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Boreal Caribou Habitat Restoration

Submitted to:

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Fish Wildlife and Habitat Management Branch,

Prince George, BC

Government of British Columbia

REPORT

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Golder Associates

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1.0 BACKGROUND

Boreal caribou (*Rangifer tarandus caribou*) are “red-listed” (threatened to endangered) in BC (B.C. CDC 2010) and listed as “threatened” under the federal *Species At Risk Act* (*SARA*) (COSEWIC 2003). In general, populations of boreal caribou have declined substantially in recent decades (EC 2011). Concurrently, resource-based industries have expanded into previously undeveloped areas and the distribution, intensity, amount and type of human activity in and near caribou ranges has been linked to compromising the integrity of caribou habitat (EC 2011, Goddard 2009, McLoughlin *et al.* 2003). Primary responsibility for the management of wildlife and lands within caribou range falls on the provinces and territories in which they are found and therefore the jurisdictional mandate for recovery and conservation of boreal caribou falls to them (EC 2011). As a result, for the Recovery Strategy to be successful, many stakeholders/constituencies will have to work together at the landscape-level planning stage (EC 2011).

Under the Accord for the Protection of Species at Risk, federal, provincial and territorial governments agreed to establish complimentary legislation and programs to protect species at risk in Canada (EC 2011). In 2011, the Federal Minister of the Environment released the “Proposed Recovery Strategy for the Woodland Caribou *(Rangifer tarandus caribou)*, Boreal Population in Canada” (EC 2011). Within the proposed strategy, actions identified to manage habitat to meet current and future caribou population requirements include undertaking coordinated actions to reclaim boreal caribou habitat through restoration efforts (e.g., restore industrial landscape features such as roads, old seismic lines, pipelines, cut-lines, temporary roads, cleared areas; reconnect fragmented ranges). Reliance on habitat restoration as a recovery action within the federal proposed recovery strategy is high; with the strategy identifying 65% undisturbed habitat in a caribou range as the threshold which provides a measurable probability (60%) for a local population to be self-sustaining. Restoration of existing anthropogenic footprint will result in a larger area becoming undisturbed.

The oil and gas industry in northeast BC is considered a major component in the provincial economy. Providing opportunities to purchase subsurface tenures and develop Petroleum and Natural Gas (PNG) resources meets the Government of BC’s commitment under the BC Energy Plan (2007) (*as cited within* Wilson et al. 2010). Boreal caribou habitat ranges overlaps extensively with oil and gas exploration and development activities in BC (*as cited within* Wilson et al. 2010).

In NE BC, the Ministry of Environment (MOE) and Ministry of Energy, Mines and Petroleum Resources (MEMPR) have developed the “Implementation Plan for the Management of Boreal Caribou (*Rangifer tarandus caribou*) in British Columbia” (BCIP) which attempts to balance future opportunities for Petroleum and Natural Gas (PNG) development with boreal caribou conservation objectives (Ministry of Environment 2011). The BCIP relies partially upon aggressively restoring habitat to improve caribou population projections. However, although analysis has indicated that habitat restoration is linked to improving caribou population projections, the feasibility and predicted outcomes of restoration activities are highly uncertain (Wilson et al. 2010; *also refer to* ALT 2009 for similar conclusions).

2.0 SCOPE / PURPOSE

Golder Associates was retained by the Fish Wildlife and Habitat Management Branch (Prince George) of the Government of British Columbia (BC) to prepare an overview document which collects knowledge and research on restoring degraded habitat for boreal ecotype woodland caribou. The objectives for this document are outlined below.

- Provide an overview of the impacts to caribou habitat from oil and gas activity typical to northeastern British Columbia. Summarize the possible implications to boreal caribou populations from those impacts.
- Identify and describe what work has been completed, or is ongoing, to test some of the conceptual methods for boreal caribou habitat restoration. This will help identify what research or operational trials may need to be conducted in British Columbia to fill in gaps and avoid duplication of this effort.
- Using the work that has been completed in Alberta to date, recommend possible restoration measures for NE BC to reduce impacts on boreal caribou, indicating which ones have some performance and which are "conceptual" and would need validation or testing.

3.0 IMPACTS TO HABITAT FROM OIL/GAS DEVELOPMENT IN NE BRITISH COLUMBIA

General Biology

Boreal caribou range is found exclusively in the lowlands of the Boreal Plains and Taiga Plains ecoprovinces in the northeastern corner of BC (Culling and Culling 2006). Prior to 2000, research on boreal caribou in northeastern BC was very limited, with some inventories of herds conducted by the Ministry of Environment (MoE), Fish and Wildlife Section, Peace Region (Goddard 2009). Herd ranges have been defined as broad areas of known historical or assumed current use that supply resources necessary to support local populations of boreal caribou, and cores as areas of high current capability and suitability based on general habitat requirements and documented occurrence. Six boreal caribou ranges have been identified in northeast BC and include the Chinchaga, Snake-Sahtaneh, Maxhamish, Calender, Prophet and Parker ranges (BCTAC 2004, Culling and Cichowski 2010).

It is estimated that there are approximately 1,300 boreal caribou in BC (Culling and Cichowski 2010). Boreal caribou in BC inhabit large home ranges (average adult home range 1,468 km^2), moving between core habitats through matrix habitats throughout the year. Although boreal caribou do not undergo seasonal migrations, they do make extensive movements throughout the year in their home ranges. Some movements appear to be associated with the selection of seasonally available resources, such as wintergreen vascular plants located along lake margins (Culling and Culling 2006). Boreal caribou occur within old growth forested habitats and black spruce peatlands (with 10-60% crown closure), areas of extremely low slope (0.0^o to 0.30^o slope), and lake clusters comprised of lakes between 5 and 50 ha in size (Culling and Culling 2006).

Boreal caribou populations occur at low densities and are sparsely distributed across available habitat. They have a low reproductive potential, as they only have one calf per year, and females do not typically produce young until three years of age. Caribou mortality rates are variable, but typically high for calves during their first month of life in ranges studied across Canada (Thomas and Gray 2002). They require large, contiguous tracts of their preferred habitats so they can maintain these low densities across their range as an anti-predator strategy. Caribou evolutionary strategy is understood as selection of low-productivity wintering habitat, (i.e., large continuous peatland areas selected by boreal ecotype), creating a spatial separation from other prey species (commonly moose), as an anti-predator strategy against wolves (Bergerud and Elliot 1998, James 1999). These areas also offer limited predator access (Bergerud et al. 1984).

