Quesnel TSA – Type 4 Silviculture Strategy

Silviculture Strategy

Version 1.1

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Project 419-23

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Strategy at a Glance

Strategy at a Glance		
Historical Context	The most recent timber supply review completed in 2011 lowered the uplift harvest level from 5.280 million m^3/yr to 4.000 million m^3/yr, with 650,000m^3/yr attributable to non-pine volume. An analysis of the mid-term timber supply was completed in 2012 that showed that without mitigation, this uplift harvest could be maintained until 2020, decline to 3.600 for five years before falling to 1.150 million m^3/yr for 46 years.	
Objective	Mitigate impacts from past mountain pine beetle (MPB) and wildfires on mid-term timber supply.	
General Strategy	Attempt to harvest the current AAC and non-pine volumes concentrating harvest on salvageable MPB-impacted pine stands. Apply an appropriate mix of silviculture activities aimed to achieve the working targets stated below.	
Working Targets	**Timber Volume Flow Over Time:**	**Short-Term** (1-5yrs): Maximize salvage of dead pine using current AAC of 4.0 million m3. **Mid-Term** (6-60yrs): Maximize mid-term harvest levels by accepting decreased long-term harvest levels of up to 10%. **Long Term** (61-200yrs): Harvest at nearly the productive capacity of the landbase (2.8 -2.9 million m^3/yr).
	Timber Quality:	Throughout the planning period, harvest stands once they achieve minimum merchantability (~ 120 m^3/ha) and maintain a supply of peeler logs (200,000m^3/yr of Sx/Df 8"top, 17'2"). **Short-Term** (1-5yrs): Capture economically viable sawlog volumes before stands deteriorate. **Mid-Term** (6-60 yrs): Maximizing stand values to the extent possible within a volume focused strategy. **Long Term** (61-200yrs): Regenerate newly harvested areas with silviculture practices that improve timber quality.
	Habitat Supply:	Throughout the planning period minimize negative impacts to water resource, ecosystems and species by meeting current legal objectives with respect to terrestrial biodiversity, aquatic, and riparian values through both operational and silviculture activities.
Major Silviculture Strategies	**Timber Volume Flow Over Time:**	**<u>Years 2013-2017</u>** • Focus fertilization on stands closest to harvest eligibility. • Begin rehabilitating eligible stands considered low priority for salvaging. • Employ enhanced basic silviculture practices on stands currently being salvaged. • Pre-commercial thin eligible stands as a set-up treatment for fertilization. **<u>Years 2018-2022</u>** • Apply various fertilization regimes (single and multiple treatments) to the limited number of eligible pine and Douglas-fir stands, with a focus on young spruce stands. • Increase rehabilitation of eligible stands and begin shifting to stands that provide additional merchantable volume. • Lower the priority of enhanced basic silviculture practices. • Continue to pre-commercial thin eligible stands as a set-up treatment for fertilization. • Start to explore opportunities for partial cutting within constrained areas while maintaining the appropriate non-timber values.
	Timber Quality:	• Continue to monitor timber profiles being harvested with particular attention on minimum merchantability criteria. • Encourage enhanced basic silviculture practices and monitor stand performance to ensure that objectives are being met.
	Habitat Supply:	• Prioritize silviculture treatments based on how they might impact designated habitat areas. • Retain coarse woody debris and wildlife trees where practicable. • Explore opportunities for partial cutting within constrained areas while maintaining the

Strategy at a Glance

appropriate non-timber values.

Silviculture Program Scenarios

Potential Program

The following sections summarize the target treatment areas adopted from the preferred scenario modelled at a $5 Million per year funding level.

Years 2013-2017

Priority	Treatment	Target Area (ha)	Unit Cost ($/ha)	Target Funding ($M/yr)
1	Fertilize	1,850	540	1.000
2	Rehab	500	1,000	0.500
3	Enhanced Basic	6,500	500	3.250
4	PCT + Fert	170	1,500	0.250

Years 2018-2022

Priority	Treatment	Target Area (ha)	Unit Cost ($/ha)	Target Funding ($M/yr)
1	Fertilize	2,780	540	1.500
2	Rehab	1,500	1,000	1.500
3	Enhanced Basic	3,500	500	1.750
4	PCT + Fert	170	1,500	0.250

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Constrained Program

The following sections summarize the target treatment areas adopted from the preferred scenario modelled at a $2 Million per year funding level.

Years 2013-2017

Priority	Treatment	Target Area (ha)	Unit Cost ($/ha)	Target Funding ($M/yr)
1	Fertilize	460	540	0.250
2	Rehab	200	1,000	0.200
3	Enhanced Basic	3,000	500	1.500
4	PCT + Fert	30	1,500	0.050

Years 2018-2022

Priority	Treatment	Target Area (ha)	Unit Cost ($/ha)	Target Funding ($M/yr)
1	Fertilize	830	540	0.450
2	Rehab	600	1,000	0.600
3	Enhanced Basic	1,800	500	0.900
4	PCT + Fert	30	1,500	0.050

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Outcomes ($5 Million/yr funding level)

Timber Volume Flow Over Time:

Short Term (years 2013-2017)
- No forecasted changes relative to the base case scenario.

Midterm (years 2018-2053)
- Harvest level increase of 16% relative to base case scenario.

Timber Quality:
- Targets were not implemented as the analysis focused on maximizing mid-term volume.

Habitat Supply:
- Assumptions applied to capture stand- and forest-level impacts from MPB and associated wildfire also suggest there are substantial risks to habitat in both the short and mid-term.

Related Plans and Strategies

Climate Change	Ecosystem Restoration	Range Management
Tree Species Deployment	Enhanced Retention	Invasive Plants
Land Use Plans	Secondary Structure	Tree Improvement and Seed Transfer
Landscape Level	Watershed Management	Forest Inventory
Biodiversity	Wildlife Habitat	
Forest Health	Recreation	
Wildfire Management		

Strategy at a Glance

Recommendations	**Implementing Strategies**	• Enhanced Basic Silviculture – Establish a task force develop guidance of how enhanced basic silviculture costs may be incorporated in planned cost of the silviculture allowance used in the stumpage calculation. • Rehabilitation – Develop a process for licensees to report "no harvest" decisions to the ministry to help guide and identify potential areas for rehabilitation treatments.
	Data Gaps and Information Needs	• Forest Inventory – Work to strengthen the inventory update process to reflect available RESULTS data and impacts from natural disturbances (e.g., harvesting, fire, insects, disease) wherever possible. • Forest Inventory – Use the VRI and apply adjustments to account for MPB impacts for (rather than LVI). • Forest Inventory – Improve yield assumptions for understory regeneration by identifying where it exists and how it develops. • Forest Health Impacts – Confirm estimates of live volume estimates on MPB-impacted stands that are critical for harvesting over the mid-term. • Site Index – Monitor managed stand yields against predicted yields. • Past Treatments – Streamline the process for retrieving past incremental silviculture treatments and verify that the data is accurate and complete. • Genetic Worth – Continue to support tree improvement and seed transfer programs and closely monitor genetic gains to apply in future analyses. • Product Profiles – Investigate linkages between desired product profiles, minimum merchantability, and harvest ages. • Riparian Management – Update the spatial assignment of riparian management areas. • Road Network – Update the spatial road network and widths for estimating non-forest areas. • Retention Areas – Capture and verify the spatial extent of areas retained from harvesting.
	Modelling Approaches	• Defining Treatment Areas – Streamline the aggregation of polygons in the model that better-represent spatially and operationally feasible treatment areas.
	Related Plans and Strategies	• General – Continue to explore ways to align silviculture activities with related plans and strategies that maximize benefits to all forest users. • Access – Ensure that road systems are maintained to access stands for treatment.
	Monitoring	• Develop a monitoring program to ensure outputs meet expectations over time.
References	1. Type 2 Silviculture Strategy Development Quesnel TSA – Initial Workshop Background Document, January 2012. 2. Quesnel TSA Type 4 Silviculture Strategy – Data Package, June 2013. 3. Quesnel TSA Type 4 Silviculture Strategy – Modelling and Analysis Report, June 2013. 4. Quesnel TSA Type 4 Silviculture Strategy – Data Package, June 2013.	

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Table of Contents

List of Tables

List of Figures

1 Introduction

In 2012, the British Columbia Ministry of Forests, Lands and Natural Resource Operations (MFLNRO) initiated a Type 4 Silviculture Strategy for the Quesnel Timber Supply Area (TSA) to help government and licensees better understand the current and future timber and habitat supply situation in the Quesnel TSA, and what can be done to improve it.

1.1 Project Objectives

In support of government objectives to mitigate impacts from past mountain pine beetle (MPB) and wildfires on mid-term timber supply, the project aims to:

1. Provide a realistic, forward-looking assessment of timber and habitat supply under a range of scenarios that will produce a preferred silviculture strategy supported locally and provincially. This strategy will clearly identify the activities that will provide the best return on investment to government.
2. Provide products that will support operational implementation of the strategy (e.g., a tactical plan).
3. Inform licensees and government on the alternative outcomes that could be achieved through different approaches to basic (mandatory) silviculture in the TSA.
4. Provide context information or indicators that would be useful to support future management decisions in the TSA.
5. Where appropriate, illustrate how the recommended treatments link with other landscape-level strategies while considering treatment risk.

