WORKING PAPER 2002-5

sustainable forest management network

réseau sur la gestion durable des forêts

The Management of Cumulative Impacts of Land-uses in the Western Canadian Sedimentary Basin: A Case Study

A Network of Centres of Excellence
Un réseau de centres d'excellence

R.R. Schneider, J.B. Stelfox, S. Boutin, and S. Wasel

For copies of this or other SFM publications contact:

Sustainable Forest Management Network
G208 Biological Sciences Building
University of Alberta
Edmonton, Alberta, T6G 2E9
Ph: (780) 492 6659
Fax: (780) 492 8160
http://www.ualberta.ca/sfm

This Working Paper is published by the Sustainable Forest Management Network. All Network Researchers are invited to present ideas and research results in this forum to accelerate their application and to foster interdisciplinary discussion on knowledge, strategies and tools leading to sustainable management of Canada's boreal forest. Working Papers are published without peer review.

The Management of Cumulative Impacts of Land-uses in the Western Canadian Sedimentary Basin: A Case Study

Richard R. Schneider[1], J. Brad Stelfox[2], Stan Boutin[3], and Shawn Wasel[4]

[1]Ministik Environmental Consulting
[2]Forem Consulting
[3]Department of Biological Sciences, University of Alberta
[4]Alberta-Pacific Forest Industries Inc.

September, 2002

A project of the Adaptive Management Experiment Team
Sponsored by: Alberta-Pacific Forest Industries Inc.

Abstract

In this paper we present a case study from northeastern Alberta, Canada. Our objective is to demonstrate a fundamentally different approach to forest management in which stakeholders weigh current management options in terms of their long-term effects on the forest in order to balance conservation and economic objectives. We use *ALCES*®, a landscape-scale simulation model, to quantify the effects of the current regulatory framework and typical industrial practices on a suite of ecological and economic indicators over the next 100 years. Our simulations suggest that if current practices continue, the combined activities of the energy and forestry industries in our 59,000 km^2 study area will cause the density of anthropogenic edge to increase from 1.8 km/km^2 to a maximum of 8.0 km/km^2. We also predict that older age classes of merchantable forest stands will be largely eliminated from the landscape, habitat availability for woodland caribou will decline from 43% to 6%, and there will be a progressive shortfall in the supply of softwood timber, beginning in approximately 60 years. Additional simulations involving a suite of "best practices" demonstrated that substantial improvements in ecological outcome measures can be achieved, while maintaining a sustainable flow of economic benefits, through alternative management scenarios. We discuss the merits of our proposed approach to land-use planning, with application to the Western Canadian Sedimentary Basin.

Introduction

The combined effects of the energy, forestry, and agriculture industries are threatening the integrity of forests of the Western Canadian Sedimentary Basin (WCSB) (Fig. 1). The root of the problem is the current system of management which lacks meaningful ecological objectives and fails to integrate the overlapping activities of resource companies. In this paper we present a case study that demonstrates a fundamentally different approach to forest management in which stakeholders weigh current management options in terms of their long-term effects on the forest in order to balance conservation and economic objectives. In our case study we use *ALCES®*, a landscape-scale simulation model, to quantify the effects of the current regulatory framework and typical industrial practices on a suite of ecological and economic indicators over the next 100 years. We also use the model to explore an alternative management scenario involving the application of several "best practices" that are currently being advocated.

Fig. 1. Extent of the WCSB in western Canada (grey), and the location of our study area (black).

Patterns of land use in the Western Canadian Sedimentary Basin

The petroleum deposits within the WCSB represent one of the world's largest hydrocarbon resources (PCF, 2000: 4). The development of this resource began in the 1950s and has been proceeding rapidly, particularly over the last decade. Forests within the WCSB are also subject to commercial forestry operations that have likewise expanded in recent decades. In addition, the Peace River region of Alberta and British Columbia supports a large agricultural industry. Collectively, these land uses are profoundly transforming the forests of the WCSB. The forest land base is shrinking, human access is steadily increasing, and forest stands are changing in composition, and becoming younger and more fragmented (AEP, 1998a).

One of the most prominent sources of change to forest structure within the WCSB is seismic exploration. This technique, involving the analysis of sound waves reflected from subsurface features, is used to identify and delineate petroleum deposits. In forested areas, conventional seismic exploration involves the cutting of linear corridors to provide access for vehicles and equipment. Until recently, these cut-lines were 6-8 m in width, though cut-lines are now generally limited to a maximum width of 5 m in areas of merchantable forest (LAD, 1999: 14). As a general rule, seismic lines are not regenerated to forest (LAD, 2000). Low light levels, soil disturbance, and continued use by all-terrain vehicles and snowmobiles further retard the regeneration of forest (Revel, 1984; Osko and MacFarlane, 2001). As a consequence, seismic lines are a semi-permanent feature of the landscape, responsible for progressive loss and fragmentation of the forest. Considering that 70,500 km of new seismic lines were approved in the forested region of Alberta in fiscal 1999 (Alberta Sustainable Resource Development, unpub. data), the cumulative impact is significant.