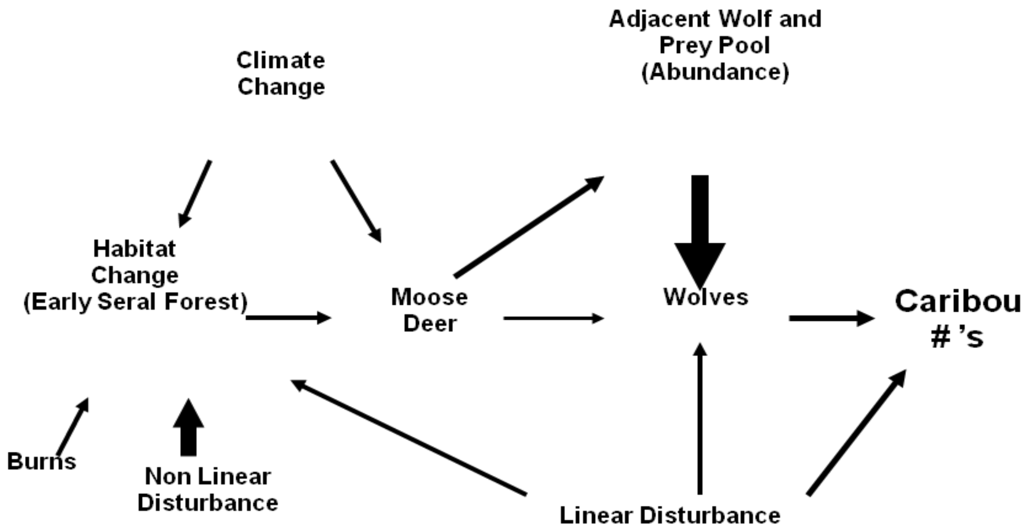
3.1 Impacts to Habitat

Human land use activities, including activities from the oil and gas industry, can both directly and indirectly make habitat less suitable for caribou. Land use activities are associated with the direct loss of habitat through landscape change, which can result in both a loss of lichen forage and a continual reduction in the amount of contiguous old forest that is favoured by caribou and not selected for by alternate prey (Smith 2004). Anthropogenic disturbances lead to early successional habitats and wildlife species preferring these habitats (e.g., deer and moose). From a natural disturbance perspective, caribou prefer older stands with lichen content that is not present at maximum levels until at least 50 years post-fire disturbance (Dunford 2003). Wittmer *et al.* (2007) reported that in BC, forest managers should be more concerned with overall habitat amount rather than minimizing habitat fragmentation as adult female caribou survival was lowest in populations associated with a higher proportion of young and mid-seral forests, with female caribou more likely to be killed by predators if they had a relatively small proportion of old forest in their range.

Indirect habitat loss occurs when good quality habitat is avoided as a result of human disturbance. Research in BC and Alberta has concluded that caribou avoid (in general) otherwise suitable habitat because of its proximity to either human infrastructure (e.g., well pads, roads) or habitat disturbances (e.g., seismic lines) (Dyer 1999, Dyer et al. 2001, James 1999, James and Stuart-Smith 2000, Oberg 2001, Neufeld 2006).

Woodland caribou distributions have declined throughout Canada and are now extirpated from many areas. In addition to avoidance of habitat, the amount of human infrastructure and habitat alteration has been linked to an imbalance in predator-prey relationships across most of the boreal caribou distribution in Canada which has resulted in high predation rates (EC 2011). Although boreal caribou across Canada are not considered a primary prey species for any major predators because they occur at low population densities in “low-energy” habitats not easily accessed by large predators, wolf and other (bear) predation is considered the major source of caribou mortality in northern BC (Bergerud and Elliot 1986); as well as throughout Canada (EC 2011).

Figure 1: Woodland Caribou Pathways Summary: Ultimate Cause of Declines Linked to Habitat. Proximate Cause of Declines Linked to Predation (adapted from ALT 2009).



Current available information indicates that anthropogenic disturbance can lead to an increase in wolf predation in three ways.

1. Increased primary prey (moose and deer) habitat quality, populations, range overlap and changes in distributions within caribou ranges:

- Disturbance (natural and industrial – oil and gas, forestry, agriculture, fire) creates habitat for primary prey species as they prefer early seral habitat over old growth forest. The availability of early seral habitat may result in increased numbers of primary prey in areas previously more suitable for caribou.
- Increased availability of habitat for primary prey species results in increasing primary prey populations. Evidence suggests that moose and deer populations are increasing steadily and that these species may also be expanding into lower quality habitats that are preferred by caribou (Latham 2009). This may lead to an increase in range overlap between caribou,moose and deer on caribou range. Another prey species influencing wolf overlap with caribou ranges, particularly during the snow-free season, is beaver (Culling and Culling 2006, Latham 2009).
- One method to reduce the abundance and/or extent of primary prey populations within boreal caribou ranges is caribou range habitat restoration which would aim to remove disturbances as quickly as possible from the disturbance footprint (Szkorupa 2002, ALT 2009, Ministry of Environment 2011).

2. Increased predator populations, range overlap and changes in distribution of predators within caribou ranges:

- Increasing primary prey populations result in increased predator populations (e.g., Latham 2009 *as compared to* James 1999).
- Increasing predator populations may expand into lower quality prey habitats in pursuit of primary prey species.
- Increased movements of predators into lower quality prey habitats may also lead to an increase in range overlap between wolves and caribou. Year-round research on boreal caribou in BC has revealed that caribou and wolf spatial overlap is greatest during the spring and that wolves prey upon adult caribou along seismic lines (Culling and Culling 2006).

3) Increased predator efficiency:

- Linear developments within caribou range increase predator efficiency through increased speed/mobility and line-of-sight (James 1999).

Increased primary prey numbers within caribou range, coupled with improved access from developments such as road, seismic lines and pipelines, may result in more predators within caribou ranges. Through the action of their shared predator, an increase in deer results in a decline in caribou, a phenomenon referred to as ‘apparent competition’ (DeCesare et al. 2010). More predators may increase contact between predators and caribou, and result in increased predation on caribou.

4.0 HISTORIC AND CURRENT HABITAT RESTORATION INITIATIVES

Management of boreal caribou habitat to maintain viable populations over time will require both minimizing the impact of future development and recovery of the existing industrial footprint. Rehabilitation of existing anthropogenic disturbances not currently in use by the oil and gas industry within caribou range will reduce functional habitat degradation (e.g., Oberg 2001) and fragmentation from these disturbances. A Caribou Range Restoration Project (CRRP) was first established within Alberta to pilot techniques with the objective of promoting re-vegetation of human disturbances as well as setting up a long-term monitoring and study design to test the effectiveness of these techniques. Although the CRRP was not extended beyond 2007 under the Alberta Caribou Committee (ACC), the project did develop a monitoring protocol for silvicultural and line blocking habitat restoration treatments (CRRP 2007) and recommended practices for implementing a habitat restoration program, from the planning through to the treatment and monitoring phases (CRRP 2006).

Outside of the CRRP investigations, seismic lines have been reported to have very slow reforestation rates when compared to natural regeneration (Revel et al. 1984; Osko and MacFarlane 2000). This slow tree regeneration has been attributed to root damage from the original disturbance, compaction of the soil in tire ruts, insufficient light reaching the forest floor, maintenance of apical dominance from surrounding stands, introduction of competitive species (i.e., planted seed mixes), drainage of sites (i.e., regeneration slowest on poorly drained sites with low nutrient availability such as bogs) and repeated disturbances (e.g., ATVs, animal browsing, repeated exploration) on seismic lines (MacFarlane 1999 and 2003; Revel et al. 1984; Sherrington 2003). The lack of recovery of plant communities on seismic lines indicates that direct management activities are required to return the disturbance footprint back to a natural successional trajectory (MacFarlane 2003). Recovery techniques that have been suggested include line-by-line silviculture preparations (e.g., to ease compaction and break up grass competition) as well as tree planting. However, this may not be feasible on the scale needed in northern Alberta (MacFarlane 2003) or BC.