1.2 Context

This document is the fourth of four documents that make up a Type 4 Silviculture Strategy:

- Situational Analysis – describes in general terms the current situation for the unit.
- Data Package – describes the information that is material to the analysis including the model used, data inputs and assumptions.
- Modelling and Analysis Report – describes modelling outputs and provides a rationale for choosing a preferred scenario.
- **Silviculture Strategy –provides treatment options, associated targets, timeframes and benefits.**

1.3 Landbase

This section summarizes material from the data package report[1] and modelling and analysis report[2] for this project. Further discussion on this summary can be accessed from these sources.

[1] Forsite Consultants Ltd. 2013. *Quesnel TSA - Type 4 Silviculture Strategy, Data Package.* Technical Report.

[2] Forsite Consultants Ltd. 2013. *Quesnel TSA - Type 4 Silviculture Strategy, Modelling and Analysis Report.* Technical Report.

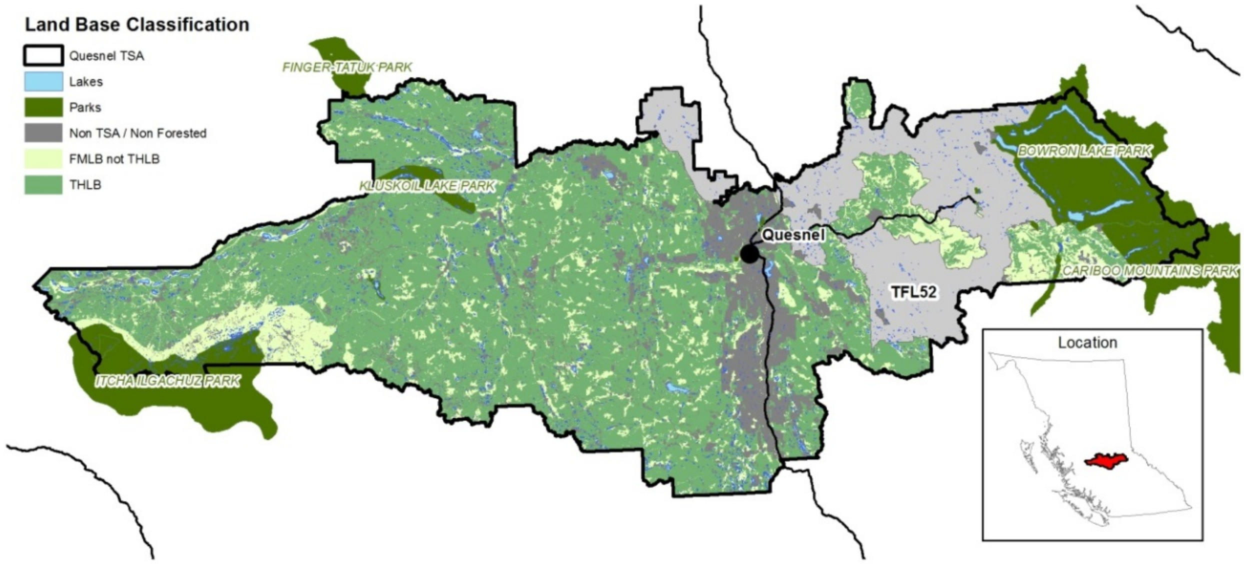


Figure 1 Quesnel TSA overview map

Including TFL areas and parks, the TSA covers about 2.08 million ha (Figure 1) of which approximately 1.4 million is considered the Forest Management Land Base (FMLB). Areas set aside as parks, protected areas, Old growth Management Areas, Caribou no-harvest areas, and other areas considered unavailable for timber harvesting account for roughly 393,000 ha. The Timber Harvesting Land Base (THLB) is approximately 1.01 million ha or 49% of the total area in the Quesnel TSA.

Table 1 TSA land base area summary

	Area (Ha)	Percent of Total Area (%)	Percent of FMLB (%)	TSR4 Areas
Total Area	**2,082,528**	**100.0%**		**2,077,289**
less:		0.0%		
Non TSA (TFL 52, Woodlots, Private, other Non-Crown	458,293	22.0%		452,035
Non-Forest / Non-Productive	214,134	10.3%		225,151
Forest Management Land Base	**1,410,101**	**67.7%**	**100.0%**	**1,400,103**
less:		0.0%	0.0%	
Protected	108,491	5.2%	7.7%	108,066
Caribou No-Harvest	65,929	3.2%	4.7%	66,317
OGMA	82,651	4.0%	5.9%	83,139
Unstable	12,093	0.6%	0.9%	12,290
Excluded Species	5,357	0.3%	0.4%	5,570
Low Site Index	13,652	0.7%	1.0%	16,248
Riparian Reserve Zone	11,360	0.5%	0.8%	14,934
CCLUP	18,832	0.9%	1.3%	3,120
Environmentally Sensitive Areas	N/A	0.0%	0.0%	12,495
Roads, Trails, and Landings (Aspatial) 3%	32,752	1.6%	2.3%	42,003
Riparian Management Zone (Aspatial)	9,186	0.4%	0.7%	14,230
Timber Harvesting Land Base	**1,049,797**	**50.4%**	**74.4%**	**1,023,757**
less:				
Future Roads, Trails, and Landings (Aspatial) 1%	10,498	0.5%	0.7%	10,238
Future Timber Harvesting Land Base	**1,039,300**	**49.9%**	**73.7%**	**1,013,519**

1.3.1 Age Class Distribution

After adjusting ages of stands dying from MPB attack[3], the age class structure for both the NHLB and THLB are shown in Figure 2. The significant age class imbalance between 20 and 100 years indicates potential future timber supply challenges.

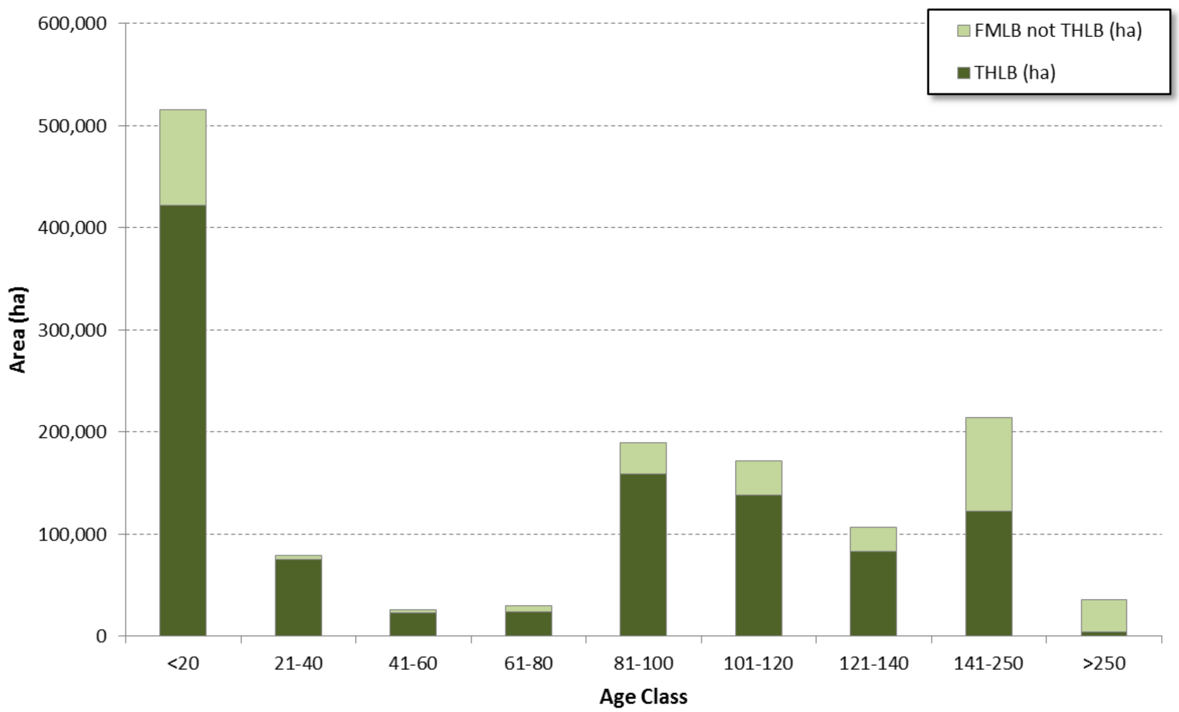
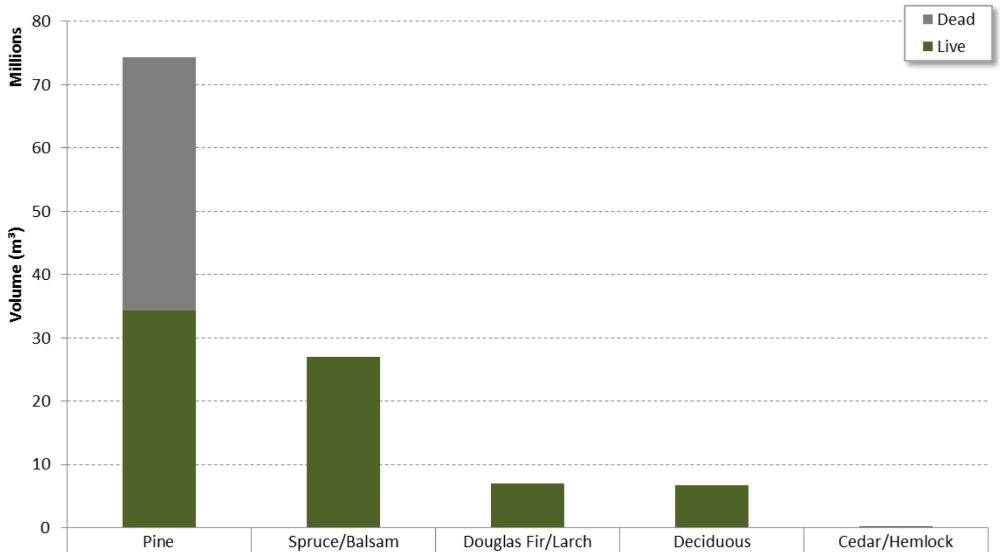


Figure 2 Age class distribution by leading species on the timber harvesting land base

1.3.2 Growing Stock and Volume Profile

The total and merchantable growing stock is currently 115 million m^3 of which approximately 102 million m^3 is considered currently eligible for harvest (i.e., ≥120 m^3/ha sawlog volume). Figure 3 shows the distribution of total growing stock on the THLB by species group. Pine comprises the majority of the volume on the land base but over 2/3 of this volume is dead.