Widespread semi-permanent deletions of forest also occur as a result of the extractive phase of petroleum development. Wellsites average one hectare in size in forested areas, and each wellsite typically has an access road leading to it and a pipeline leading away from it. The wellsite, road, and pipeline right-of-way are all maintained in a non-forested state throughout the active life of the well. Decades later, when the well is no longer productive, the site is reclaimed, generally to grass instead of forest (LAD, 2001: 10).

The forest industry is also responsible for changes in forest structure, even though companies are required to reforest the areas they log. In part, this is because older stands are preferentially targeted for harvest, due to their high volume and potential loss to fire, insects, or disease. In conventional forestry operations these old-growth stands are never replaced, because timber yields are highest if regenerating stands are re-harvested prior to reaching the old-growth phase. Consequently, old-growth stands are progressively eliminated from the forest landscape (Bergeron et al., 1998). In addition, the regeneration practices of forestry companies are typically geared towards the rapid regeneration of selected tree species, instead of the mixed-species stands typical of boreal forests in western Canada (Lieffers and Beck, 1994). In time, these practices lead to a shift in the species composition of the forest.

Every forest stand that is logged includes an in-block haul road and a landing where timber is stored prior to transport. Forest regeneration on these roads and landings can be substantially delayed and, consequently, they form another source of semi-permanent loss and fragmentation of the forest. The permanent road network that is used to provide access for logging trucks to harvest sites is responsible for additional deletions.

Finally, the expansion of agriculture along the Peace River and along the southern border of the boreal forest continues at a rapid pace (EC, 1991: 5-9). This includes the clearing of forest for growing grain and forage crops and the use of forests for cattle grazing.

Integrated resource management in Alberta

Of the various provinces and territories included in the WCSB, industrial development occurred first, and has progressed the farthest, in Alberta (Wetherell and Kmet, 2000). Hence, Alberta serves as a microcosm for development patterns that can be expected throughout the WCSB.

Although attempts at integrated resource management have been made in Alberta since the 1970s, different industrial sectors continue to be managed by different government agencies utilizing different policy instruments (Kennett, 2002). If there is any unifying feature among these agencies it is a common mandate for economic growth (e.g., ARD, 2001: 43). Environmental protection continues to be handled through piecemeal regulation focused on mitigating local short-term effects of specific industrial activities. Strategies for achieving long-term ecological objectives at the regional scale, including limits on cumulative industrial effects, have yet to be implemented (Kennett, 2002). For example, despite a surfeit of regulations governing the conduct of seismic exploration, there is no limit on the cumulative density of lines.

In the absence of an integrative planning framework, resource companies generally plan their activities independently — even if they operate on the same land base. For example, the planning and construction of road networks by petroleum companies and forestry companies is usually done independently, in spite of obvious cost savings and reduced environmental effects associated with a combined network.

Nothing within the current regulatory framework will prevent further increases in the cumulative industrial footprint. This presents a risk that populations of sensitive forest species will decline and that the province's general goal of maintaining forest integrity will not be achieved. For example, species such as woodland caribou (*Rangifer tarandus caribou*) and walleye (*Stizostedion vitreum*) have been shown to be adversely affected by linear disturbances and increased human access (Dyer et al., 2001; Post and Sullivan, 2002). Other species, including many forest birds, are adversely affected by the loss of old-growth stands (Benkman, 1993; Kirk et al., 1996). Concern has also been expressed that the progressive loss of timber from petroleum industry activities and fire, which were not accounted for when forestry tenures were allocated, may threaten the viability of some forestry companies in future decades.

Methods

Study area

The study area was the Forest Management Agreement area of Alberta-Pacific Forest Industries Inc. (Al-Pac), encompassing 59,054 km^2 in northeast Alberta, Canada (Fig. 1). The area has minimal topographic relief, with the exception of a few scattered hill systems. Upland sites are typified by pure and mixed stands of aspen and white spruce, though jack pine predominates on drier sites (AEP, 1994a). Lowland sites are characterized by open stands of black spruce and tamarack, and by extensive peatland complexes (AEP, 1994a).

The study area contains 23,842 km^2 of potentially merchantable forest and is underlain by extensive oil and gas deposits. The oil deposits include conventional liquid oil, heavy oil (low viscosity), and oil sands (a mixture of semi-solid oil and sand). In an area of approximately 37 townships the oil sands are sufficiently close to the surface to be extracted using surface mines. The remaining deeper oil sands deposits must be extracted by special well systems that use steam to heat the oil and mobilize it.

Industrial activity within the study area was minimal in the first half of the 20th century (Wetherell and Kmet, 2000), but expanded rapidly thereafter. Small-scale forestry operations producing dimensional lumber and conventional oil and gas operations were active first. In 1967 the first full-scale commercial oil sands mine went into operation, ushering in a period of rapid growth of the petroleum sector. In 1990 the Al-Pac Forest Management Agreement was signed, and the company's $1.3 billion pulp mill went into operation in 1993. The forest industry currently clears a total of 16,000 ha/year on the study area (10,000 ha/year by Al-Pac, and 6,000 ha/year by smaller forestry companies), compared with 11,000 ha/year for the petroleum sector. Because petroleum industry features, such as seismic lines, well sites, and pipelines, persist on the landscape they have a greater cumulative impact than forest industry features, most of which are immediately regenerated to forest.

