planning.

Resource Valuation Layer (RVL)

Geologic data that RVL is largely based on is up to 14 years old, and therefore does not include a significant amount of newer exploration data. Newer data could reveal that areas classified as low RVL might actually have high resource value. Other factors that influence the calculation of RVL (*e.g.* proximity to infrastructure, technologic capacity to develop reservoirs) are continually changing. However, in the absence of alternative datasets, RVL was determined to be useful for directing restoration priority away from areas more likely to be developed, in continuity with Versions 1.0 and 2.0. RVL only applies to areas outside of OSIP operating, approved, applied for, and announced project boundaries, as all area within these project boundaries were considered to be unavailable for restoration. Nevertheless, this report illustrates guiding principles that can be applied to multi-scale restoration planning that considers multiple values.

Future petroleum and natural gas development and yet-to-be announced oil sands projects are not considered in this analysis, nor are peat harvesting or sand/gravel operations. When developing restoration projects, it is critical to communicate with all tenure holders in a proposed restoration area to ensure that decisions are being made with the most up-to-date information available for a given area. As such, restoration decisions should not be driven by RVL in isolation and should take into account, among other things, current and future levels of resource exploration and development.

Links to Range Planning

Linear feature restoration will play a key role in caribou range planning throughout Alberta. As range plans begin to be developed in the region (AEP & ECCC 2019), spatial and aspatial information and decision-support to identify priority restoration areas will only become more important. While Versions 1.0-3.0 of this work may all play a role in providing this information, the range planning will necessarily take a wider lens, including in ways that influence restoration implementation. In particular, developing regional access management plans is a critical component of land-use management within caribou ranges, with ramifications for restoration logistics. While Version 3.0 addresses access in the Project-Level Considerations section discussion on line stranding, access is not directly integrated in a formal or consistent manner. Future versions of this prioritization work should consider a network analysis to develop a comprehensive restoration schedule that minimizes line stranding. This would provide valuable information on how any potential access management plan could influence restoration logistics. Another key access management issue is the requirement to leave some linear features open, such as active pipelines, active transmission lines, and some seismic lines being used for trapper or community access. This has a significant impact on the ability to create large, intact areas; comprehensive access management planning, and especially increased engagement and education of Indigenous Peoples and stakeholders, are critical to minimizing the number and extent of features left unrestored.

Currently, the Government of Alberta is using ABMI's human footprint layer – omitting low-impact seismic lines – as the basis for calculating disturbed habitat for the purposes of caribou range planning (Government of Alberta 2017). It is therefore unclear if reporting the ECCC-calibrated disturbance calculations is meaningful. Range planning guidance (ECCC 2016) allows for range plans to use disturbance mapping methods or data different than that of the Recovery Strategy (Environment Canada 2012), but notes that the 35% disturbance threshold is based on an equation developed using the Recovery Strategy data, *i.e.* a 30m-resolution landcover layer. The implications of using a more detailed disturbance layer for range planning are unclear.

Liability for reclamation and restoration

Dispositions for use of public land are issued by the Government of Alberta, whether in the form of formal dispositions, authorizations or approvals, and these dispositions set out specific requirements for closure. In many cases dispositions have met closure requirements yet remain apparent as 'disturbance' on the landscape as defined in the Recovery Strategy for Woodland Caribou (Environment Canada 2012). Assessment and prioritization of features on the landscape for restoration does not imply that liability for restoration, which differs from reclamation, lies with the current or former disposition holder.

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Appendix 1: Caribou Habitat Value Metrics

Five alternative metrics were considered to represent caribou habitat quality, each differing in their complexity, tractability, and data availability: biophysical habitat, resource selection functions, predation risk, demographic habitat quality, and current caribou use patterns. A brief description of each metric is presented below, with the principal advantages and disadvantages summarized in Table A1.1. Each approach was evaluated against the following criteria:

- Simplicity and ease of understanding and use
- Data availability and feasibility of additional analysis required to develop metrics
- Data permissions
- Operational considerations
- Relationship to caribou fitness
- Any other underlying assumptions

1. Biophysical Habitat

Caribou biophysical habitat is defined by the federal Recovery Strategy for the Woodland Caribou as the "biophysical attributes required by boreal caribou to carry out life processes" with specific requirements distinguished for each ecozone (Environment Canada 2012). The Alberta Draft Provincial Woodland Caribou Range Plan outlines Alberta's approach to mapping biophysical habitat in each range (Government of Alberta 2017).