[3] Unsalvaged stands with ≥60% MPB mortality had their ages set to zero in the year of maximum infestation (typically 2006).



	Pine	Spruce/Balsam	Douglas Fir/Larch	Deciduous	Cedar/Hemlock
Dead	39,997,000				
Live	34,285,000	26,985,000	6,978,000	6,711,000	189,000

Figure 3 Total growing stock on the timber harvesting land base by species

1.3.3 Site Productivity Profile

Figure 4 shows the distribution of site productivity used for existing natural stands (inventory SI in red) relative to the adjusted estimates for managed stands (SIBEC SI in green).

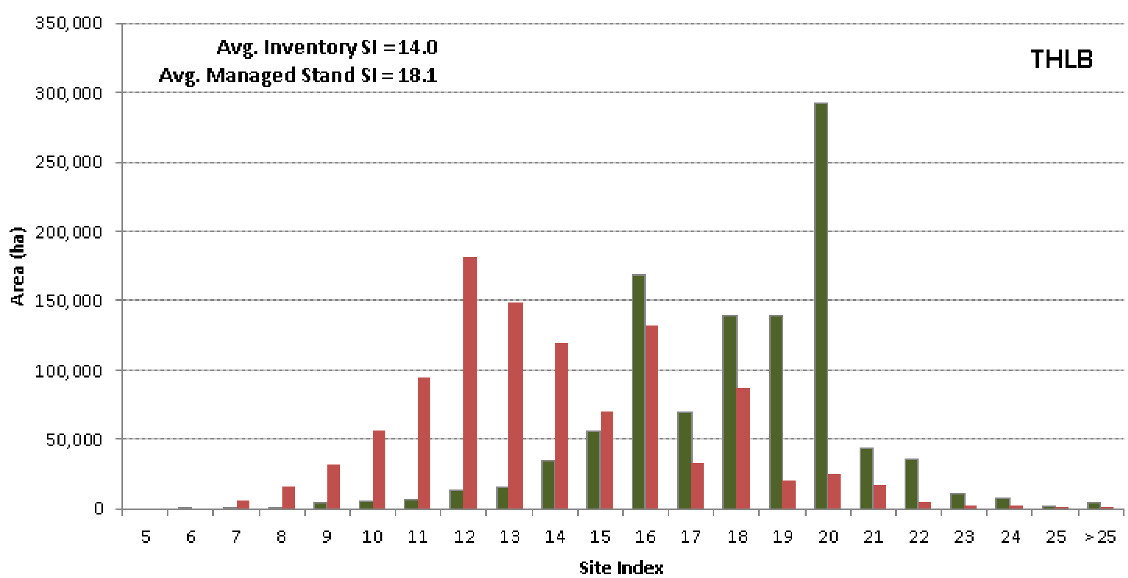


Figure 4 Site productivity distributions on the timber harvesting landbase

1.4 Key Issues and Considerations

This section summarizes material from the data package report[4] for this project. Further discussion on this summary can be accessed from that source.

1.4.1 Harvest Levels

Over the past 3 decades, the allowable annual cut (AAC) for the Quesnel TSA has been fairly dynamic (Table 2) as it reflects several MPB outbreaks, the establishment of partition cuts, and the inclusion of deciduous stands and problem forest types. The current AAC in effect is 4.0 million m^3/yr and allows for a limited harvest of non-pine species (up to 650,000 m^3/yr or 16.25%).

Table 2 Historical and current AAC

	1981	1985	1989	1990	1992	1996	2001	2004	2011
AAC (000,000m3)	2.3	3.45	3.5	2.45	2.35	2.34	3.248	5.28	4.0

Figure 5 shows that harvesting performance over the past several years has often not logged the full AAC (averaged ~3.7 million m^3/yr), but has been largely focused on pine (83%[5]).

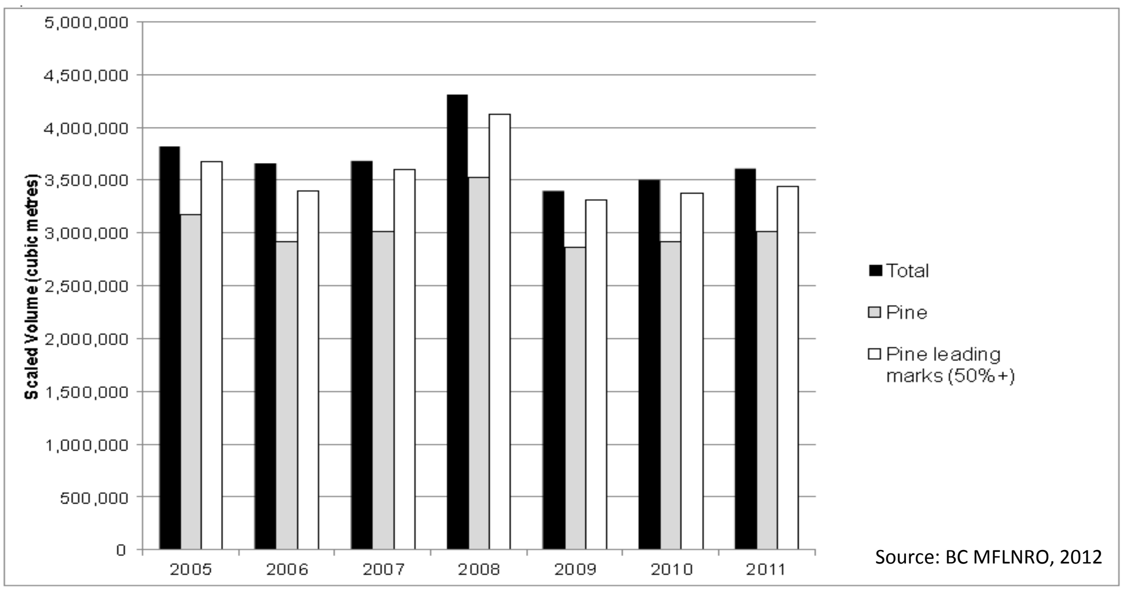


Figure 5 Total harvest, pine harvest and harvest from pine-leading marks

1.4.2 Forest Inventory

The existing forest inventory is comprised of several projects spanning many years. While assumptions are made to account for disturbance from harvesting, fires and forest health issues, there is considerable uncertainty regarding how well the adjusted inventory reflects current forest conditions (e.g., LVI stand volumes, dead %). While the MFLNRO is working to investigate these concerns, the information used here is considered the best available for the scale and timing of this project.

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[4] Forsite Consultants Ltd. 2013. *Quesnel TSA - Type 4 Silviculture Strategy, Data Package.* Technical Report.

[5] BC Ministry of Forests, Lands and Natural Resource Operations. 2012. *Monitoring Harvest Activity Across 28 Mountain Pine Beetle impacted Management Units.*

1.4.3 Timber Supply

The prevalence of pine-leading stands on the TSA (67% of the forested landbase), and very high mortality rates (81%) in mature Pl result in severe implications on timber supply. Figure 6 shows projections of the cumulative pine volume killed by the MPB assuming no management intervention[6].

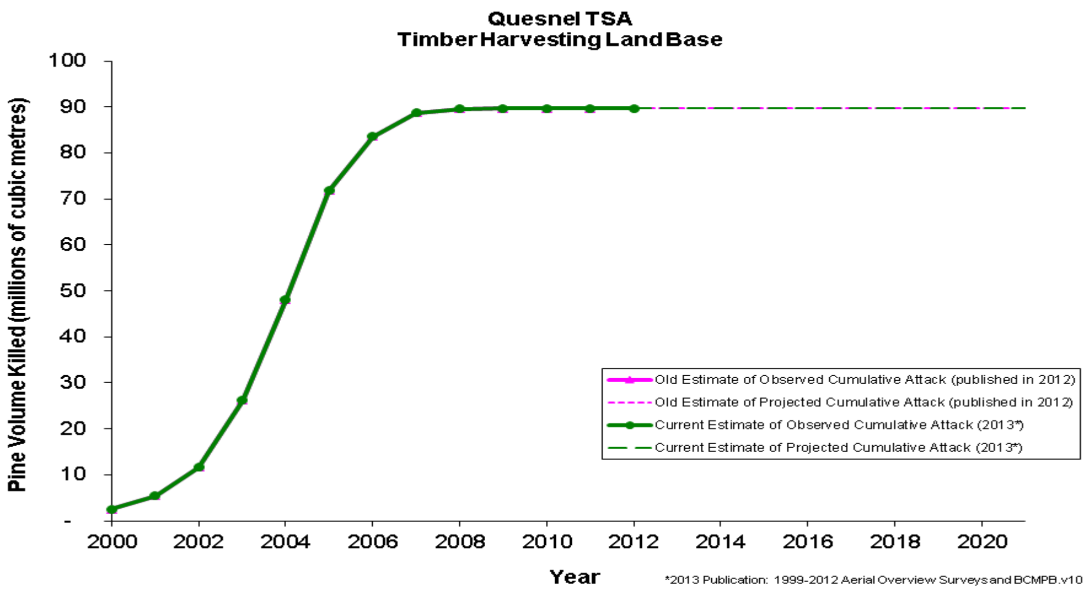


Figure 6 Data and projections of cumulative volume killed by the MPB.