GIS map overlays provided by Al-Pac were used to quantify the industrial footprint of the study area in 2002 (Table 1). Included in the industrial footprint were all areas of the forest land base currently in a non-forest state as a result of industrial activity. Forestry cutblocks were not included in the tally because they are immediately regenerated to forest; however, in-block haul roads and landings (which experience delayed regeneration) were included. These data were used to define the initial state of the forest for the *ALCES* model runs.

The ALCES model

ALCES (A Landscape Cumulative Effects Simulator) was developed over a period of seven years for the purpose of tracking industrial footprints and ecological processes under alternative management scenarios. To facilitate scenario analysis *ALCES* provides results within minutes, even for very large landscapes (such as our 59,000 km^2 study area). *ALCES* is, in essence, a bookkeeping model, depending largely on user input to describe the processes being simulated. The user must specify the initial state of the landscape and provide quantitative assumptions concerning future industrial activities, natural disturbances, and regeneration trajectories for each disturbance type. Given this information the model tracks and updates the state of the landscape in one-year time steps for as long as requested.

When only forest harvesting and regeneration are activated, the model is functionally equivalent to the aspatial timber supply models used by forestry companies for long-term harvest planning (Forestry Corporation, 2002). The major advantage of *ALCES* is that the user can include a variety of additional natural and human-origin disturbances in model runs. The suite of available ecological output measures is also far greater than what is typically included in timber supply models.

Table 1. Area of the forest land base in a non-forest state in 2002 resulting from industrial disturbance.

Type of disturbance	Area (ha)
Seismic lines	41,082
Pipelines	22,258
Roads (minor)	20,000
Pasture grass	19,992
Wellsites	15,516
Roads (major)	11,606
Roads (wellsite)	7,346
Oilsand surface mine	5,829
Recreation areas	3,100
In-block losses	2,800
Towns	2,460
Misc. agriculture	1,809
Transmission lines	1,000
Peat mine	234
Miscellaneous	130
Total disturbed area	155,162

To simulate large landscapes rapidly using current computer hardware it is not possible to track the spatial location of all landscape features. Instead, *ALCES* permits users to stratify the landscape into multiple subunits that are tracked independently. For example, the forest land base can be stratified into several stand types, and different harvest and regeneration strategies can be applied to each stratum.

For some types of industrial activity new disturbances may overlap existing features. For example, new seismic programs are sometimes conducted along existing seismic lines that have not yet regenerated. To account for spatial overlap in *ALCES* the user must specify the average proportion of new disturbances that overlap existing features. Changing the proportion of overlap of features between model runs may be an important component of a scenario comparison, as it was in this study.

For the most part, *ALCES* allows industrial activities and natural disturbances to occur either deterministically or stochastically.

Modeling assumptions

For the analysis presented here the disturbance types were limited to forest harvesting, petroleum exploration and development, road construction, and fire. Forest harvesting protocols were matched to conventional practices in use in Alberta. The basic approach is a 2-pass clearcut system with a 70-year rotation for hardwoods and a 100 year rotation for softwoods. Silvicultural systems and stand growth and yield curves were also matched to current industry norms. Further detail concerning current forestry practices in Alberta is provided in the provincial *Operating Ground Rules* (AEP, 1994b).

The future trajectory of petroleum industry activities was based on the assumption that drilling would continue at the current rate (Fig. 2) until reserves are depleted (Fig. 3). Only 1% of the 50 billion m^3 of potentially recoverable oil sands reserves have been recovered to date; therefore, oil sands reserves will last well into the next century (AEUB, 2001:2). Separate trajectories for conventional oil, gas, and oil sands were used in the model (Fig. 4).

Historical trend data on the rate of seismic line development were incomplete for the study area. However, from Al-Pac's GIS dataset we determined that an average of 3 km of seismic lines are generated for each well drilled and this relationship was used in the model runs. Similarly, we used a ratio of 0.1 km of pipeline for each well drilled. Other petroleum sector variables were varied as part of the scenario comparison (described below).

Based on Al-Pac's road development plan, together with anticipated road construction associated with energy sector development, we estimated that 75 km/year of permanent roads would be built over the next 50 years. At that point the permanent road network in the study area will be relatively complete. We also estimated that an average of 500 km

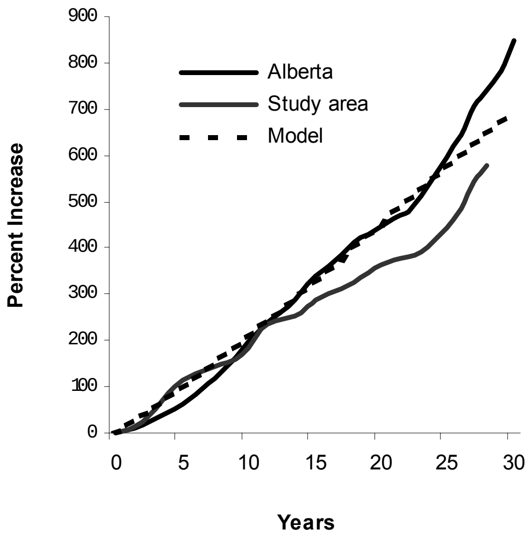

Fig. 2. Cumulative number of wells in the study area and Alberta, 1970-1999. Superimposed are the cumulative number of wells in the first 30 years of the model run. Data are expressed as the annual percent increase relative to year 0, to facilitate direct comparison.