Several other initiatives and trials have been completed or are ongoing to effectively restore the linear disturbance (principally seismic lines, lease roads and pipelines), and polygon features such as wellsites which occur within caribou range from the oil and gas industry (Table 1). Restoration of the historical footprint initiatives have generally focused on revegetation and access control programs and studies, and limiting plant species that are favourable to alternate prey. Habitat restoration programs include tree planting initiatives, coarse woody debris management best practices, habitat enhancement programs and habitat restoration on caribou range. Lessons learned from these programs have been incorporated into large scale habitat restoration projects near Grande Prairie, Cold Lake, and Fort McMurray, Alberta. The use of construction and reclamation techniques to promote revegetation of disturbed sites has also been investigated through the University of Alberta. Forest industry initiatives include the use of alternate logging strategies that promote large contiguous patches of unlogged areas, limiting shrub and hardwood growth following harvest, and promoting lichen retention through the use of specific harvest methods. Planning initiatives have an important role in boreal habitat restoration, and include modeling tools, a linear footprint management tool, the Canadian Boreal Forest Agreement (CBFA), and the Foothills Landscape Management Forum. The information provided here mainly focuses on projects and trials that have been conducted, or are on-going, to restore habitat to promote the recovery of the historical oil and gas footprint in caribou areas.

Table 1: Historic and Current Habitat Restoration Initiatives

Company or Group	Initiative Name or Goal	Description	Accomplishments and/or Learnings	Key Contact (s) and/or Reports
Consortium composed of oil/gas companies, Environment Canada, Alberta Conservation Association, the Alberta Caribou Committee, and Alberta Sustainable Resource Development (ASRD)	Caribou Range Restoration Project (CRRP)	■ Program active from 2001 to the end of 2007 ■ Mandate was to use an adaptive management approach to restoring caribou habitat while testing methods to speed recovery of man-made linear disturbance ■ Involved trials to increase the recovery path of seismic and other linear corridors to treed cover, studying the effect of access management techniques on wildlife and humans, performing a cost/benefit analysis, and drafting recommended operating practices and planning strategies from the construction through to the reclamation phases of oil and gas developments ■ Field treatments included: transplanting trees and shrubs, seeding, tree seedling planting , using planting enhancements, soil decompaction, mounding, slash rollback, and installation of wooden fences for line of site breaks ■ Planning strategies included the use of aerial imagery for collecting vegetation inventories, and developing logistical best practices for tree seedling planting in wetland areas during the summer	■ Tested site preparation techniques as they pertain to promoting revegetation and limiting human use of linear corridors, including excavator mounding, defragmentation, and slash rollback ■ Researched and tested the use of aerial imagery and LiDAR for collecting vegetation inventories on linear disturbances, of which aerial imagery was proven to be successful and adopted for other habitat restoration programs ■ Managed the macro-scale Suncor/ConocoPhillips Caribou Habitat Restoration Pilot implemented within the Little Smoky caribou range in 2006 ▪ Over 100 kilometers of linear corridors treated, encompassing several townships ▪ Included site preparation techniques excavator mounding and slash rollback ▪ Included planting of tree seedlings on a variety of different eco-sites, treatment types, and disturbances ▪ Included the installation of wooden fences at the beginning of linear corridors to serve as line of sight breaks ▪ Focused on access management by using excavator mounding at the beginning of linear corridors Installation of signs at treatment sites	Although the CRRP is no longer in existence, key contacts for further information include: Brian Coupal, Golder Associates (403)532-5715 Matt Besko, ASRD, (780)427-7769 Carol Engstrom, Husky Energy(403)298-7044 Suncor 2007 CRRP 2007 CRRP 2006 Neufeld 2006

Company or Group	Initiative Name or Goal	Description	Accomplishments and/or Learnings	Key Contact (s) and/or Reports
			■ Produced an unpublished draft document on recommended practices for implementing a habitat restoration program, from the planning through to the treatment and monitoring phases ■ Produced an unpublished monitoring manual for collecting revegetation data on linear corridors ■ Conducted trials in the transplanting of existing tree species under winter and summer conditions ■ Sponsored trials in frozen tree seedling planting ■ Sponsored trials in the use of encapsulated seed products for reclamation purposes ■ Sponsored a line blocking study, as part of Lalenia Neufeld's Master's Thesis on wolf/caribou dynamics in the Little Smoky caribou range	
Suncor Energy	Accelerated Seismic Line Restoration	Program initiated in 2000 ■ Objective was to promote re-vegetation of seismic lines through the use of tree seedling planting, bioengineering (willow staking), and transplanting existing vegetation ■ Techniques tried on upland, transitional wetlands and wetland ecosites ■ No follow-up monitoring beyond this program	Four years post treatment: ■ Upland black spruce transplants have survived but show signs of stress ■ Black spruce and willow plugs worked better than transplants ■ Poor results for lines with mulch on them ■ Transitional wetland black spruce transplant showed high survival but low growth or vigour rate ■ Wetland transplants and plugs had poor survival, but slightly better survival when planted in elevated microsites.	Golder 2005

Table 1: Historic and Current Habitat Restoration Initiatives (continue)

Canadian Natural Resources Limited (CNRL), Diversified Environmental Services	Ladyfern Pipeline Re-vegetation Program (natural gas pipeline running from NE BC into NW Alberta)	Pipeline construction occurred in 2002 ■ Promoted revegetation on a pipeline development by: minimizing root disturbance during construction, deferring mechanical seeding of the ROW to areas of erosion concern only, promoted the growth of native species from seed, planting of tree seedlings, and transplanting of existing tree species ■ Goal was to create line of sight breaks as introduced tree species grow over time ■ Upland habitat: tree seedlings were planted primarily with white spruce and lodgepole pine species ■ Lowland habitat: planted larger, locally collected and transplanted black spruce	■ Annual monitoring of species composition and percent vegetation ground cover was conducted for two growing seasons ■ Survival rates higher in upland sites than lowland sites (focus on lowland sites was black spruce transplants) ■ Poor survival of locally collected transplanted black spruce ■ Coniferous tree seedling (nursery stock white spruce and lodgepole pine) survival and growth appeared to be more successful than using locally collected transplants. ■ Natural regeneration in both upland and lowland sites was noted in areas that had minimized root disturbance during construction of the pipeline and where mechanical seeding of grass seed had been deferred ■ Re-colonization of coniferous species provided the best visual barrier; deciduous species are the most immediately effective ■ Recommended that transplants should be conducted in the fall when trees are dormant, but still have sufficient time to establish roots ■ Recommended that most effective method for establishing a line of sight break is to concentrate efforts on productive uplands ■ Recommended that smaller trees (20-30cm) be selected for further transplants	DES 2004

Table 1: Historic and Current Habitat Restoration Initiatives (continue)