Key timber supply issues that arise as a result of the severe MPB outbreak include:

- While the current harvest is focused on severely attacked stands in the TSA, it is likely that a large number of stands will die and remain unsalvaged. This will lead to a period of high fire hazard due to the high incidence of standing dead timber and/or impaired regeneration. The MPB fuel hazard will continue to be an issue for up to 50 or 60 years depending on the site characteristics.
- As a result of growing stock losses from MPB, the forecasted harvest flow exhibits a significant mid-term trough for 40-60 yrs. How fast managed stands can be brought online directly affects the size and depth of this trough.
- Shelf life refers to the time period over which dead Pl stands degrade until they are no longer economically viable. While varying throughout the landbase, dead Pl tends to retain at least a portion of its value for sawlogs for 14 years after attack.
- It is probable that many immature Pl stands impacted by the MPB have little or poor natural regeneration and will require some form of rehabilitation to remove existing stems, prepare the site and reforest.
- Some unsalvaged MPB-attacked stands contain sufficient understory advanced regeneration and non-pine trees as secondary stand structure to contribute to the mid-term timber supply. Section 43.1 of the FPPR requires protection of this secondary stand structure.

[6] BC Ministry of Forests, Lands and Natural Resource Operations. 2013. *Provincial-Level Projection of the Current Mountain Pine Beetle Outbreak: Update of the infestation projection based on the Provincial Aerial Overview Surveys of Forest Health conducted from 1999 through 2012 and the BCMPB model (year 10).*

- Given the magnitude of area affected by MPB across many age classes there will be a significant shift of stands into a narrow range of age classes leading to increased fuel continuity across the landbase which can result in more severe wildfires. In turn, these stands, unless impacted by wildfire, will all become available for harvest again at the same time period in the future and, once again, become susceptible to a future MPB infestation.

1.4.4 Timber Quality

Key timber quality issues that arise as a result of the severe MPB outbreak and subsequent dead pine salvage include:

- Dead standing pine trees will gradually decay and eventually fall down or burn up. Shelf life assumptions are used to estimate the average rate of this process.
- The salvage period for MPB-killed pine is generally expected to yield low harvest volumes with small piece sizes mixed with incidental harvest of live trees.
- After the salvage period, as the harvesting enters the mid-term period, green stands will become available and timber quality is expected to improve.
- Near the end of the mid-term (approximately 50 years from now), the harvest is expected to again consist of young, low volume, small piece sizes from stands that are 40 to 60 years old.
- Minimum merchantability criteria reflect the smallest average piece size or stand volume acceptable for harvesting. Reducing the minimum timber quality expectations can often support a higher mid-term harvest level. Typically, this becomes critical towards the end of the mid-term period as harvesting transitions from existing natural stands to managed stands. The desired quality of available timber during this critical period is therefore associated with these minimum merchantability criteria and shorter rotation ages that lead to decreasing piece sizes.

1.4.5 Habitat Supply

Key habitat supply issues that arise as a result of the severe MPB outbreak include:

- Lands currently reserved to protect sensitive species, riparian habitat, wildlife tree patches, designated wildlife habitat areas and old growth management areas are affected both directly and indirectly.
- In the mid-term, when timber availability is at its lowest, harvesting will be forced into non-pine stands that are also important for their non-timber values.
- In many cases, the pattern of pine mortality has reduced the structure and value associated with existing plans for landscape connectivity.
- Some wildlife species will be negatively affected by the increased relative road density required to salvage dead pine.
- Cattle use within riparian areas and newly planted areas will continue to be a concern for managing both habitat and timber supply.

1.4.6 Landscape and Watershed

Key landscape and watershed issues that arise as a result of the severe MPB outbreak include:

- The loss of mature and old pine will likely increase risks of higher peak flow and impacts to aquatic species/ecosystems and supply of domestic water.

- Accelerated harvest rates for salvaging dead pine stands increases road densities and overstory removal that can alter water quality and quantity aspects within watersheds.
- Development and monitoring of a landscape retention strategy on retaining forest structure in large-scale salvage operations was identified as means to maintain non-timber values that contributes towards increasing mid-term harvest levels.
- Land use plans may no longer be synchronized with the current status of the productive forest. Updating these plans could significantly impact the availability of short- and mid-term volumes.
- Increased wildfire activity coupled with harvesting impacts will result in less standing timber and vertical structure for the range of ecosystem services it provides.

1.4.7 Climate Change

The exact timing, location and magnitude of future climate change and the unavoidable impacts associated with increased climate variability and extreme events are uncertain – but we expect them to occur. Examples of how climate change is affecting forests and forest ecosystems include:

- Some tree species are increasingly vulnerable to damage and mortality on specific sites:
  - Spruce in the SBS from drought stress and forest health;
  - Pine in the IDF and SBPS from Elytroderma needle cast and drought stress;
  - Douglas-fir in grassland-forest interfaces from drier conditions; and
  - Whitebark pine in the ESSF from blister rust and MPB.
- Some ecosystems are becoming increasingly vulnerable to damage:
  - Salmon streams from low flow, warmer temperatures and little opportunity to shift to better habitat;
  - High elevation forests trapped between unproductive alpine areas and the upward shift of lower elevation forests;
  - Spruce in wetter subzones of the SBS from decreased precipitation;
  - Forested wetlands turning to productive forest from dropping water tables
- Weather is the main influencing factor on:
  - Fire starts with lightening as a major cause;
  - Fire spread, as many major fires are the result of a combination of extended drought drying fuels, and wind that pushes fire spread;
- Weather is quite unpredictable from year-to-year (e.g., 2009 and 2010 were record extreme fire years, while 2011 was a record for being a non-forest fire year);
- Future conditions as a result of climate change remain somewhat uncertain and depend upon numerous factors, one of which is which global emission scenario plays out. Even with optimistic carbon reduction projections, significant impacts are predicted for the southern interior of BC.
- Haughian, S. et al (2012) predicts an increase of 4^0C by 2080 will:
  - increase fire size (doubling from an average of 7,961 ha to 19,076 ha);
  - increase fire severity (by 40% in spring, 95% in summer and 30% in fall);

- increase fire season length and fire frequency (by 30%);
- increase crown fire ignition and severe fire behaviour (by 4% to 7%) and,
- decrease the extent of fire free areas (by -39%).

- Haughian, S. et al (2012) also predicts the annual area burned in the boreal ecozones will increase by 50% to 300% in the next 100 years. This estimation is supported by research done in the US National Research Council that shows an increase in median area burned for a 1^0C increase in global average temperature from 241% for northern rocky mountain forest to 428% for cascade mixed forest – both forest types that extend into the southern portion of British Columbia (National Research Council, 2011).

Long-term adaptation strategies for climate change must complement short- and medium-term strategies for mitigating impending timber supply and environmental challenges resulting from the MPB epidemic.

1.4.8 Uneven-aged management in dry-belt Douglas-fir

For decades, Douglas-fir stands in dry-belt ecosystems were harvested using partial cutting systems and restocked by natural regeneration. However, little reliable information is available for these uneven-aged stands that will become a necessary portion of the harvest profile moving forward.

2 Silviculture Strategy

2.1 Working Targets

Provincial Timber Management Goals and Objectives (under development) will provide context and direction for the Quesnel TSA. Local timber goals and objectives rationalize the provincial priorities and goals in the context of local conditions, needs and local values. These objectives will be linked to a set of management targets. Provincial timber management targets (e.g., for timber volume flow over time, timber quality, tree species compositions and productivity and growing stock, inherent site capacity) derived from the TSR or similar processes must be achieved at the management unit level unless there is a rationale for not doing so.

Working targets were created and used to influence modelling decisions and in-turn, outcomes for all of the modelled scenarios in this project. Not all targets are achievable because of limited budgets or conflicts between targets, but they are still presented in Table 3 to frame the high level objectives of the Quesnel TSA:

Table 3 Working Targets

Indicator	Working Targets
Timber Volume Flow Over Time:	**Short-Term** (1-5yrs): Maximize salvage of dead pine using current AAC of 4.0 million m3. **Mid-Term** (6-60yrs): Maximize mid-term harvest levels by accepting decreased long-term harvest levels of up to 10%. **Long Term** (61-200yrs): Harvest at nearly the productive capacity of the landbase (2.8 -2.9 million m^3/yr).
Timber Quality:	Throughout the planning period, harvest stands once they achieve minimum merchantability (~ 120 m^3/ha) and maintain a supply of peeler logs (200,000m^3/yr of Sx/Df 8"top, 17'2").
	Short-Term (1-5yrs): Capture economically viable sawlog volumes before stands deteriorate. **Mid-Term** (6-60 yrs): Maximizing stand values to the extent possible within a volume focused strategy. **Long Term** (61-200yrs): Regenerate newly harvested areas with silviculture practices that improve timber quality.

Habitat Supply:	Throughout the planning period minimize negative impacts to water resource, ecosystems and species by meeting current legal objectives with respect to terrestrial biodiversity, aquatic, and riparian values through both operational and silviculture activities.