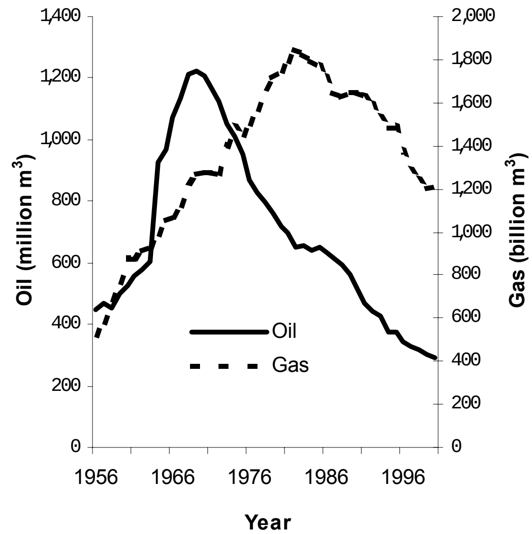

Fig. 3. Conventional oil and gas reserves in Alberta, 1956-2000 (AEUB, 2001 and earlier AEUB reports).

of temporary access roads would be required each year for the next 50 years, and thereafter the construction of temporary roads would gradually taper off. Permanent and temporary roads represent long-term deletions from the forest land base.

Since 1980 fire has burned an average of 0.65% of northern Alberta per year (excluding water bodies), and the rate appears to be trending upwards (ASRD, 2002). Estimates of long-term rates of fire, based on mathematical analysis of forest age structure and fire history data, range from 0.4% per year (Cumming, 1997) to 2.2% per year (Murphy, 1985). Balancing these various sources of information we selected a fire rate of 1% per year for the model runs. Instead of varying the area burned stochastically we utilized a constant fire rate, so as to simplify comparisons between alternative management scenarios. Fire salvage logging was not included in the model.

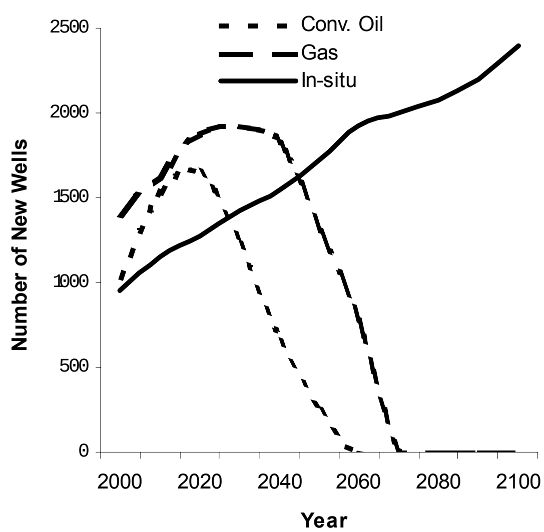

Fig. 4. Annual number of new wells used in all model runs, by product type.

Scenario analysis

To demonstrate the utility of the model we investigated two management scenarios. The first was a representation of conventional practices, which we termed "business as usual" (BAU). The other scenario, termed "best practices" (BP), was a modified management strategy intended to be more ecologically and economically sustainable. The list of elements defining best practices was not comprehensive. Our intent was simply to demonstrate the gains that could be expected through a few basic measures that could realistically be implemented without major technological impediments.

For the forestry sector, best practices included a change in harvesting protocols, such that a proportion of older stands would be excluded from harvest (Table 2). There was also an increase in variability in cutblock size and a reduction of in-block losses. For the petroleum sector a series of changes were implemented to decrease the magnitude of the annual footprint (assuming a fixed rate of development), including increased road harmonization with the forestry sector (Table 2). Best practices for the energy sector also included measures to promote the reclamation of disturbances.

Table 2. Model assumptions used in the scenario analysis.

Variable	**Business as Usual**	**Best Practice**
Harvest of hardwoods	Oldest first; minimum harvest age = 70 years.	No harvest of stands > 120 years; minimum harvest age = 70 years.
Harvest of softwoods	Oldest first; minimum harvest age = 100 years.	No harvest of stands > 140 years; minimum harvest age = 100 years.
Cutblock size	All cutblocks = 21-40 ha in size	Cutblock size distribution: - 1-21 ha = 20% - 21-40 ha = 45% - 41-80 ha = 25% - 81-160 ha = 10%
In-block losses (haul roads, landings)	5%	2%
Road harmonization between the petroleum sector and forestry sector	10% sharing of new roads	50% sharing of new roads
Width of seismic lines	5 m	1 m
Reforestation of seismic lines	25 year lag (seeded to grass)	4 year lag
Spatial overlap of new seismic lines with existing linear disturbances	10%	50%
Spatial overlap of new pipelines lines with existing linear disturbances	10%	50%
Number of wells per drill pad	1	2
Reforestation of well sites after decommissioning	25 year lag (seeded to grass)	Immediate replanting of trees