Axys Environmental	Recommended Peatland Restoration Techniques for Oil and Gas in Boreal Forest	■ Axys conducted a literature review of successfully used peatland reclamation techniques within wildlife habitats in the boreal forest	■ A mean water table level higher than 40 cm and preferably within 20 cm promotes peatland growth[1] ■ Removing drainage ditches following decommissioning will help restore peatlands[2] ■ Water table management is essential to ensure successful re-vegetation of peatlands and to guide the direction of re-vegetation. Soil chemistry adjustment may be required for problem soils[3] ■ To achieve improved black spruce seedling growth and environmental quality, use selected mycorrhizal fungi when reclaiming dense black spruce bogs[4] ■ Re-establish site hydrology, site topography, and appropriate bog vegetation to reclaim raised bogs ■ Patches of discontinuous permafrost (e.g., in northeastern Alberta) are not yet possible to reclaim[5]	Axys 2003 [1]Tedder and Turchenek 1996 [2]Girard et al. 2002 [3]Naeth et al. 1991 [4]Khasa et al. 2001 [5]Robinson and Moore 2000 [5]Turetksy et al. 2000 [5]Camill 1999

Table 1: Historic and Current Habitat Restoration Initiatives (continue)

Company or Group	Initiative Name or Goal	Description	Accomplishments and/or Learnings	Key Contact (s) and/or Reports
Enbridge Pipelines (Athabasca)	Waupisoo Pipeline Habitat Restoration	Pipeline construction occurred in the winter of 2007/08 ■ Promoted revegetation on a pipeline development within critical moose and caribou habitat by: deferring mechanical seeding of the ROW to areas of erosion concern only, promoted the growth of native species from seed, planted tree and shrub seedlings, transplanted existing shrub species, and usde slash rollback for access control and micro-site creation for seedlings and natural seeding processes ■ Goal was to use growth of planted tree species to create line of sight breaks, directly restore habitat, and to create access controls	■ Approximately 250,000 seedlings planted at strategic locations over 3 summers. Locations included: ▪ Intersections with other linear corridors ▪ Upland sites to create line of sight breaks ▪ Riparian areas ■ Slash rollback applied on some steeper slopes and at some intersections with all-season and winter roads ■ Shrub species alder and willow transplanted successfully on the banks of the Christina River during the winter. ■ Planting sites are currently subject to monitoring over a 5 year period ■ Good survival of seedlings on upland sites, lowland sites subject to monitoring in the fall of 2012 ■ Vegetation ingress of clover and native grasses has had a negative impact on seedling survival in some areas ■ Where no access control measures have been put in place, human use of the ROW by ATV damaged many seedlings ■ Seedlings planted in conjunction with slash rollback had not been damaged	Jeannette Gasser, Enbridge Pipelines, (780)420-8675 Enbridge 2010 Golder 2011

Table 1: Historic and Current Habitat Restoration Initiatives (continue)

Company or Group	Initiative Name or Goal	Description	Accomplishments and/or Learnings	Key Contact (s) and/or Reports
Canadian Natural Resources Limited, Wolf Lake	Interconnect Pipeline	Pipeline construction occurred in the winter of 2007/08 ■ Promoted revegetation on a pipeline development adjacent to the Cold Lake Air Weapons Range (CLAWR) by planting of tree and shrub seedlings ■ Goal was to use growth of planted tree species to create line of sight breaks, limit the overall width of the developed corridor that the pipeline parallels, directly restore habitat, and to create access controls	■ Approximately 60,250 seedlings planted at strategic locations over 2 summers. Locations included: ▪ Intersections with other linear corridors ▪ Upland sites to create line of sight breaks ▪ Riparian areas ■ Planting sites are currently subject to monitoring over a 5 year period ■ Good survival of seedlings where mechanical seeding was avoided ■ Areas mechanically seeded to native grass mixtures had lower survival and vigour of planted seedlings possibly due to increased competition for sunlight, water, and nutrients, and vegetation falling over and smothering the seedlings when snowfall occurs ■ Damage to seedlings from ATV use in many monitoring plots ■ Other environmental factors such as frost and wetland encroachment possibly contributing to seedling mortality	Paul Kip, CNRL, (780)815-4557 Golder 2012

Table 1: Historic and Current Habitat Restoration Initiatives (continue)

Company or Group	Initiative Name or Goal	Description	Accomplishments and/or Learnings	Key Contact (s) and/or Reports
University of Alberta led project, supported by a number of oil/gas companies, Canadian Association of Petroleum Producers (CAPP), Forest Resource Improvement Association (FRIA), and ALPAC	Integrated Land Management	■ Ongoing study began in 2004 and focused on contributing to best practices for wellsite construction and reclamation on forested lands in the Green Area of northeastern Alberta. Techniques toenable appropriate revegetation and accelerate recovery of ecological processes after disturbance were studied ■ Old wellsites component involved monitoring soils and vegetation ■ New wellsites component researched methods to use during well-site construction that will promote the prompt revegetation of the site during the reclamation phase	■ Report produced in 2010, "Recommended Practices for Construction and Reclamation of Wellsites on Upland Forests in Boreal Alberta", that evaluated soil and vegetation responses to different winter construction and reclamation techniques ■ Recommendations included: ▪ Maximizing low disturbance construction practices ▪ Use of snow/water to level sites as opposed to stripping ▪ Retain root zone when stripping and store soil layers in separate piles ▪ Plant seedlings promptly after reclamation to lessen impact of native vegetation competition ▪ Slash rollback is preferable to mulching ▪ Mulch layers need to be less than 10 cm thick when present ▪ Avoid planting tree and shrub species that may impact predator/prey dynamics and do not occur naturally in the area. For example, planting of species palatable to moose in caribou areas ▪ Pre-disturbance assessments and prescription planning can pay dividends at the reclamation stage	(Osko and Glasgow 2010)

Table 1: Historic and Current Habitat Restoration Initiatives (continue)

Company or Group	Initiative Name or Goal	Description	Accomplishments and/or Learnings	Key Contact (s) and/or Reports
Oil Sands Leadership Initiative (OSLI)	Faster Forests	■ Ongoing since 2007, planting trees to increase the pace of reclamation	■ Planting shrubs along with trees allows for trees to grow healthier, faster and less competition for nutrients and water from fast-growing grasses. ■ Planted 143,850 seedlings on 113 sites in 2009 ■ Planted 238,632 seedlings on 120 sites in 2010 ■ Planted > 600,000 seedlings in 2011 on 200 sites (included 4 tree species, 7 shrub species)	Scott Grindal, ConocoPhillips Jeremy Reid, Nexen Inc. (403)699-5961 Tim Vinge, Government of Alberta OSLI 2012
	Winter Wetland Planting Trial	■ Wetlands re-vegetation trials consisting of winter planting of black spruce seedlings to address challenges involved with planting disturbed wetland sites during the summer months ■ Goal is to improve reclamation performance	■ Planted 900 trees in winter 2011 ■ >90% survival rate in spring 2011 ■ Findings were used to help develop a larger scale frozen seedling program for the on-going Algar Reclamation Program	
	Algar Reclamation Program	■ Program targeting the restoration of seismic lines through re-vegetation and access control to improve wildlife habitat in a caribou area with historic seismic disturbance ■ The Algar area of north-eastern Alberta covers approximately 6 townships (each township is 6 miles by 6 miles)	■ Inventory of linear disturbance completed using remote sensing methods ■ Detailed restoration plan developed ■ Stakeholder consultation led by ASRD on the closure of selected seismic lines to the general public(i.e., to provide some level of protection to areas with restoration treatments) ■ Macro-scale restoration activities began in winter 2011/2012 and include: ▪ Excavator mounding ▪ Slash Rollback ▪ Frozen tree seedling planting	