2.2 Overview of Scenarios

Three base case sensitivities and eight silviculture scenarios were modelled and assessed for their impact on timber quantity, quality, and habitat supply (see Table 4). Each silviculture strategy was assigned a maximum budget (typically $5 million/yr) for implementation of incremental treatments. Input assumption and details for each scenario or silviculture activity are provided in the Quesnel Type 4 Data Package and/or Modelling and Analysis Report.

Table 4 Scenario Overview

Scenario Type	Scenario	Scenario Description / Objective
Base Case	Base Case	Models current practice as best as possible using best available information.
Base Case Sensitivities	Lower 1st period	Examines the effect on mid-term harvest levels from an immediate reduction in the current AAC uplift.
	Longer MHAs	Explores the effects of applying MHAs based on culmination of mean annual increment to achieve the maximum long term harvest level.
	Longer MHAs & Commercial thin	Explores the combined effects of longer MHAs and a commercial thinning program to gain access to volume earlier.
Silviculture Scenarios	Single Fertilization	Examines the effects of fertilizing eligible Pl, Sx, Fd stands once prior to being harvested.
	Multiple Fertilization	Examines the effects of fertilizing eligible Pl, Sx, Fd stands multiple times prior to being harvested.
	Rehabilitation	Examines the effects of rehabilitating MPB impacted stands considered un-merchantable after shelf-life expiration in order to establish improved forest crops (knock down and plant).
	Pre-Commercial Thinning	Investigates the effect on harvest flow when high density stands are thinned to remove the least desirable trees and make room for expected crop trees.
	Enhanced Basic Silviculture	Investigates the effect on harvest flow when regeneration practices aimed at maximizing stand productivity are implemented on good-to-medium sites.
	Partial Cut	Investigates the change in harvest flow realized from partial harvesting stands (by 30%) that would otherwise be constrained from clearcut harvesting due to visuals, mature seral goals, or caribou constraints.
	Combined Silviculture ($5 M/yr)	Model is allowed to choose from all of the above-mentioned silviculture strategies within a budget of $5million/yr.
	Combined Silviculture ($2 M/yr)	Model is allowed to choose from all the above-mentioned silviculture strategies within a budget of $2 million/yr. Meant to guide silviculture expenditures under a relatively constrained budget.

Table 5 provides a summary of the relative impacts to timber quality, quantity, and habitat supply indicators resulting from scenarios/activities investigated. The number of arrows represents the magnitude of change relative to the base case, where three arrows represent the maximum change. The Quesnel Type 4 Analysis Report provides more quantitative details.

Table 5 Summary of impacts to indicator categories for each scenario

	Timber Supply			Timber	Caribou &	Old + Mat	Watershed	
Scenario	**Short**	**Mid**	**Long**	**Quality**	**Deer**	**Seral**	**ECAs**	**Visuals**
Low 1st Period	↓	↑	Nil	Nil	↑	↑	↓	↑
Longer MHAs	↓	↓	↑	↑↑↑	↑	↑↑↑	↓↓↓	↓
Long MHA & Comm. Thin	Nil	↓	↑	↑↑	↑	↑↑	↓↓	↓
Single Fert	Nil	↑	↑	Nil	Nil	↓	↑	↓
Multiple Fert	Nil	↑↑	↑↑	↑	Nil	↓	↑	↓
Rehabilitation	Nil	↑	↑	Nil	Nil	↓	↑	↑
PCT plus fert	Nil	↑	Nil	↑/↓	Nil	↓	↑	↓
Enhanced Basic	Nil	↑↑	↑↑	↑	Nil	↓	↑	↓
Partial cutting	Nil	↑	Nil	Nil	↑	↑	↓	↓
Combined ($5 M)	Nil	↑↑↑	↑↑↑	↑	Nil	↓	↑	↓
Combined ($2 M)	↓	↑↑	↑	↑	Nil	↓	↑	↓

The following points summarize some of the key trends learned from this exercise:

- Reducing salvage immediately leaves more green timber on the landbase that can be harvested throughout the mid-term. However, this benefit comes at the cost of increased loss of dead Pl (less salvage) and the economic loss of a reduced short-term harvest level.
- Waiting longer to harvest managed stands (i.e., age based on culmination of MAI versus the minimum stand volume criteria of > 120 m^3/ha) significantly lowers and prolongs the projected mid-term but improves the long-term harvest level, product profile, and harvest costs (also reduces hectares harvested per year and improves age classes distribution).
- Longer harvest ages combined with commercial thinning 50-70 years from now (transition to harvesting managed stands) could be used to achieve long term benefits while also improving the midterm relative to just using longer harvest ages alone. If implemented, nearly half of the harvest area must be commercial thinning 50-70 yrs from now. This is a relatively expensive harvest method so technological advances and use of smaller equipment is likely required to make this more economically viable.
- Despite the number of times stands can be fertilized, there are limited opportunities for fertilization in the short-term (next 20 years). This is due, in part, to the current lack of stands in suitable age classes (20-60 year old stands) and forest health conditions for this treatment. Fertilization opportunities increase 20-40 years from now.
- Single-fertilization treatments are best carried out closer to harvest to maximize the NPV and minimize risk – but government budgets should be utilized whenever they are available to ensure the benefit is captured.
- While more opportunities for multiple-fertilization treatments are available sooner, risk of investment loss are increased as costs are carried longer.
- Cumulative gains from multiple-fertilization of spruce stands make this treatment the most economically favourable. Still, fertilization of pine stands should not be overlooked given the relative abundance of these stands.
- Rehabilitation of marginally-economic stands as the salvage period expires (towards the end of shelf-life) should provide some harvest volume at the time of treatment while also producing regenerated volume at the end of the mid-term (50-60 years from now) and into the long-term

(80+ years). The eligible area for this strategy is largely dependent on market prices for fibre plus innovative funding mechanisms being available (ITSLs, FLTCs).

- Given some uncertainty with regenerated stand densities, there are limited opportunities for pre-commercial thinning in the short-term (next 20 years) and future opportunities are difficult to predict. While this treatment provides little direct benefit to timber supply, it can contribute by improving timber quality and preparing suitable stands for other treatments, like fertilization.
- The enhanced basic silviculture strategy (e.g. planting at higher densities, increased brushing, etc.) results in significant timber supply gains near the end of the mid-term (50-60 years from now) and into the long-term (80+ years). With elevated harvest levels in the short-term (next 5-10 years), significant opportunities exist for this strategy. While licensees may be able to move more toward target stocking levels within existing frameworks, administrative changes that incent excellence (vs. regulate minimums) will be required to get significant engagement from forest companies. This strategy aligns well with the need to incent any higher cost treatments that may be required to best adapt to climate change.
- The partial harvesting within constrained areas strategy is most opportune near the end of the mid-term when available merchantable volumes are low. Provided forest cover and ecosystem functions remain intact, or improve, this strategy can provide access to volume within areas otherwise constrained by non-timber values such as landscape biodiversity, visuals, wildlife habitat and watersheds.
- Regardless of the budget allocated to alleviate the mid-term timber supply shortage, a combination of scheduled activities produces the highest overall gains in timber supply and return on investment.

2.3 Preferred Silviculture Strategy

The forest estate model used in this analysis applied a goal-seeking approach that schedules numerous activities across time and space to arrive at the best solution for the defined targets. Consequently, for any given funding level, the combined silviculture treatments strategy should produce a preferred silviculture strategy.

Compared to all other strategies explored, the $5 million /yr budget strategy produced the:

- Highest increase in the mid-term harvest level (277,000 m^3/yr or 16.2%),
- Highest increase in the long-term harvest level (258,000 m^3/yr or 9.4%), and
- Highest total net present value (NPV) over the planning horizon.

Figure 7 shows the increases in harvest forecast resulting from the preferred silviculture strategy.

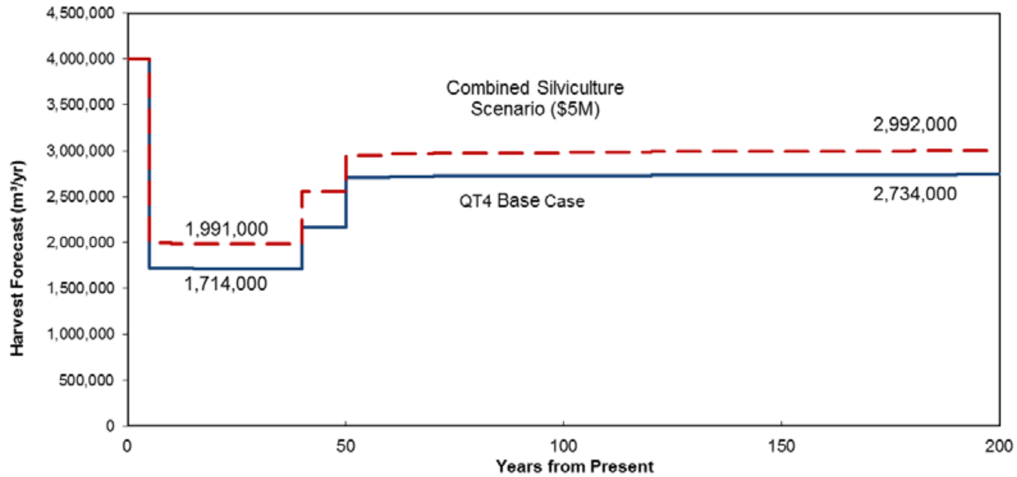


Figure 7 Harvest flow over time for the preferred silviculture strategy

Figure 8 shows the preferred scenario's silviculture expenditures over time by treatment activity. Due largely to lack of currently eligible stands to fertilize, rehabilitate, or pre-commercial thin within the TSA, the majority of budget in the first 15 years was spent on enhanced basic silviculture activities to maximize the growth potential of harvested areas. This activity is expected to increase timber supply near the end of the mid-term trough (50-60 years from now) and into the long-term (60+ years from now). As more stands became eligible for fertilization and rehabilitation, the relative expenditures on these activities also increased.