ALCES is able to report on a broad suite of ecological and economic indicators, in addition to basic output measures such as harvest volume, forest age class structure, and amount of anthropogenic edge. For the purpose of this study we selected habitat availability for caribou as an additional ecological indicator. Parameter estimates for caribou habitat availability used in the model represent the consensus estimate of 20 biologists with caribou experience, arrived at through a workshop process. The key parameter affecting the scenario analysis is the avoidance distance of caribou from human disturbances (ranging from 100 m for seismic lines to 500 m for roads). These data largely reflect the findings of Dyer et al. (2001) who quantified caribou avoidance of industrial features using radiotelemetry.

Results

Under the BAU scenario, the industrial footprint within the study area increased dramatically over the 100-year simulation period. The clearest measure of this footprint is the density of anthropogenic edge, which increased from 1.8 km/km^2 to a maximum of 8.0 km/km^2 (Fig. 5). Under the BP scenario the maximum density of anthropogenic edge was 3.2 km/km^2.

Ecological attributes also experienced a major change in the BAU run. Old-growth stands of softwoods (> 140 years) were eliminated within 20 years, and old-growth stands of hardwoods (> 100 years) in 65 years (Figs 6a and 6b). Available caribou habitat declined rapidly from 43% of the land base to 6% of the land base (Fig. 7). Under the BP run the amount of old-growth declined as well, but the rate of decline was not as rapid, particularly for the softwoods (Figs. 6a and 4b). There was also a decline in the availability of caribou habitat in the BP run; however at least half of the original amount remained at all times (Fig. 7).

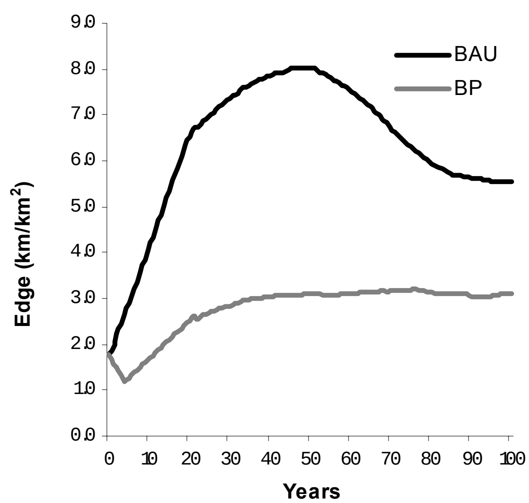

Fig. 5. Density of anthropogenic edge expressed as km of edge/km^2.

In the BAU scenario a shortfall of softwood timber was observed, relative to the approved annual allowable cut, beginning in approximately 60 years (Fig. 8). A similar pattern was observed in the BP run, though the onset of the shortfall was delayed by about a decade. A shortfall in the hardwood harvest did not occur in either scenario.

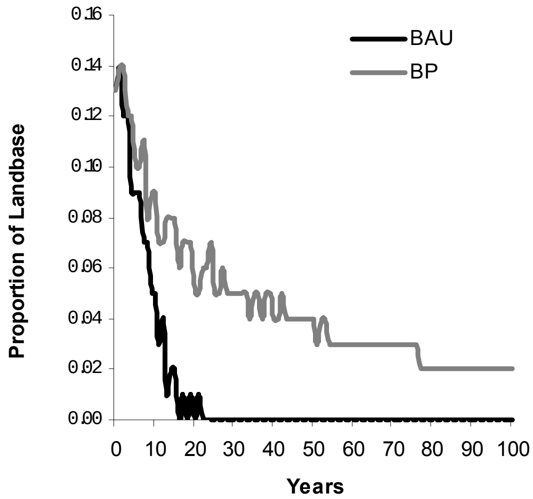

Fig. 6a. Proportion of the land base in old-growth softwood.

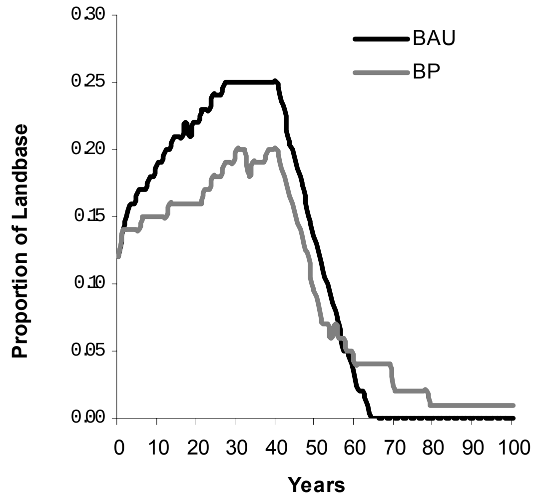

Fig. 6b. Proportion of the land base in old-growth hardwood.