2. Resource Selection Functions

A resource selection function (RSF) is quantitative habitat selection model based on telemetry data that expresses how much individuals use a given resource (*e.g.* landcover type) relative to its availability at one or more spatial scales. For caribou, the relevant spatial scales are selecting the population home range within caribou geographic range, individual home ranges within the population range, or individual telemetry locations within an individual home range (DeCesare et al. 2012b).

3. Predation Risk

This metric represents the risk of predation from the perspective of caribou predators, *i.e.* wolves and potentially black bears. At its simplest, predator density can be used as a proxy for predation risk, but this does not incorporate the spatial variation in predation risk at finer scales, for example due to landscape characteristics that influence predator resource use. For example, linear features increase wolf space use (DeMars & Boutin 2018) and search rate (DeCesare 2012; Dickie et al. 2017) in caribou habitat, leading to locally higher predation risk. Spatially explicit predation risk can be quantified using a statistical model based on predator (*i.e.* wolf or bear) GPS collar data with known kill site locations (*e.g.* DeCesare 2012; McPhee et al. 2009).

4. Demographic Habitat Quality

This metric is a spatial representation of a key demographic parameter (*e.g.* adult female survivorship or recruitment) based on environmental covariates. For example, DeCesare et al. (2014) used survival data from GPS-collared adult female caribou to fit Cox proportional hazard models that predicted seasonal survival probabilities as a function of caribou selection (RSF; DeCesare et al. 2012b) and predation risk (DeCesare 2012). Although DeCesare et al. (2014) used RSF and predation risk as predictor variables (which were, in turn, based on landscape characteristics), the same approach could be used without the intermediate step of developing RSFs or predation risk maps; that is, a Cox proportional hazard model explaining observed caribou survival could be fit to landscape data directly (*e.g.* McLoughlin et al. 2005).

5. Current Caribou Use

Rather than developing a quantitative or landscape-based metric, this approach prioritizes areas based on current use by caribou (*e.g.* individual home ranges or utilization distributions) and builds out to less-used regions of caribou population ranges. This approach should also incorporate both winter and summer (calving) home ranges. Caribou home ranges have been developed by the Government of Alberta based on telemetry data from GPS collared caribou.

Table A1.1. Summary of advantages and disadvantages of alternative caribou habitat value metrics for use in prioritizing linear feature restoration.

Metric	Advantages	Disadvantages
1. Biophysical Habitat	• Draft version available • Links to Recovery Strategy & provincial caribou range plans • Easy to understand	• Binary, simplistic • Little variation at TWP level • No mechanistic link to predation • Currently undergoing revision
2. Resource Selection Function	• Analysis already completed for winter range. Partially complete for calving range. • High degree of variability at TWP level	• Relative value only • Complex interpretation • No direct link to caribou fitness; may be selecting for sub-optimal habitat • Extrapolation or model development required for 3 ranges
3. Predation Risk	• Directly addresses mechanism of caribou decline	• Complex • Requires considerable analysis to develop • Predator telemetry & kill site data to develop model is largely unavailable
4. Demographic Habitat Quality	• Direct link to caribou survival and fitness	• Complex • Requires considerable analysis to develop • Data to develop may not be available
5. Current Caribou Use	• Readily available • Easy to understand and operationalize • Leads to restoring large, aggregated areas • Easy to combine with other metrics	• Assumption that current GPS collar data represents all/enough caribou within each range • No direct link to caribou fitness; may be using sub-optimal habitat

Appendix 2: Alternative Weightings and Sensitivity Analysis

Caribou use is highly skewed across the study area, with a small number of townships receiving the majority of caribou space use (Figure A2.1). Therefore, incorporating caribou habitat value, represented by areas of high caribou space use, can significantly alter the priority zones, depending on the weighting system used. We assessed three alternative weightings to combine the township-level caribou-use index with the RVL-adjusted bang-for-buck values:

A. Use RVL-adjusted Bang-for-Buck only, and incorporate the caribou-use index to differentiate among high-priority townships only. This approach prioritizes creating undisturbed habitat first, with less emphasis on areas of caribou use.
B. Multiply the RVL-adjusted Bang-for-Buck score by the caribou-use index for each township, and develop the priority zones with the resulting output. This option places the most weight on caribou use.
C. Numerically rank each township by RVL-adjusted Bang-for-Buck and caribou-use index, and multiply the ranks together. This approach is intermediate between 1 and 2 in terms of weighting of caribou.

Option A uses the same calculations as in Version 2.0, therefore it does not result in an appreciably different zonation map, other than a handful of townships changing as a result of changes in footprint or OSIP boundaries that influence the potential gain-in-undisturbed habitat. Therefore, this option represents the smallest incremental change from Version 2.0, with caribou habitat value only being used to differentiate within priority zones.

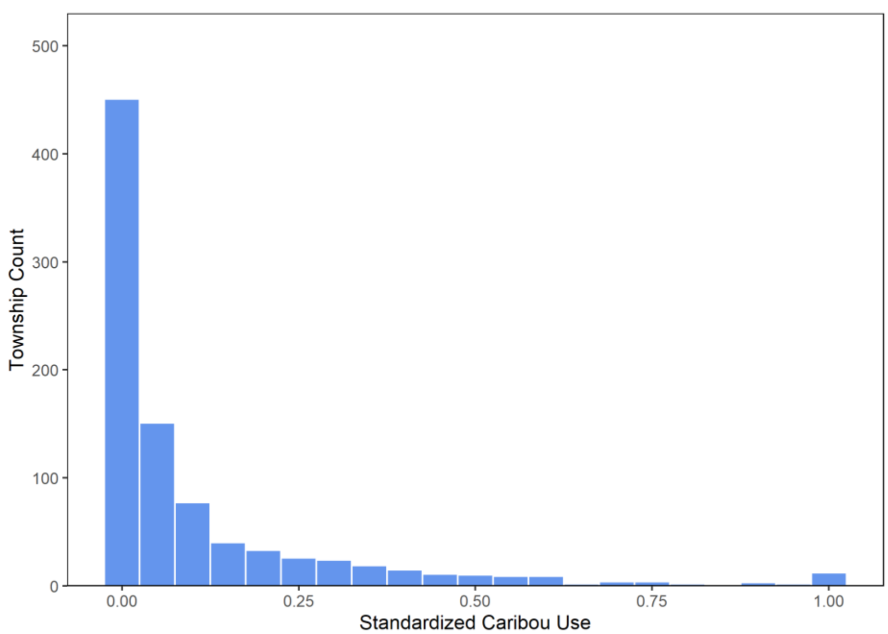

Figure A2.1. Frequency distribution of caribou-use scores across townships, normalized by range. By definition, each range has one township with a maximum value of 1 (with the exception of ESAR, in which each herd has one township with a value of 1).

Option B places the most weight on caribou habitat value, with all of the very high caribou-use areas being placed into Zone 1, with the exception of a handful of very low bang-for-buck or very high RVL townships (Figure A2.1). This is a result of the skewed distribution of caribou habitat use (Figure A2.1); because so many townships have a relatively low caribou-use index, the process of multiplying each township's RVL-adjusted Bang-for-Buck score by its caribou score pushes the very small number of extremely high-caribou townships to the high priority zone. Additionally, priority zones are created to be equal-area, such that a zone is approximately 1/5 of the total range area. However, the area used intensively by caribou is much less than 1/5 of the range (*i.e.* the small number of townships on the right-hand side of Figure A2.1), so there is ample room in Zone 1 to capture the small number of extremely high-use townships. As in Option A above, differentiating the highest caribou-use areas within Zone 1 is a subsequent step that can be taken when selecting restoration projects to further guide restoration to the highest caribou value areas. Option C is an intermediate weighting between Options A and B; many, but not all of the high caribou-use areas are placed into Zone 1.