Table 1: Historic and Current Habitat Restoration Initiatives (continue)

Company or Group	Initiative Name or Goal	Description	Accomplishments and/or Learnings	Key Contact (s) and/or Reports
Alberta School of Forest Science and Management / Oil Sands Leadership Initiative (OSLI)	Coarse woody debris management-best practices	■ Goal to come up with consistent standards that industry users can implement when spreading woody debris on their sites	■ Developed a guide for improved management of coarse woody debris materials as a reclamation resource ■ Best practices manual was prepared through consultation with resource managers and operators, consideration of economic and ecologic requirements, and synthesis of the most relevant and current scientific knowledge ■ Wood mulch depths exceeding 3 to 4 cm form an insulating layer over the soil surface limiting plant growth ■ Use of whole logs enhances forest recovery by creating microsites which creates ideal conditions for vegetation to establish and grow ■ Total roll back of material along the entire length of exploration and access features is the most effective way to discourage recreational use of lines ■ Well designed scientific monitoring of wildlife use is needed to provide managers with an understanding of treatment effectiveness	Jeremy Reid, Nexen Inc. (403)699-5961 OSLI 2012

Table 1: Historic and Current Habitat Restoration Initiatives (continue)

Company or Group	Initiative Name or Goal	Description	Accomplishments and/or Learnings	Key Contact (s) and/or Reports
Canadian Natural Resources Ltd.(CNRL)	Habitat Enhancement Program	■ Program is part of the Terms and Conditions of the *Environmental Protection and Enhancement Act* (EPEA) approval for the construction, operation and reclamation of the Canadian Natural Primrose and Wolf Lake (PAW) Project ■ Program targeting the restoration of seismic lines, old lease roads, and abandoned well and core holes sites through re-vegetation and access control to improve wildlife habitat on a caribou range within the Cold Lake Air Weapons Range (CLAWR) ■ Focused on restoration of historic (pre-oil sands development) features on the landscape that are recovering poorly, either due to environmental conditions (cold, wet soils) , historical clearing and reclamation practices, or recent clearing for winter access ■ Focused on areas outside of 10 year development plan to avoid re-entry into areas where restoration treatments are placed.	■ Used aerial imagery to conduct linear corridor vegetation inventories on all of CNRL's CLAWR operations, encompassing approximately 9 townships ■ Detailed restoration plan developed ■ Ground truthed sites which appeared on aerial imagery as having little to no woody plant regeneration ■ Focusing on access control and micro-site creation for introduced tree seedlings, using the following three treatments: ▪ Mounding ▪ Tree seedling planting ▪ Slash Rollback ■ Planting sites are subject to monitoring over a 5 year period ■ To date, only monitored black spruce seedlings planted in the summer on sites treated in the winter with excavator mounding in treed bog and fen sites ■ Excellent survival and vigour of seedlings after 1 growing season at all sites ■ Additional site preparation and seedling planting scheduled for 2012	Paul Kip, CNRL, (780)815-4557 Golder 2010

Table 1: Historic and Current Habitat Restoration Initiatives (continue)

Company or Group	Initiative Name or Goal	Description	Accomplishments and/or Learnings	Key Contact (s) and/or Reports
ConocoPhillips, Canadian Association of Petroleum Producer's and Suncor Energy	Caribou Habitat Restoration Pilot Study	■ Remote camera study (summer 2008) initiated within the Little Smoky caribou range in Alberta. Objectives included comparing wildlife (caribou, deer, moose, bear, wolf) presence and use between naturally restored seismic lines and open cutlines.	■ Pooled prey species (caribou, deer, moose) preferentially select restored seismic lines (> 1.5 m vegetation heights, average age of trees 23 years) over non-vegetated sites. ■ Deer had the strongest preference for restored sites, with the preference attributed to the increased forage within the restored sites, as well as reduced line of site and potentially predator avoidance. ■ Caribou were shown to have a slight preference for re-vegetated seismic line sites, over non-vegetated, but with limited data there was no statistical difference. However, caribou on control sites were observed to be running much more frequently then on re-vegetated sites and engaged in standing related behaviours only while on re-vegetated sites. Data indicate that caribou are more likely to travel quickly through open seismic lines, which may be a response to the minimal vegetation cover .	Scott Grindal, ConocoPhillips (Golder 2009)

4.0 RECOMMENDED RESTORATION TREATMENTS

Section 3 identified existing small and large scale initiatives to test the impact of different treatment types on the restoration of caribou habitat. Several of these initiatives have included critical pre- planning to use remote sensing imagery to determine the current state of revegetation on past developments, and to focus efforts on areas where re-development was unlikely to occur. The focus of most of the initiatives have been on establishing vegetation along linear corridors, with the goals of directly restoring habitat with transplanted vegetation, planting shrub and tree seedlings, sewing native shrub and tree seed, and of controlling human access to these features to promote, rather than hinder, undisturbed vegetation growth. An additional objective has been to create line of sight breaks along linear developments.

Recommended habitat restoration treatment types are summarized in Table 2. These treatment types are recommended as best practices based on the current state of knowledge around habitat restoration which has been derived from the initiatives summarized in Section 3.

Table 2: Recommended Treatment Types for Linear Development Habitat Restoration

Type of Mitigation Prescription	Objective(s)	Specifications	Comments
Bio-engineering	To help control: ■ access; ■ erosion; ■ to break up line of sight; and ■ to restore habitat.	Site dependent as to species and densities to utilize.	Bioengineering is the use of existing live vegetation to revegetate a site. Vegetation used is either found at the site to be treated, or collected nearby in the form of cuttings. Willows and poplar can be used as cuttings. Both species are fast growing which establishes line of sight breaks more quickly, and work well for riparian restoration.
Tree/Shrub seeding	- To help control access - To help control erosion - To help replace habitat - To help break the line of sight	Site dependent as to species and application rates required.	Seeding is considered a long-term mitigation treatment. Current application rates, and preferred sites for seeding, require further investigation.

Type of Mitigation Prescription	Objective(s)	Specifications	Comments
Tree/Shrub seedling planting	To help control: ■ access; ■ erosion; ■ to break up line of sight; and ■ to restore habitat.	Seedlings planted to 2000 stems/ha or greater. Determination of which species to plant is determined at the planning stage of a restoration program. Species are determined based on the adjacent forest stand. Shrub and tree seedlings often planted together, and are dependent upon site conditions and anticipated natural revegetation of both species.	Seedling planting is considered a long-term mitigation treatment due to the length of time it takes to establish effective line of sight breaks, hiding cover, and access deterrents.
Excavator Mounding	To enhance micro-sites for planted seedlings in areas where it is deemed to be effective. To enhance the site to enable seed to establish, speeding the natural re-growth of woody species. To help control human access by pick-up and/or ATV's.	For access control purposes, mounds should be created using an excavator. Mounds should be ~0.75 m deep, if possible. The resulting material is dumped right beside the hole. Target density of mounding for access control and/or micro-site creation purposes can vary from 1400 to 2000 mounds/ha.	For the purposes of enhancing micro-sites for planted seedlings, mounding is a well researched and popular site preparation technique in the silviculture industry. It is commonly used in wetter, low lying areas to allow higher, dryer, micro-sites for seedlings. Mounding treed fen and bog areas can enhance a site to naturally re-vegetate over time, as higher, drier spots are created that seed can eventually settle into and germinate. Mounding has been used as access control measure on old roads and seismic lines to discourage ATV usage.