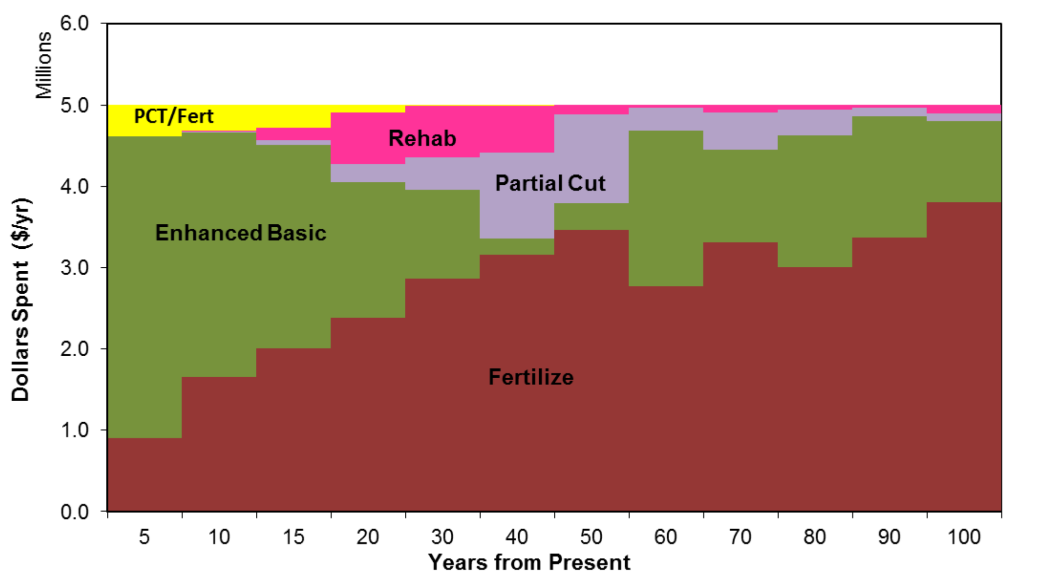


Figure 8 Silviculture expenditures by silviculture activity for the preferred silviculture strategy

A modelling artifact prevented the model from implementing the rehabilitation strategy sooner; MPB impacted stands first need to undergo the transition to a post-shelf life stands before they are eligible for rehabilitation (as opposed to a regular clearcut or salvage harvest treatment). This delay created a brief period where some stands were ineligible for salvage, clear cut or rehabilitation treatments. Rehabilitation may also be delayed because although relatively little volume is harvested from this treatment type, the volume that is captured still contributes to improving the mid-term harvest level when merchantable timber volume is scarce.

Adapting outputs from the strategic plan into a tactical plan requires interpretation of the learning achieved from the individually modelled silviculture scenarios, as well as, an understanding of the modelling assumptions and limitations. Figure 9 shows the silviculture expenditures levels used to inform the tactical plan for the next 20 years.

The primary goal of the strategy is to deliver more timber volume at the end of the mid-term trough (40-60 yrs from now), thereby increasing the entire mid-term harvest level.

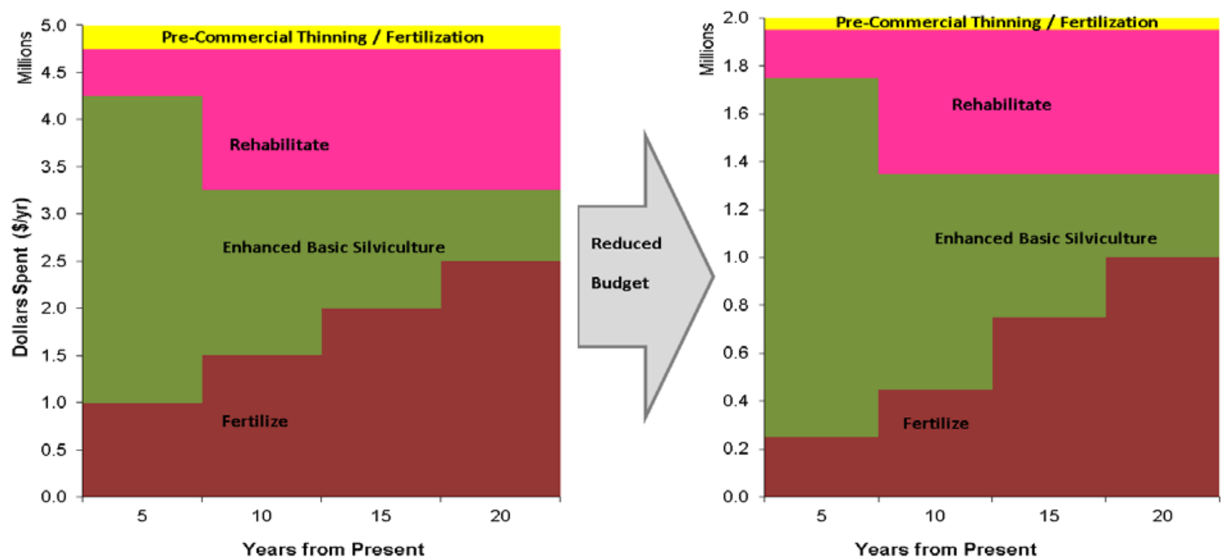


Figure 9 Silviculture expenditure levels used to inform the tactical plan ($5M vs. $2M budgets)

The following rationale was used to determine this appropriate mix of silviculture activities aimed to achieve the working targets:

- **Fertilization** should be the top priority that focuses on stands closest to harvest eligibility within the next 5-10 years – this will minimize risk of loss, maximize financial return, and slow the rate of logging currently-available stands. The next priority is to fertilize young spruce-leading stands in the next 10-20 years to put them on an intensive multiple fertilization regime. Then silviculture budgets should be directed towards Douglas-fir-leading stands eligible for treatment, and finally pine-leading stands. Pine has been shown to be less responsive to fertilization and also poses a higher risk of loss.
- **Rehabilitation** should be regarded as a high priority since converting poorly performing stands into productive ones will provide more harvest opportunities during the critical timber supply pinch point forecasted within 40 to 60 years. The relatively low level of rehabilitation shown over the first 5 years reflects the current salvage (and regeneration) program making rehab candidates more challenging to identify. Ideally, stands with the highest site productivity would be treated first after ensuring they are unlikely to be salvage harvested (i.e., low unit volumes due to age). A more significant rehabilitation program can occur once salvage operations have largely completed.
- **Pre-Commercial Thinning** should be used to set-up future fertilization activities and may be considered as a treatment for cleaning-up stands for success. Currently, limited opportunities

exist for the PCT treatment on existing managed stands and it is difficult to forecast opportunities on future stands. This activity is regarded as a lower priority due to the limited opportunities and questionable timber quality benefits.

- **Partial Cutting** in constrained areas is not expected to be useful right away but will be effective to leverage volume from areas that are otherwise inaccessible throughout the midterm, when fiber supply is tight. Given a limited budget, this treatment is best left for the next 20 years or so. Other than a few trials, this activity does not inform the tactical plan in the short-term – but could be useful to licensees in the short-term if appraisal allowances render it as a 'no incremental cost' scenario.
- **Enhanced Basic Silviculture** treatments on stands currently being salvaged is a high priority in the near term. This is due, in part, to the lack of candidate stands for other treatments such as fertilization and rehabilitation, but also because it delivers volume into the back end of the midterm trough allowing for an Allowable Cut Effect (ACE). In addition to the timber supply benefits, the higher density stands with this activity could result in timber quality improvements such as lower knot sizes, reduced risks from damaging agents and climate change, and provide options for further stand management.

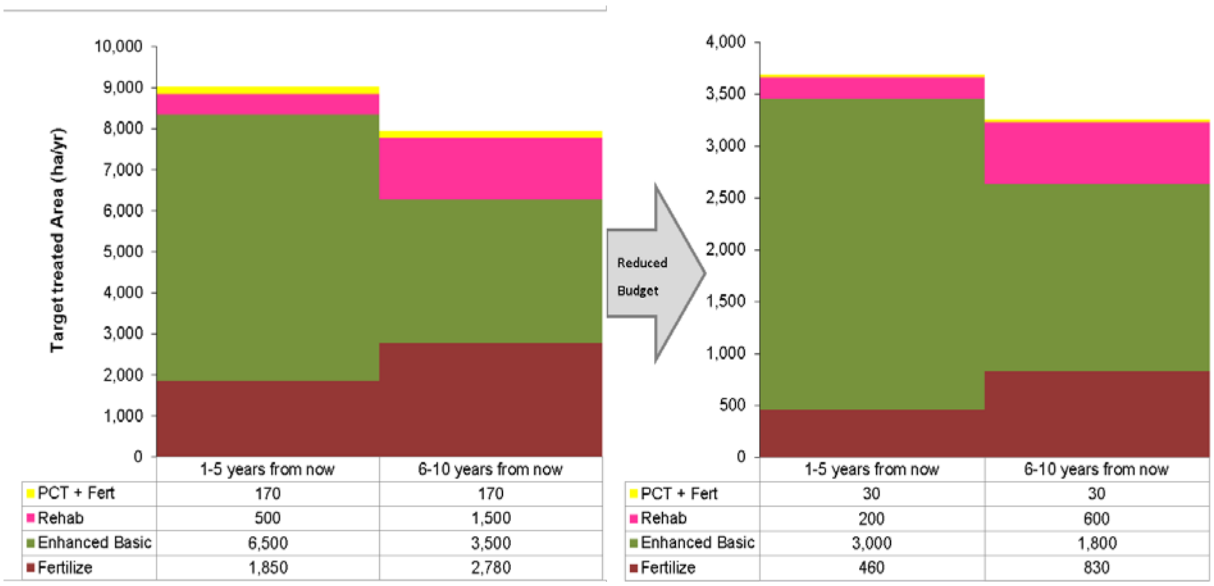
If budgets are more constrained (e.g., $2 Million/yr), pre-commercial thinning and fertilization are reduced at the expense of enhanced regeneration, while rehab remains similar. This occurs because enhanced regeneration delivers additional volume into the back of the mid-term trough that supports a higher mid-term harvest level (ACE occurring). Enhanced regeneration represents a longer time frame between investment and stand level gains, but the ACE allows benefits to be realized much sooner (at the front of the mid-term trough). This should be viewed with caution because the risk of investment loss is not factored into the assessment. Fertilizing should still be considered an important element of this strategy due to its immediate impact and therefore reduced risk of loss (fewer years of exposure to natural disturbance). Overall though, a diverse mix of investments will help to minimize these potential losses.