All three Options prioritize townships that are both high RVL-Adjusted bang-for-buck and high caribou use, however we suggest that Option B is the preferred weighting scheme. In Option B, Zone 1 is large enough to capture all of the highest caribou-use areas, as well as other high RVL-Adjusted bang-for-buck townships that have moderate caribou use (*i.e.* many of the high-priority townships from Version 2.0). The only high RVL-Adjusted bang-for-buck townships that get down-prioritized using Option B are those that have near-zero caribou use. One particular example of interest is the northwest corner of WSAR, which is generally lower priority when caribou use is incorporated. This area of WSAR is dominated by upland mesic forest, a habitat type that is not considered biophysical habitat, and is likely of low value to caribou regardless of its age or successional state (Government of Alberta 2017). Therefore, this area is unlikely to be important caribou habitat regardless of restoration or disturbance levels. The outcome of using Option B is that most of the high priority townships from version 2.0 are maintained, important caribou areas to serve as focal points for new restoration efforts are identified, and restoration efforts are not inappropriately directed toward areas that have minimal value for caribou. In contrast, Option A prioritizes restoration in a handful of low-use caribou areas, while Option C is an intermediate approach and therefore subject to the same issue, although to a lesser degree.

Finally, each township's zones from Options A-C were summed, such that the lowest scores represent townships with high priority in each of Options A-C. This sensitivity map highlights townships that are always given a high priority, regardless of weighting method used (Figure A2.3). Table A2.1 shows the percentage of townships in each range that fall into each of the zonation categories from Figure A2.3.