Type of Mitigation Prescription	Objective(s)	Specifications	Comments
Slash rollback	To help control: ■ human access during snow free periods; ■ erosion, particularly along steep slopes. To help protect planted seedlings from extreme weather, wildlife trampling, and damage from human access (pick-ups, ATV's). To help provide nutrients to introduced planted seedlings as the slash decomposes over time. To provide microsites for natural seed ingress.	Spread slash evenly across the entire ROW width. Ensure woody debris is consistently dense enough on the ground to discourage ATV use along a right of way (ROW). Current slash rollback trials are implementing a coverage of 50 to 80 m^3/hectare, and are combining tree planting and seeding treatments with the slash rollback to take advantage of microsite creation. Osko and Glasgow recommend slash loads to not exceed 400 tonnes/hectare.	The length of a slash rollback segment is proportional to the amount of available slash. Longer segments are a more effective treatment at controlling human access as. ATV riders will be less inclined to try to ride through the slash, or traverse around the slash in adjacent forest stands, if slash continues for an extended distance. The use of slash rollback is only relevant when sufficient quantities of slash are left on site during clearing of new disturbance.

Transplanting native vegetation has not been included as a recommended treatment. This technique may have efficacy, but is difficult to implement on a large scale as part of a habitat restoration program due to the following:

- lack of consistently available vegetation suitable for transplant;
- potential for degradation of neighbouring forest stands if transplants are sourced from adjacent stands;
- transplanting programs have often resulted in the storage of plant materials under less-than-ideal conditions due to uncontrollable factors (i.e., weather); and
- other treatments, such as seeding and seedling planting, have been shown to be more successful in comparison.

Due to the lack of monitoring and the time lag that exists to restore caribou habitat, there is currently no direct link to indicate that the restoration treatments when implemented are having an impact on caribou populations. However, based on modelling scenarios of management options for caribou, the restoration of habitat should have benefits in the long term as restoration of these features will contribute to restoring large contiguous habitat patch sizes, which are favourable to caribou (e.g., ALT 2009).

Effective methods of vegetation re-establishment identified (Table 2) through the large scale habitat restoration projects, such as the Suncor/ConocoPhillips Little Smoky Caribou Habitat Restoration Pilot and the Canadian Natural Habitat Enhancement Program, are now serving as templates for developing and implementing other habitat restoration projects.\. These programs are primarily operational programs with a strong vegetation monitoring component, and based on the successful re-establishment of vegetation, are recommended as a starting point for caribou habitat restoration in NE BC. In addition, the Government of Alberta is currently developing a conservation offset manual for reclamation. The status of this document is unknown, but once available should be considered when developing silvicultural prescriptions for large scale habitat restoration programs.

5.0 KNOWLEDGE GAPS

Despite the efforts which have occurred around identifying treatments suitable for caribou habitat restoration, the restoration of industrial features is challenging without a clear definition, or goal, of what fully restored habitat should be. From a species recovery perspective, reclaimed boreal caribou habitat has been defined (in Alberta) as:

> "an area was deemed reclaimed when caribou no longer exhibit reduced use, on or near, a land-use feature (i.e., removal of zone of influence). Reclaimed also assumes that caribou are spatially separated from moose and predators and as such experience natural levels of predator encounter rates." (ALT 2009).

To date, vegetation recovery following industrial energy activity has been poorly documented. Lack of time sequence recording for industrial seismic lines and other developments, reduces the ability to estimate natural rates and types of vegetation recovery. Some estimates exist for natural recovery rates along disturbances. Lee and Boutin (2004) suggest that only 11% of seismic lines develop a woody vegetation cover within 35 years following disturbance in the boreal forest of northern Alberta, attributed in part, to the reuse of these features. Bayne (2007) suggests that limited data from the southern NWT indicates that recovery patterns seen in southern portions of the boreal forest may not hold for more northern climates and ecosystems. Alternatively, Oberg (2001) indicates that recovery of conventional seismic lines to functioning caribou habitat occurs within 20 years following disturbance in west-central Alberta. Similarly, a trial natural restoration/revegetation response inventory program in west central Alberta suggested that 85% of disturbed sites do not require artificial recovery, as a natural recovery projection was noted on previously disturbed sites (Suncor 2007). A cursory examination of wildlife use (caribou, deer, moose, wolf, bear) along a subset of these naturally restored linear features indicated that prey species (caribou, deer, moose) preferentially select restored seismic lines (> 1.5 m vegetation heights, average age of trees 23 years) over non-vegetated seismic lines (Golder 2009).

The current lack of inventory of disturbances and associated lack of both vegetation and wildlife response monitoring has resulted in the following information gaps:

- the amount, quality, and rates of natural recovery remain uncertain (affects modelling scenarios);
- the range of successional pathways and ecosite response to recovery;
- tree species (i.e., pine, spruce) and ground story species composition response;
- slope, aspect, elevation and line orientation differences on rate of recovery;
- the relationship of linear disturbance response to existing permanent sample plot data;

- the relationship between cutblock response and linear disturbance response; and
- the relationship between restoration treatments and the numerical and behavioural response of wildlife populations.

6.0 NEXT STEPS

There have been a number of small and larger scale initiatives to test the impact of different treatment types on the restoration of caribou habitat. The focus of most of the initiatives have been on establishing vegetation along linear corridors, with the goals of creating line of sight breaks, of directly restoring habitat with transplanted vegetation, planting shrub and tree seedlings, sewing native shrub and tree seed, and of controlling human access to these features to allow undisturbed vegetation growth. Due to the lack of monitoring and the time lag that exists to restore caribou habitat, there is currently no direct link to indicate that the restoration treatments when implemented are having an impact on caribou populations. However, based on modelling scenarios of management options for caribou, the restoration of habitat should have benefits in the long term as restoration of these features will contribute to restoring large contiguous habitat patch sizes, which are favourable to caribou.

Although caribou population response to habitat restoration treatments has not been monitored, effective methods of vegetation re-establishment have been identified through large scale habitat restoration projects, such as the Suncor/ConocoPhillips Little Smoky Caribou Habitat Restoration Pilot and the Canadian Natural Habitat Enhancement Program. These programs are now serving as templates for developing and implementing other habitat restoration projects, such as the OSLI initiatives in NE Alberta. These programs have a primarily operational focus with a strong vegetation monitoring component, and are based on the goal of successful re-establishment of vegetation within previously disturbed areas. These programs are recommended as a template when establishing a caribou habitat restoration program in NE BC.

A Proposed Habitat Restoration Mitigation Program

A caribou habitat restoration mitigation program should consist of three components; program considerations, current vegetation inventory and restoration treatments.

Program Considerations

- Restoration treatments, such as slash rollback and use of timber to minimize human access, need to consider fire protection guidelines.
- Restoration treatments, such as tree planting and seeding, must be accompanied with a well established access control plan. If human access is not controlled, restoration treatments are less likely to be successful. This access control plan should consider a public and industry awareness of the impact of human access use on habitat restoration success.
- A caribou habitat restoration program will be more successful if planned within an area where future industrial footprint is not planned to occur. This requires stakeholder input (e.g., Resource Review Areas). Coordinated planning between resource users (e.g., Integrated Landscape Management (ILM) initiatives to coordinate road access and clearing to accommodate both petroleum and forest sector requirements) enhances opportunities to eliminate footprint and unnecessary habitat restoration.