3 Tactical Plan

The tactical plan for this project is comprised of target treatment areas and spatially explicit treatment layers selected for a given funding level – in this case, the preferred silviculture strategy was established at a funding level of $5 Million/year so that sufficient opportunities are highlighted for whatever funding level actually occurs.

3.1 Target Treatment Areas

Figure 10 shows the target treatment area by activity developed from the preferred silviculture strategy (Section). This is a key component of the tactical plan generated from the model as a spatial treatment schedule of candidate stands. This tactical plan will be used to support the preparation of operational plans.



	1-5 years from now	6-10 years from now
PCT + Fert	170	170
Rehab	500	1,500
Enhanced Basic	6,500	3,500
Fertilize	1,850	2,780

	1-5 years from now	6-10 years from now
PCT + Fert	30	30
Rehab	200	600
Enhanced Basic	3,000	1,800
Fertilize	460	830

Figure 10 Target Treatment Areas for the Tactical Plan ($5M vs. $2M budgets)

3.2 Treatment Layers

Two spatially explicit layers were prepared for producing the tactical plan map for this project: priority stands and eligible stands. These were both produced from model-generated spatial treatment schedule (STS) for the preferred silviculture strategy, but further interpretation was required to translate the model's selection of candidate stands into operationally feasible treatment areas.

The spatial resolution for the modelling was quite fine (average polygon size = 4.0 ha), due in part to the number of spatial layers, but mostly from the resolution of the forest cover[7] in the central portion of the TSA. Treatment areas were not actively clustered in the model so in many cases, only small portions of larger openings were selected for treatments even though conditions in neighbouring polygons also met eligibility criteria.

Rather than using the model's resultant polygons to generate treatment layers, GIS post-processing and visual confirmation steps were taken to identify stands that are more appropriate for operational planning. Treatment layers were created from the original forest cover polygons that joined to the model selections. The non-THLB was then dissolved and used to erase areas from the treatment layers.

Eligible Stands

For each planning period, the model identified candidate blocks as a list of polygons that met the predefined eligibility criteria. Using the approach described above to generate treatment layers, the candidate blocks areas identified in the STS were used to create **eligible stands** for each treatment.

Priority Stands

For each planning period, the model's scheduled treatments were used to create **priority stands** for each treatment (again using the post-processing approach described above).

[7] Landscape Vegetation Inventory (LVI)

The next sections describe how **priority** and **eligible** stands were represented for each treatment. Sources of information on the treatment layers for creating and downloading maps are provided in Table 6.

Table 6 Sources for information on treatment layers

Source	Link
Silviculture Strategies	www.for.gov.bc.ca/hfp/silstrat/strategy%20index.htm#SIFR
ArcServer Treatment Layers (Tactical Plan)	View in ArcGIS Explorer or View in ArcGIS Webmap

3.2.1 Fertilization

Because of the limited number of eligible stands identified for this treatment in the short-term, plus the relatively narrow eligibility window, fertilization treatments are more sensitive to time. Treatment layers for the first 10 years were separated into two 5-year periods. Each fertilization regime (number of fertilizer applications) is also attributed in these layers.

3.2.2 Pre-Commercial Thinning

Opportunities for pre-commercial thinning were difficult to extract from the forest cover so there may be more opportunity on the ground than reported here. Only the priority stand treatment layer was prepared because there were no additional eligible stands identified by the model (i.e. all opportunities that the model recognized were taken). For the potentially eligible theme, the definition was extended by excluding the site index criteria to flag high density stands where imperfect site index information may have prevented some stands from being considered.

3.2.3 Rehabilitation

Although rehabilitation was not selected in the modelling for another 20 years, it is prudent to rehabilitate stands as soon as possible. At a forest level, due to variable market conditions, declining merchantable volumes for MPB-killed pine, and the absence of a current inventory with enough resolution to assess timber quantity and quality conditions, identification of stands for rehabilitation over salvage (clearcut) harvesting cannot be done with much certainty. Accordingly, a spatial treatment schedule for this activity was not created.

Rehabilitation treatments improve the mid-term harvest flows in two ways. For example, some stands rehabilitated early (within the next 5 years) can alleviate some pressure on merchantable growing stock at a critical point in the harvest forecast - the end of the mid-term. More significantly, rehabilitation treatments conducted throughout the mid-term add incidental harvest volumes that would otherwise be left standing and susceptible to further damage from other forest health agents.

Ways to identify candidate stands for a rehabilitation treatment are:

- Conduct rehabilitation treatments where fire hazard abatement is a priority. Knocking down and removing standing dead trees will reduce the fire hazard of these stands.
- Low-volume stands with high pine and/or dead stand percentages (i.e., ≥80%) with little natural regeneration or understory stocking are good candidates for early rehabilitation because they are unlikely to provide much green volume in the mid-term when timber availability is limited.
- Identify stands that were checked for harvesting but were not actually pursued. These stands were likely considered because they appeared to provide enough live and dead merchantable volume but upon closer inspection and assessment of extraction costs and values recovered,

were determined to be uneconomic to harvest. This suggests that at least some volume and value may be recovered from the rehab treatment to offset the costs.

Other criteria that should be considered to identify or prioritize stands for rehabilitation treatments include, but are not limited to: potential benefits to non-timber values, the amount of remaining green volume, site productivity, distance from communities, access difficulties, and proximity to appropriate seed sources.

3.2.4 Enhanced Basic Silviculture

The silviculture expenditures used to inform the tactical plan (Figure 10) shows most of the budget allocated to enhanced basic silviculture treatments. However, the location of this treatment depends entirely on where harvest has occurred, so a spatial treatment schedule for this activity was not created.

While there are many techniques to enhance basic silviculture treatments, the modelling assumptions were adjusted in two general ways: increased planting densities with lower operational adjustment factors (OAF1); and more reliance on planting with shorter regeneration delays and genetic gains.

Ideally, enhanced basic silviculture should be prioritized for stands that will realize the largest incremental gains (e.g., more productive stands assumed to be naturally regenerated). Ultimately, local silviculture practitioners are best positioned to identify potential stands that will provide the greatest incremental gains. There is a need to explore how to make changes to the existing stocking standards and incorporate them into FSP stocking standards for these stands.

In order for enhanced basic silviculture to be implemented, the current appraisal system would have to recognize the additional costs. However, this may not requires changes to appraisals but simply a better understanding of how to use planned costs as the silviculture allowance used in the stumpage calculation. To some extent, incentives for this strategy are in place for area-based tenures, but are unavailable to volume-based licensees. Until this is addressed, it is unlikely that enhanced basic silviculture will become a viable silviculture strategy – despite the obvious gains associated. There are currently no plans to pay for this type of treatment through the Forests for Tomorrow (FFT) program.

3.3 Applying the Tactical Plan

Target treatment areas (Section 3.1) together with treatment layers (Section 3.2) form the tactical plan developed from this project. With an aim to mitigate the lower harvest levels throughout the mid-term, this tactical plan provides a schedule of activities, at ideal and constrained funding levels.

This tactical plan is intended to guide silviculture practitioners in developing operational plans that identify specific stands for treatment. Points presented in following sections should be considered when applying the tactical plan for preparing an operation plan.

3.3.1 Translate budget to area

- Prioritize and schedule treatments for the operational time-line by considering the annual budget against the recommended treatment proportion from the tactical plan (Figure 10).
- Calculate target areas based on relative costs for each treatment. Cost assumptions used to develop this tactical plan are provided in the data package for this analysis.

3.3.2 Consider treatment risk

- Assess the financial risk associated with the proposed suite of activities by considering the time these treatments are exposed to natural disturbance events before becoming eligible for harvesting.
- Review local wildfire management plans (section 4.6) to identify areas where priorities for specific treatments are lower or higher. This should include visiting the wildfire management website where plans are being made to show this tactical plan alongside wildfire management strategies.

3.3.3 Consider related plans and strategies

- Check how the treatments considered align with related plans and strategies – particularly for forest health, wildfire management, ecosystem restoration, and watersheds (see section 4 below). Identify locations or conditions that might protect or improve timber and non-timber values.
- Periodically update information on related strategies to ensure they are current.
- Identify locations or conditions that might be explored to help inform future treatments and strategies.