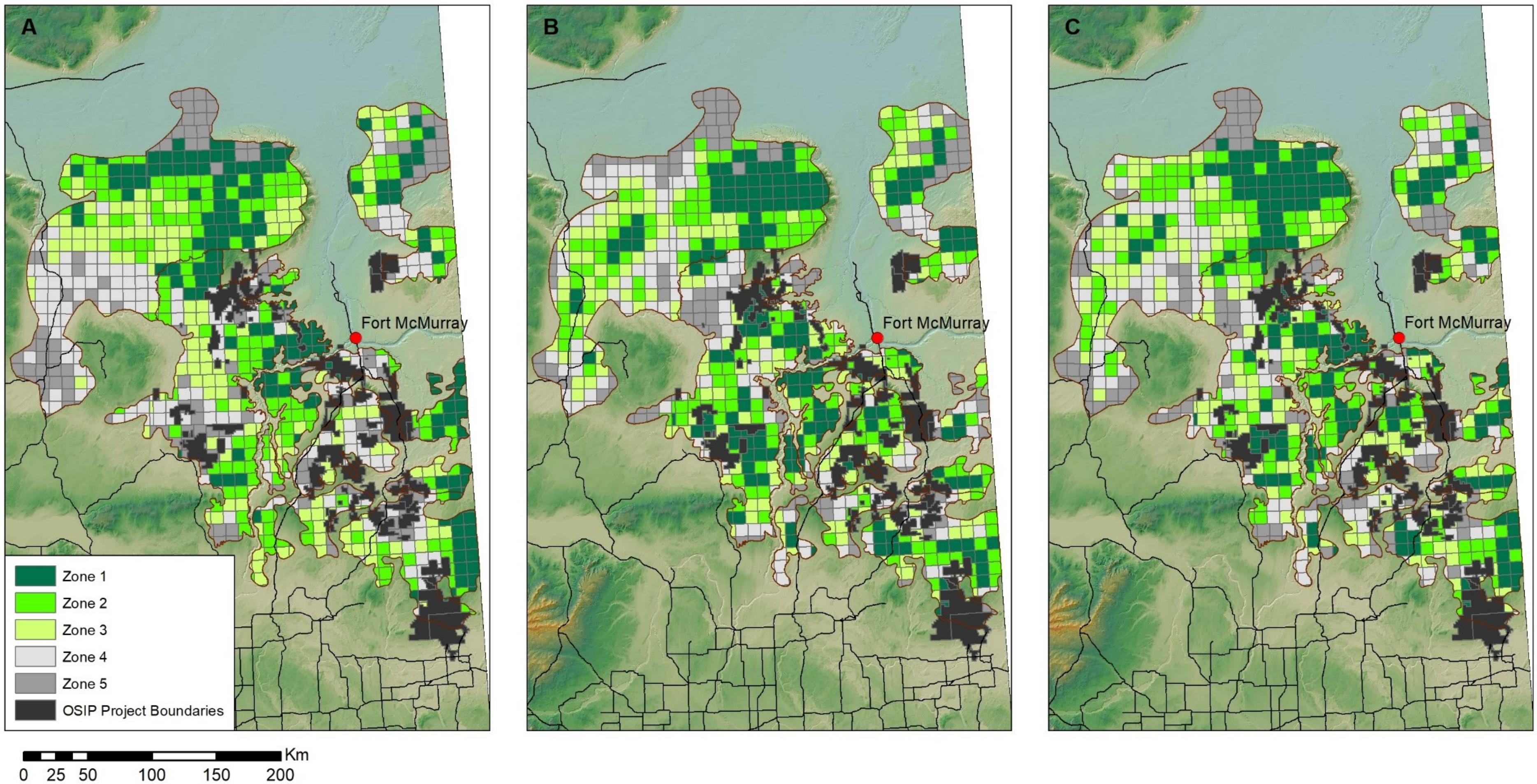

Figure A2.2. Priority zones under 3 alternative zonation weightings, with priority based on A) RVL-adjusted B4B (*i.e.* Version 2.0 approach with updated data), B) Caribou use * RVL-Adjusted B4B, and C) the product of separate rankings for each of RVL-Adjusted B4B and caribou-use index. Townships are ranked into priority zones for restoration, with Zone 1 being highest priority and Zone 5 (dark grey) the lowest. Any area within 2016 OSIP boundaries (operating, approved, applied for, and announced projects), are considered non-candidate areas for restoration (black).