- A restoration program should consider prescriptions for new clearing activities which promote re-establishment of habitat following clearing and construction. Examples include clearing and construction under frozen ground conditions, high blading and use of mulchers to avoid impact to the duff layer, no and low-grade access routes, use of matting and minimizing stump removal. Artificial seeding of grass and legume based mixes should be avoided as these species out compete native shrub and tree species. (BC).

Current Vegetation Inventory

- Determine an area for a large scale treatment program. Consider factors such as preferred caribou habitat (core areas), potential for establishing large contiguous habitat patch sizes, level of expected future disturbance to the area, and level of co-operation with area stakeholders. These areas may be deemed demonstration areas, where treatments are applied and a long term monitoring program established.
- Once an area is selected, use aerial imagery interpretation to classify the level of existing disturbance to the area, and the state and type of regrowth on those features. A consideration would be to date each disturbance using remote imagery in an effort to determine natural recovery rates in the area where no treatments/prescriptions have been applied previously.
- Conduct a ground inventory of disturbance features which are determined by aerial imagery classification as having insufficient natural regeneration; to assess the amount, type, successional pathway and rate of natural recovery.
- Determine the amount and extent, of disturbance features in the area which would benefit from artificially introducing vegetation and/or site preparation treatments.
- Consult stakeholders once a draft restoration treatment plan is in place.

Restoration Treatments and Response of Treatments

- Determine appropriate treatment type to use on disturbance features that would benefit from artificially introducing vegetation and/or site preparation treatments, using Table 2 as a guide for treatments to use.
- Once treatments are completed, establish monitoring plots to study the survival and growth of both the introduced vegetation and the naturally occurring vegetation.
- To address knowledge gaps, it is recommended that monitoring also occur on the re-use of treated (or naturally recovered) disturbance features by both humans and wildlife.
- Long-term monitoring should focus on the caribou response, either on an individual or population level, to the restoration treatments implemented.

7.0 CLOSURE

This report was prepared by Golder Associates Ltd. (Golder) for the Fish Wildlife and Habitat Management Branch (Prince George) of the Government of British Columbia. The material in this report reflects Golder's best judgment in light of information available to it at the time of preparation. If Fish Wildlife and Habitat Management Branch edits, revises, alters or adds to the material in this report in any way, all reference to Golder, and Golder's employees must be removed unless changes are agreed to by Golder. 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 party. Golder accepts no responsibility for damages, if any, suffered by any third party as a result of decision made or action based on this report.

We trust the information contained in this report is sufficient for your present needs. Should you have any questions regarding the project, please do not hesitate to contact the undersigned at (780) 483-3499.

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REFERENCES

Axys Environmental Consulting Ltd.(Axys). 2003. Literature review of reclamation techniques for wildlife habitats in the boreal forest. Prepared for: Biodiversity and Wildlife Subgroup of the Reclamation Working Group, Cumulative Effects Management Association. Prepared by Axys Environmental Consulting, Calgary, Alberta.

Athabasca Landscape Team (ALT). 2009. Athabasca Caribou Landscape Management Options Report. 99 pp.

B.C. Conservation Data Centre. 2010. BC Species and Ecosystems Explorer. B.C. Minist. of Environ. Victoria, B.C. Available: http://a100.gov.bc.ca/pub/eswp/ (accessed Feb 15, 2010).

Bergerud, A. T. and J. P. Elliott. 1998. Wolf predation in a multiple-ungulate system in northern British Columbia. Can. J. Zool. 76:1551-1569.

Bergerud, A.T., R.D. Jakimchuk and D.R. Carruthers. 1984. The Buffalo of the North: Caribou (*Rangifer tarandus*) and Human Developments. Arctic, 37 :7-22.

Boreal Caribou Technical Advisory Committee (BCTAC). 2004. A Recovery Strategy for Boreal Caribou in British Columbia. Ministry of Water, Land and Air Protection, Victoria, B.C.

Camill P. 1999. Patterns of boreal permafrost peatland vegetation across environmental gradients sensitive to climate warming. Can J Bot 77:721–33.

Caribou Range Restoration Project (CRRP). 2006. Caribou Range Restoration Project: Guidelines for Planning and Implementation, May 16, 2006. Draft Unpublished Document.

Caribou Range Restoration Project (CRRP). 2007. Permanent Sample Plot Manual for the Caribou Range Restoration Project in Alberta, March 23, 2007. Draft Unpublished Document.

COSEWIC, 2003. Canadian Species at Risk, May 2003. Committee on the Status of Endangered Wildlife in Canada.

Culling, D.E., and B. A. Culling. 2006. Ecology and Seasonal Habitat Selection of Boreal Caribou in the Snake-Sahtaneh Watershed, British Columbia 2000 to 2004. Technical Report. Prepared for: Canadian Forest Products Ltd., Fort Nelson, BC. Prepared by: Diversified Environmental Services, Fort St. John, BC. 80 pp.

Culling and Cichowski. 2010. Scientific Update for the Boreal Caribou (Rangifer tarandus caribou) in British Columbia, 2010. 54 pp.

Decesare, N. J., J. Whittington, M. Hebblewhite, H. Robinson, M. Bradley, L. Neufeld, and M. Musiani. 2011. The Role of Translocation in Recovery of Woodland Caribou Populations. Conservation Biology 25(2):365-373.

Diversified Environmental Services (DES). 2004. Canadian Natural Resources Ltd. Ladyfern Pipeline d-87-H/94-H-1, British Columbia to NE Section 20- Township 94-Range 12 W6M, Alberta: Revegetation Monitoring Report Year 2 (2003). Prepared for: Canadian Natural Resources Ltd. Prepared by:Diversified Environmental Services, Fort St. John, B.C. 18 pp. + Appendices.

Dunford, J. S. 2003. Woodland Caribou-Wildfire Relationships in Northern Alberta. M.Sc. Thesis. University of Alberta.

Dyer, S.J. 1999. Movement and Distribution of Woodland Caribou (*Rangifer tarandus caribou*) in Response to Industrial Development in Northeastern Alberta. M.Sc. Thesis. University of Alberta. 106 pp.

Dyer, S.J., S.M. Wasel, J.P. O'Neill and S. Boutin. 2001. Avoidance of Industrial Development by Woodland Caribou. Journal of Wildlife Management. 65(3): 531-542.

Enbridge Pipelines (Athabasca) Inc. December 15, 2010. Waupisoo Pipeline Project: 2010 Green Area Post-Construction Reclamation Assessment. Submitted to Alberta Sustainable Resource Development.

Environment Canada (EC). 2011. Recovery Strategy for the Woodland Caribou, Boreal population *(Rangifer tarandus caribou)* in Canada [Proposed]. *Species at Risk Act* Recovery Strategy Series. Environment Canada, Ottawa. vi + 55 pp.

Girard, M., Lavoie, C., and Thériault, M. 2002. The regeneration of a highly disturbed ecosystem: A mined peatland in southern Québec. Ecosystems, 5: 274–288.