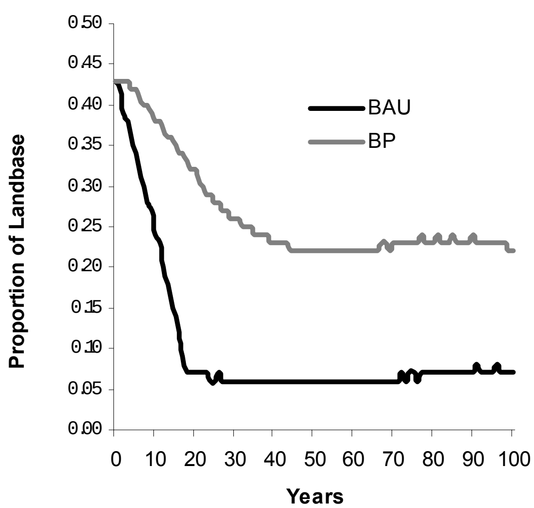

Fig. 7. Availability of caribou habitat.

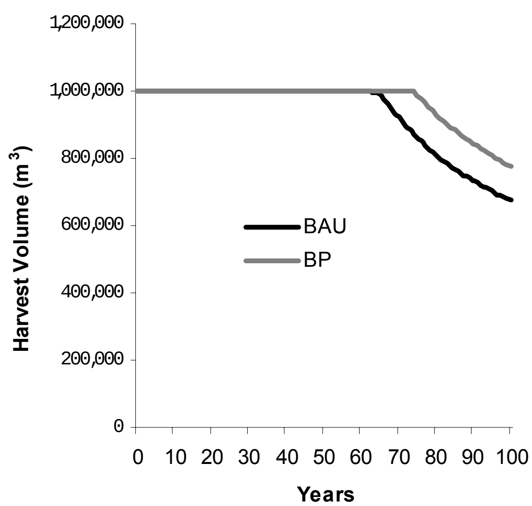

Fig. 8. Annual harvest volume of softwoods.

The model also demonstrated that existing practices carry a substantial economic cost. Petroleum companies must pay a prescribed fee to forestry companies for wood that they remove as part of their operations. These timber damage fees averaged $1,316,000 per year in the BAU run, compared with $521,000 in the BP run. The difference in biotic carbon storage between the two runs amounted to 5.8 tonnes/ha. Based on the current rate of $10/tonne for carbon credits, this amounts to $342 million over the study area.

Discussion

Until about 1950, our study area could be characterized as boreal wilderness (Wetherell and Kmet, 2000). By 2000 it had undergone a profound transformation, as a consequence of accelerating industrial development (AEP, 1998a). However, this transformation pales in comparison to the changes we predict are yet to occur in coming decades unless changes are made to the current regulatory framework and operating practices.

According to our model there will be a progressive reduction in the forest land base, the remaining forest will become progressively younger and more fragmented, and there will be a marked increase in human access. The cumulative industrial footprint, in terms of density of linear disturbance and total area disturbed, will quadruple over the next 20-30 years, and then moderate.

Because these predictions are for the most part based on a simple projection of current trends, they are relatively robust. Indeed, localized examples of development at the high intensities predicted by the model already exist in Alberta in areas where industry is mature (AEP, 1998a). Moreover, more than $50 billion dollars in new petroleum developments in northern Alberta have already been announced (ARD, 2001: 15). In cases where accurate estimates of model parameters were unavailable, we intentionally chose conservative estimates so that our results would not be construed as a worst-case scenario.

The increase in density of anthropogenic edge is primarily attributable to industrial features that persist on the landscape, leading to cumulative impacts far in excess of the annual rate of disturbance. Most prominent among these features are seismic lines, because they are generated at a high rate and require decades to regenerate under current practices (Revel, 1984; Osko and MacFarlane, 2001). Roads, wellsites, pipelines, and in-block losses associated with harvesting are also important contributors of anthropogenic edge.

Our finding that the industrial footprint will expand most rapidly over the next two decades and then decline is somewhat counterintuitive, given that conventional oil and gas reserves are already in a state of decline in Alberta (AEUB, 2001). However, the annual rate of production in the near term is primarily limited by economic factors and industry capacity, not the size of reserves. Provincial government policy is focused on maximizing short-term economic returns from the remaining reserves, and the royalty system has been structured to ensure this occurs (Macnab et al., 1999). Petroleum companies share the desire to develop rapidly because there exists a risk that alternative forms of energy may reduce demand for petroleum in the future, and because oil that is extracted provides cash for investment, whereas oil in the ground does not. In consequence, the conventional oil and gas sector is poised to undergo a pronounced "boom and bust" cycle over the next 20-30 years, ending when reserves are depleted.

The exception to this pattern is the development of oil sands deposits, which are sufficiently large to last well into the next century (AEUB, 2001).

Another structural change to the forest predicted by our model is the elimination of old-growth, beginning with softwood stands. This result is the direct manifestation of current forestry practices in which oldest stands are logged first (AEP, 1994b). Although forest clearing by the petroleum industry and fire do not target older stands specifically, they do remove some old growth by chance, and hence increase the rate at which old-growth is lost.