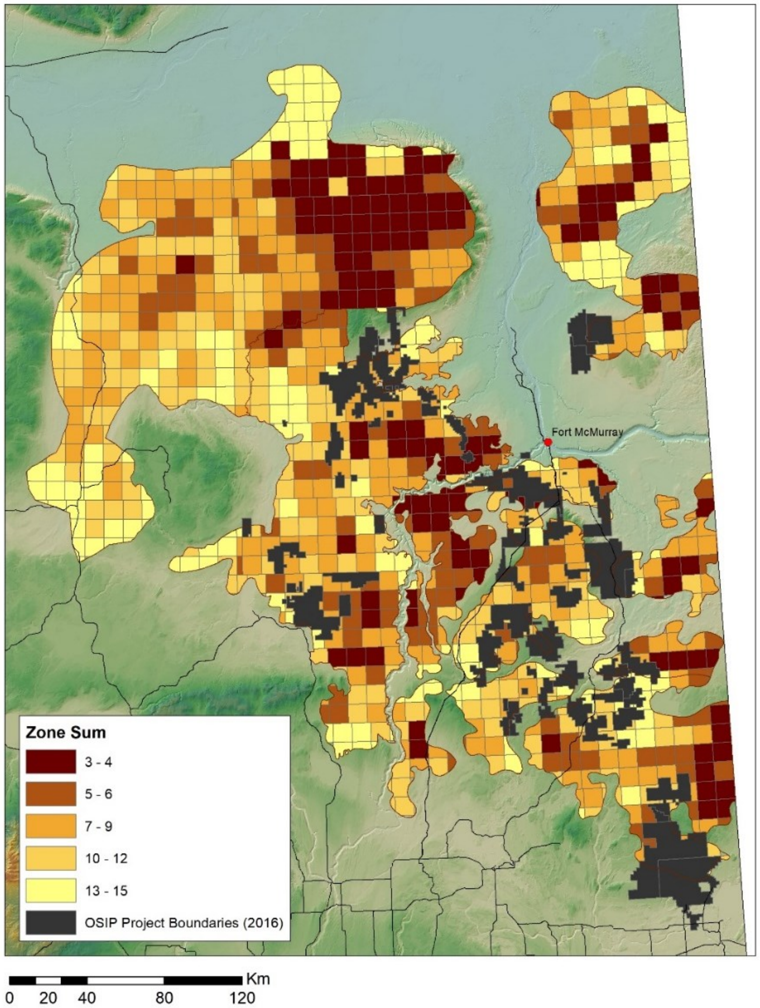

Figure A2.3. Summed zonation scores from Options A-C. Darker townships are those classified as higher priority in >1 weighting option. Note that these zones are not equal-area. Any area within 2016 OSIP boundaries (operating, approved, applied for, and announced projects), are considered non-candidate areas for restoration (black).

Table A2.1. Percentage distribution of summed zonation categories by range, based on Figure A2.3

	Summed Zonation Category				
Range	**3-4 (Dark Brown) Always High Priority**	**5-6**	**7-9**	**10-12**	**13-15 (Yellow) Always Low Priority**
Red Earth	17%	13%	24%	24%	21%
Richardson	17%	14%	23%	20%	26%
WSAR	10%	15%	31%	24%	20%
ESAR	15%	15%	25%	24%	21%
Cold Lake	11%	22%	20%	24%	23%

Appendix 3: Disturbance Calibration Results

The 35% disturbance target (Environment Canada 2012) is derived using a 30m resolution landcover layer. In contrast, ABMI's 2017 human footprint layer is of a higher resolution, and thus identifies smaller features such as seismic lines. As a result, ABMI's human footprint layer shows a higher level of disturbance for a given parcel of land than would be recognized by Environment Canada's disturbance data used to develop the 35% disturbance target. Therefore, ABMI disturbance estimates were calibrated to ECCC disturbance estimates at the township level for each range following the method used in Version 2.0 (ABMI 2017).

Disturbance values calculated using ABMI's human footprint layer (2017) consistently estimated higher disturbance values than those used by Environment Canada (2012; Table A3.1). The two data layers were highly correlated, and as such the relationship was used to calibrate the values from ABMI's human footprint layer to correspond to Environment Canada's (Table A3.2).

Table A3.1. Current amount of disturbed habitat within caribou ranges, calculated using ABMI (2017) and ECCC (2015) disturbance layers. Low-impact seismic lines are omitted.

Range	Total % Disturbed (Current)		
	ABMI	ECCC-Calibrated	Difference
Cold Lake	87.0%	71.9%	15.1%
ESAR	88.9%	78.5%	10.4%
Red Earth	68.0%	46.9%	21.1%
Richardson	35.9%	23.2%	12.7%
WSAR	85.5%	70.2%	15.3%

Table A3.2. Empirical relationships between ECCC's 2015 disturbance and ABMI 2017 disturbance for each range, with and without fire. Model coefficients, standard error, and p-values are reported for linear regressions predicting ECCC disturbance as a function of ABMI disturbance, with townships within each range used as the sampling unit.

Range	Variable	Human Footprint				Human Footprint and Fire			
		Coefficient	SE	P	R^2	Coefficient	SE	P	R^2
Cold Lake	Intercept	-22.3	10.4	0.035		-12.3	8.08	0.13	
	ABMI %	1.09	0.118	<0.001	0.52	1.06	0.087	<0.001	0.75
ESAR	Intercept	-14.0	4.43	0.002		-9.74	5.62	0.085	
	ABMI %	1.03	0.0491	<0.001	0.69	1.01	0.061	<0.001	0.57
Red Earth	Intercept	-2.65	2.32	0.25		14.0	2.79	<0.001	
	ABMI %	0.731	0.0305	<0.001	0.66	0.715	0.032	<0.001	0.62
Richardson	Intercept	-9.14	2.04	<0.001		-19.2	3.37	<0.001	
	ABMI %	0.890	0.0387	<0.001	0.85	1.18	0.036	<0.001	0.92
WSAR	Intercept	-8.40	3.69	0.024		-5.66	6.91	0.41	
	ABMI %	0.915	0.0427	<0.001	0.69	0.856	0.078	<0.001	0.36