Golder Associates Ltd. (Golder). 2005. Firebag Project 2004 Seismic Line Reclamation Study Annual Report. Submitted to: Suncor Firebag Inc.

Golder Associates Ltd. (Golder). 2010. Canadian Natural Resources Limited: Primrose and Wolf Lake: Wildlife Habitat Enhancement Program Development and Implementation. Submitted to: Canadian Natural Resources Ltd, Calgary, AB.

Golder Associates Ltd. (Golder). 2011. Waupisoo Pipeline 2011 Seedling Monitoring Plot Summary. Submitted to Enbridge Pipelines (Athabasca) Inc.

Golder Associates Ltd. (Golder). February 23, 2012. Interconnect Pipeline 2011 Seedling Monitoring Plot Summary. Memo submitted to CNRL.

Golder (Golder Associates Ltd.). 2009. Caribou Habitat Restoration Pilot Study. Prepared for Conoco Phillips Canada, Suncor Engery and Canadian Association of Petroleum Producers. 41pp.

Goddard, A. D. 2009. Boreal Caribou in Northeastern British Columbia: Biological Rationale, Data Summary & Literature Review. Peace Region Technical Report, Fish & Wildlife Section, Ministry of Environment, Fort St. John, BC.

James, A.R.C. 1999. Effects of Industrial Development on the Predator-Prey Relationship Between Wolves and Caribou in Northeastern Alberta. Ph.D. Thesis Submitted to the University of Alberta. Edmonton, AB.

James, A.R.C. and A. K. Stuart-Smith. 2000. Distribution of caribou and wolves in relation to linear corridors. Journal of Wildlife Management 64:154-159.

Khasa PD, Sigler L, Chakravarty P, Dancik BP, Erikson L, Mc Curdy D. 2001. Effect of fertilization on growth and ectomycorrhizal development of container-grown and bare-root nursery conifer seedlings. New For 22:179–197.

Latham, A. D. M. 2009. Wolf ecology and caribou-primary prey-wolf spatial relationships in low productivity peatland complexes in northeastern Alberta. Ph.D. Thesis. University of Alberta. 197pp

Lee, P., and S. Boutin. 2006. Persistence and developmental transistion of wide seismic lines in the western Boreal Plains of Canada. Journal of Environmental Management. 78:240-250.

MacFarlane, A. 1999. Revegetation of wellsites and seismic lines in the boreal forest. B.Sc. Honour’s Thesis, Department of Biological Sciences, University of Alberta, Edmonton, Alberta, Canada.

MacFarlane, A. K. 2003. Vegetation Response to Seismic Lines: Edge Effects and On-line Succession. Master of Science Thesis, Department of Biological Sciences, University of Alberta, Edmonton, AB.

McLoughlin, P. D., E. Dzus, B. Wynes, and S. Boutin. 2003. Declines in populations of woodland caribou. Journal of Wildlife Management 67(4):755-761.

Ministry of Environment. 2011. Implementation Plan for the On-going Management of Boreal Caribou (*Rangifer tarandus caribou* pop. 14) in British Columbia. Victoria, BC, 17 pp.

Naeth, M.A., White, D.J., Chanasyk, D.S., Macyk, TM., Power. CB., and Thacker, D.J. 1991. Soil physicaI properties in reclamation. Alberta Land Conservation and Reclamation Council. Report No, RRTAC 91-4. ISBN 0-7732-0880-I, Edmonton, AB. 216 pp.

Neufeld. L. 2006. Spatial dynamics of wolves and woodland caribou in an industrial forest landscape in west-central Alberta. M.Sc. Thesis, Department of Renewable Resources, University of Alberta, Edmonton, AB. 155 pp.

Oberg, P. R. 2001. Responses of Mountain Caribou to Linear Features in a West-central Alberta Landscape. M.Sc. Thesis, University of Alberta, Edmonton, AB. 126 pp.

Oil Sands Leadership Initiative (OSLI). 2012. Projects Land. http://www.osli.ca/projects/land Access on March 13, 2012.

Osko, T. J. and A. K. MacFarlane. 2000. Natural reforestation rates on seismic lines and wellsites in comparison to natural burns or logged sites. Alberta- Pacific Forest Industries, Boyle, Alberta.

Osko and Glasgow, 2010. Removing the Well-Site Footprint: Recommended Practices for Construction and Reclamation of Well-sites on Upland Forests in Boreal Alberta. Department of Biological Sciences, University of Alberta.

Revel, R. D., T. D. Dougherty, and D. J. Downing. 1984. Forest Growth and Revegetation Along Seismic Lines. University of Calgary Press, Calgary, AB.

Sherrington, P. M. 2003. Measuring Boreal Forest Fragmentation Change in Response to Seismic Line, Wellsite and Road Revegetation with Scanned False-Colour Infrared Aerial Photography. Master of Science Thesis, Department of Geography, University of Calgary, Calgary, AB.

Smith, K. G. 2004. Woodland Caribou Demography and Persistence Relative to Landscape Change in West-central Alberta. M.Sc. Thesis, Department of Biological Sciences, University of Alberta, Edmonton, AB. 112 pp.

Suncor Energy. February 2007. Little Smoky Caribou Habitat Restoration Pilot Project Summary. Unpublished document prepared by the Caribou Range Restoration Project. Prepared for Suncor Energy, ConocoPhillips, Canadian Forest Products and Alberta Newsprint Co.

Szkorupa, T. 2002. Caribou Range Recovery in Alberta: 2001/02 Pilot Year. Alberta Sustainable Resource Development, Fish and Wildlife Division, Alberta Species At Risk Report No. 48. Edmonton, AB. 8 pp.

Tedder,W.S. and Turchenek, L.W. 1996. Natural Revegetation of an Alberta Peatland After Horticultural Peat Extraction. 4th Annual Canadian Peatland Restoration Workshop, 13-14 July, Quebec City, Canada; Universite Laval, Faculte des Sciences de Sciences de L'agriculture et de l'alimentation, Quebec City, Canada;; 62 PP. (Abstract, P. 51)

Thomas, D. C. and D. R. Gray. 2002. Update COSEWIC status report on the woodland caribou *Rangifer tarandus caribou* in Canada, in COSEWIC assessment and update status report on the Woodland Caribou *Rangifer tarandus caribou* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-98 pp.

Turetsky M.R., Wieder R.K., Williams C.J., Vitt D.H. 2000. Organic matter accumulation, peat chemistry, and permafrost melting in peatlands of boreal Alberta. Écoscience 7:379–392.

Robinson, S.D., and Moore, T.R., 2000. Carbon and peat accumulation over the past 1200 years in a landscape with discontinuous permafrost. *Global Biogeochemical Cycles,* 13, p. 591-601.

Wilson, S. F., C. Pasztor, and S. Dickinson. 2010. Projected Boreal Caribou Habitat Conditions and Range Populations. Prepared for: British Columbia Ministry of Energy, Mines and Petroleum Resources and Ministry of Environment.

Wittmer, H.U., B.N. McLellan, R. Serrouya, and C.D. Apps. 2007. Changes in landscape composition influence the decline of a threatened woodland caribou population. Journal Of Animal Ecology. 76:568-579.

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