The changes in forest structure predicted by the model are expected to have a significant effect on forest wildlife. Species dependent on old-growth and interior habitat are likely to decline as their preferred habitat types are lost from the landscape (Benkman, 1993; Donovan et al, 1995; Kirk et al., 1996). Species that are sensitive to human disturbance, such as woodland caribou, are also likely to experience a decline. In our model the availability of caribou habitat decreased from 43% of the study area to 6% as a consequence of industrial development. Because caribou are already listed as threatened in Alberta (Dzus, 2001), this magnitude of effective habitat loss is a serious cause for concern. The great increase in road infrastructure is also likely to result in problems. In addition to the loss and fragmentation of habitat, roads result in soil erosion, disruption of water and fish movements, changes in animal movement patterns, and increased access by humans (resulting in increased hunting and poaching) (Jones et al., 2000; Trombulak and Frissell, 2000).

In addition to the aforementioned ecological effects, the current system of forest management will have negative socio-economic repercussions. Foremost among these is a shortfall in the supply of softwood timber, beginning in approximately 60 years. Because mills have substantial fixed costs, running below full capacity translates into reduced economic return, and in some cases may result in mill closure. The timber shortfall occurs because annual harvest rates are currently based on the rate of tree growth, without accounting for losses from fire and the activities of the petroleum sector (AEP, 1996). Salvage logging cannot fully compensate for these external losses because more than half of the merchantable forest lost to fire and the petroleum sector is too young, too damaged, or too inaccessible to be used (Al-Pac, unpub. data). Moreover, as time passes, and the forest becomes progressively younger, less wood lost to external causes is suitable for salvage and all sources of disturbance effectively become additive.

There are economic repercussions for the petroleum industry as well. The fees that petroleum companies must pay to forestry companies for timber damage will amount to tens of millions of dollars in coming decades. This is a lose-lose situation in that the economic loss to the petroleum industry does nothing to restore the forest in the areas that are disturbed. The current system also ignores potential credits that could be gained by petroleum companies for maintaining carbon stores on the landscape. According to our simulation these credits could amount to hundreds of millions of dollars for the petroleum industry if best practices were implemented. Finally, the current system foregoes substantial cost savings that would accrue if the petroleum industry and forest industry were to harmonize their road network.

The underlying reason for the various problems illustrated by our modeling exercise is that the current system of forest management in Alberta is a relic of earlier times. The system is essentially unchanged from the 1950s, when it was established to maximize economic returns from resource extraction in the north. Since then, two important changes have occurred. First, the once pristine forest is now so densely occupied by industrial operators that interference among companies and sectors is commonplace. Second, as a consequence of shifting public values there now exist ecological objectives (e.g., AFCSSC, 1997) that cannot be adequately addressed by the current system of management.

What is required, to start, is an acceptance that the days of the open frontier are over. The attitude that the forest can be all things to all interests is no longer tenable, if indeed it ever was. Although the boreal forest presents a seemingly endless expanse, it does in fact have limits, and they are now being reached. Consequently, future management of the forest will occur in the context of tradeoffs among competing interests and objectives.

Finding the appropriate balance among competing objectives requires three features lacking in the current system of forest management: meaningful stakeholder involvement, integrated planning, and an assessment of how current management decisions will affect the forest of the future. Given the complexity of forest management issues, a decision support system of some form should be considered a necessity.

Computer models designed to address specific forest management issues are already prevalent (e.g., timber supply models, habitat supply models), so it is remarkable that decision support systems have not previously been applied to management of the forest as a whole. The scenario analysis we present here is intended to demonstrate the utility and feasibility of such a global system. Through our modeling exercise the cumulative landscape-level effects of small localized disturbances became clearly apparent. We were able to demonstrate that the current system of forest management in Alberta is unlikely to achieve the government's stated ecological objectives (AEP, 1998b) and is also deficient with respect to economic objectives. Furthermore, we were able to demonstrate that a few basic changes in management protocol, primarily involving integration among sectors, reduction in the impact of petroleum industry activities, and retention of old-growth, would have a major beneficial effect on ecological outcomes.

Even though our collection of best practices did not represent a comprehensive list of possible changes they did produce major improvements in several ecological outcome measures relative to current practices. Best practices were of particular value in minimizing fragmentation and human access, and in maintaining caribou habitat. Our findings suggest that additional measures will be required to maintain old-growth, though our set of best practices did have some benefit. Finally, although the best practices did not alleviate the short-fall in softwood timber supply, they did not worsen it either. On the other side of the equation, the best practices were associated with significant economic benefits to the petroleum industry from reduced timber damage fees, reduced road construction costs, and credits for carbon storage. It is important to note that our suite of best practices did not include any reduction in production of hydrocarbons.

In practice, we expect that a set of modeling assumptions and management objectives would be agreed upon by a representative group of stakeholders. The decision support system would then permit a rapid assessment of the costs and benefits associated with alternative management options. Put another way, the model would help stakeholders understand the limitations of a finite system. The intent is not to predict the future, but to balance objectives and effectively manage risk by avoiding management approaches with a very high likelihood of failure. We expect this approach to be of particular utility to less developed regions of the WCSB, as the range of management options would be less constrained by existing industry than it is in Alberta.

Literature Cited

AEUB (Alberta Energy and Utilities Board). 2001. Alberta's reserves 2000 and supply/demand outlook 2001-2010. Statistical Series 2001-98. Alberta Energy and Utilities Board, Calgary, AB.

AEP (Alberta Environmental Protection). 1994. Alberta timber harvest planning and ground rules. Alberta Environmental Protection, Edmonton, AB.

AEP (Alberta Environmental Protection). 1994. Natural regions of Alberta. Alberta Environmental Protection, Edmonton, AB.

AEP (Alberta Environmental Protection). 1996. The status of Alberta's timber supply. Alberta Environmental Protection, Edmonton, AB.

AEP (Alberta Environmental Protection). 1998a. The Boreal Forest Natural Region of Alberta. Alberta Environmental Protection, Edmonton, AB.

AEP (Alberta Environmental Protection). 1998b. The Alberta forest legacy. Alberta Environmental Protection, Edmonton, AB.

AFCSSC (Alberta Forest Conservation Strategy Steering Committee). 1997. Alberta forest conservation strategy. Alberta Environmental Protection, Edmonton, AB.

ARD (Alberta Resource Development). 2001. Annual report 2000/2001. Alberta Resource Development, Edmonton, AB.

ASRD (Alberta Sustainable Resource Development). 2002. Historical wildfire database. Alberta Sustainable Resource Development. On-line database available at: http://www3.gov.ab.ca/srd/index.html

Benkman, C. 1993. Logging, conifers, and the conservation of crossbills. Cons. Biol. 7:473-479.

Bergeron, Y., P. J. Richard, C. Carcaillet, S. Gauthier, M. Flannigan, and Y. T. Prairie. 1998. Variability in fire frequency and forest composition in Canada's southeastern boreal forest: a challenge for sustainable forest management. Cons. Ecol. [online] 2(2): Available from the Internet. URL: www.consecol.org/vol2/iss2/art6

Cumming, S. G. 1997. Landscape dynamics of the boreal mixedwood forest. Ph.D.Dissertation. University of British Columbia, Vancouver, B.C.

Donovan, T., F. Thompson, J. Faaborg, and J. Probst. 1995. Reproductive success of migratory birds in habitat sources and sinks. Cons. Biol. 9:1380-1395.

Dyer, S. J., J. P. O'Neill, S. M. Wasel, and S. Boutin. 2001. Avoidance of industrial development by woodland caribou. J. Wildl. Manage. 65:531-542.

Dzus, E. 2001. Status of the woodland caribou (*Rangifer tarandus caribou*) in Alberta. Alberta Wildlife Status Report No. 30. Alberta Ministry of the Environment, Edmonton, AB.

EC (Environment Canada). 1991 . The state of Canada's environment . Environment Canada , Ottawa, ON.

The Forestry Corporation. 2002. *ALCES* Timber supply validation: comparison of *ALCES* and Woodstock/Stanley. Prepared for Alberta Environment and the Alberta Forest Products Association.

Jones, J., F. Swanson, B. Wemple, and K. Snyder. 2000. Effects of roads on hydrology, geomorphology, and disturbance patches in stream networks. Cons. Biol. 14:76-85.

Kennett, S. 2002. Integrated resource management in Alberta: past, present and benchmarks for the future. Canadian Institute of Resources Law, Calgary, AB.

Kirk, D., A. Diamond, K. Hobson, and A. Smith. 1996. Breeding bird communities of the western and northern Canadian boreal forest: relationship to forest type. Can. J. of Zool. 74:1749-1770.

LAD (Land Administration Division). 1999. Guidelines for the submission of the Geophysical Field Report. Land Administration Division, Edmonton, AB.

LAD (Land Administration Division). 2000. Geophysical site condition report. Land Administration Division, Edmonton, AB.

LAD (Land Administration Division). 2001. Instructions for the submission of the Environmental Field Report with applications for dispositions under the Public Lands Act . Land Administration Division , Edmonton, AB.

Lieffers, V., and J. Beck. 1994. A semi-natural approach to mixedwood management in the prairie provinces. For. Chron. 70:260-264.

Macnab, B., J. Daniels, and G. Laxer. 1999. Giving away the Alberta advantage: are Albertans receiving maximum revenues from their oil and gas? Parkland Institute, Edmonton, AB.

Murphy, P. 1985. Methods for evaluating the effects of forest fire management in Alberta. Ph.D. Thesis, U. of British Columbia, Vancouver, BC.

Osko, T., and A. MacFarlane. 2001. Natural reforestation on seismic lines and wellsites in comparison to natural burns or logged sites. Alberta-Pacific Forest Industries, Boyle, Alberta.

PCF (Petroleum Communication Foundation). 2000. Canada's oil sands and heavy oil. Petroleum Communication Foundation, Calgary, AB.

Post, J. R., and M. Sullivan. 2002. Canada's Recreational Fisheries: The Invisible Collapse? Fisheries 27:6-17.

Revel, R. D., T. D. Dougherty, and D. J. Downing. 1984. Forest growth and regeneration along seismic lines. University of Calgary Press, Calgary, AB.

Wetherell, D., and I. Kmet. 2000. Alberta's north: a history, 1890-1950. University of Alberta Press, Edmonton, AB.