3.3.4 Verify data

- Determine whether new or better information is available for key spatial layers such as: ownership, old growth management areas, wildlife habitat areas, ungulate winter ranges, and visual landscape polygons.
- Check silviculture history records to identify stands where similar treatment activities have occurred in the past and assess efficacy of those similar treatments (Note: this may be included on the silviculture strategy mapping website).

3.3.5 Identify candidate treatment areas

- Review candidate treatment areas presented on the silviculture strategy mapping website.
- Use the treatment layers to identify candidate stands that will be assessed in the field[8]. Polygons may be relatively small and isolated from other potential treatment areas making them impractical on their own.
    - Identify **priority stands** for the specific treatment
    - Include **eligible stands** close to the priority stands to guide field survey crews in developing logical treatment programs
    - Add other stands that meet the treatment eligibility criteria but were excluded based on deficient or inaccurate forest inventory data.

3.3.6 Assess candidate treatment areas

- Assess candidate treatment areas in the field. Survey crews may include neighbouring eligible stands for a treatment program when visiting the priority stands identified.

[8] While the best available forest-level data were used to develop the silviculture strategy and tactical plan, these data are not considered to be accurate at a stand level. All candidate stands must be assessed in the field before treatments are prescribed.

- Track all assessments to explore trends with the data and record the outcomes for areas that have already been assessed.
- Develop a mechanism to identify and track miscellaneous stands that are not already represented spatially (e.g., rehabilitation, pre-commercial thinning)
- Determine whether there are any timing issues that must be incorporated (e.g., linkages to related activities, road access, restoration and rehabilitation treatments).

4 Related Plans and Strategies

When implementing the silviculture strategy described above, it will be important to consider and incorporate elements from other related strategies into these implementation plans. The following section provides a brief introduction to these initiatives, an explanation of how and where they might influence or integrate with planned silviculture treatments or actions, a discussion on how they might be impacted by climate change, and references to more information. Future iterations of projects like this one are intended to integrate these issues more fully.

4.1 Climate Change

The rate of change in climate over the last 100 years is equivalent to the rate of change of the preceding 1000 years. Rapid change in climate is an overarching pressure on the forest, affecting both timber and environmental values. Table 7 provides links to sources for information on climate change.

Table 7 Sources for information on climate change

Source	Link
Overview of Guidance to Adapt Forest Management for Climate Change in the Kamloops TSA	www.for.gov.bc.ca/ftp/HFP/external/!publish/Web/FFESC/reports/NelsonrevisedK2adaptationguidanceoverview120607.pdf
Successional Responses to Natural Disturbance, Forest Management, and Climate Change	jem.forrex.org/index.php/jem/article/viewFile/171/113
Climate-based seed transfer modelling	www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr048.htm
Tree species regeneration vulnerability assessment for the central Interior of BC	www.for.gov.bc.ca/ftp/hfp/external/!publish/web/ffesc/reports/FFESC-Technical-Report_ProjectA2_Nitschke.pdf
Kamloops Future Forest Strategy II	www.for.gov.bc.ca/ftp/HFP/external/!publish/Web/FFESC/reports/Nelsonfinalreport.pdf
Transdisciplinary vulnerability assessment, Nadina Forest District	bvcentre.ca/research/project/a_multi-scale_trans-disciplinary_vulnerability_assessment
Stand/landscape level decision-support to reduce drought & disturbance risks	www.for.gov.bc.ca/hfp/future_forests/council/#completed-projects
Climate Change in Prince George Summary of Past Trends and Future Projections 31 August 2009	pacificclimate.org/sites/default/files/publications/Werner.ClimateChangePrinceGeorge.Aug2009.pdf
Preliminary Analysis of Climate Change in the Cariboo-Chilcotin Area of British Columbia	pacificclimate.org/sites/default/files/publications/Werner.ClimateChangeCaribooChilcotin.Sep2008.pdf
Effects of Climate on Mortality of Young Planted Lodgepole Pine	foothillsresearchinstitute.ca/Content_Files/Files/FGYA/FGYA_2008_12_Qknte12_EffectsClimateMortalityYoungLodgepolePine.pdf
Impacts of Climate on Forest Health - Lodgepole pine ecosystems 2010	foothillsresearchinstitute.ca/Content_Files/Files/FGYA/FGYA_2010_10_Poster_ImpactsClimateChangeOnForestHealth.pdf
Managing Risk and Uncertainty in Lodgepole Pine – A Shifting Paradigm	www.growthmodel.org/wmens/m2011/Dempster.pdf
Pacific Climate Impacts Consortium	www.pacificclimate.org/tools-and-data/plan2adapt

ClimateBC Map – UBC Centre for Forest Conservation Genetics	www.genetics.forestry.ubc.ca/cfcg/ClimateBC40/Default.aspx

To encourage more discussion and possible modelling in future silviculture strategies, the sections below include a brief discussion of how climate change might affect each related plan and strategy.

4.2 Tree Species Deployment

Concerns have been expressed about the diversity of tree species over time and the lack of clear objectives (e.g., Auditor General's report[9]). A recent report from FLRNO[10] focuses on the harvested landbase and provides an assessment of the species distribution from a variety of data sources and points in time.

Table 8 summarizes the direction towards a desired percentage by species by Biogeoclimatic subzone. This guidance was informed by ecological benchmarks based on historical levels as well as the plausible impacts of climate change as interpreted by local ecologists and silviculturalists. These trends will be tracked yearly and evaluated to determine if the trends are being achieved. A narrative describing progress will be provided. This is meant as a first step in management of species at the landscape scale. Future iterations may recommend finer scales and promote not only species direction but provenances as well. Sowing requests will be used to help track direction in the short term.

Table 8 Guidance for tree species deployment on harvested areas

Biogeoclimatic variant	Desired Trend			Comments
	Sx	Pl	Fd	
SBSdm	⇩	-	⇧	
SBSmc	⇩	-	-	Manage Bl as naturals
SBSwk	-	-	⇧	
SBPSdc	-	-	-	Manage At as naturals
MSxv	-	-	-	
ESSFwk	-	-	-	Manage Bl as naturals

Table 9 provides links to sources for information on tree species deployment.

Table 9 Sources for information on tree species deployment

Source	Link
Species Monitoring Report - Province	www.for.gov.bc.ca/hfp/sof/species/Spp%20Monitoring%20Report%20-%20Province%20(May%2010,%202012).pdf
A Short History of the Control of Species Selection for Reforestation in BC	www.for.gov.bc.ca/hfp/silviculture/Stocking_stds/How%20Species%20Have%20Been%20ControlledDraftver2%20(2).pdf

4.3 Land Use Plans

The Central Cariboo Land Use Plan (CCLUP), legal orders and Forest Stewardship Plans (FSP) provide a framework for land use and forest management in the Quesnel TSA and establish areas for non-timber values. However, MPB impacts are not limited to areas available for timber harvest. Lands reserved to provide protection for sensitive species, riparian, wildlife tree recruitment, and old growth

[9] http://www.bcauditor.com/pubs/2012/report11/timber-management

[10] Species Monitoring Report Quesnel TSA, May 2012, MCMFLNRO Resource Practices Branch

representation, are also affected both directly by increased mortality of pine and indirectly by impacts of roads, water quality and quantity, and associated habitat impacts.

Until land use plans and other strategies are revisited and amended to address the severe changes in forest structure, prescribing foresters are guided by the established objectives.

Climate change is not expected to impact land use plans directly but rather influence objectives applied in future plans.

Table 10 provides links to sources for information on land use plans.

Table 10 Sources for information on land use plans

Source	Link
CCLUP	ilmbwww.gov.bc.ca/slrp/lrmp/williamslake/cariboo_chilcotin/index.html
Quesnel SRMP	www.ilmb.gov.bc.ca/slrp/srmp/north/quesnel/index.html

4.4 Landscape Level Biodiversity

The loss of mature and old forest (pine and pine mixed with other species) over recent years will have significant impacts on associated aquatic, terrestrial and water values. The partial cut scenario was explored as a silviculture strategy for extracting some timber throughout the mid-term while maintaining or improving current and/or future condition of established mature seral management areas and other identified areas. Thinning has the potential to accelerate old growth attributes.

Stand structures that serve to connect habitats across a landscape will be impacted by accelerated salvage harvesting, reduced retention and the risk of large-scale fires and can result in disproportionate impacts to species at risk or those confined to isolated pockets of suitable habitat. Connectivity is provided in the Quesnel TSA through various mechanisms including strategies that prescribe retention for specific resource management zones, conservation legacy areas, mature and old seral retention, and riparian management provisions.

Prescribing foresters can enhance connectivity by increasing retention levels in large cutblocks within riparian areas, gullies, connectivity corridors for Caribou and surrounding wildlife habitat features.

Climate change is expected to impact landscape biodiversity through increased forest disturbance. This may be mitigated by treatments designed to reduce risk of damage from wildfire or pests.

Table 11 provides links to sources for information on landscape level biodiversity.

Table 11 Sources for information on landscape level biodiversity

Source	Link
Successional Responses to Natural Disturbance, Forest Management, and Climate Change	jem.forrex.org/index.php/jem/article/viewFile/171/113
Current State of Knowledge Regarding Secondary Structure in MPB Impacted Landscapes	www.for.gov.bc.ca/hts/pubs/MPB_Impacted_Stands_Report_January_20_2012.pdf

4.5 Forest Health

The forest health strategy [11] aims to recommend actions to address forest health issues. A list of significant forest health agents and current strategies is provided in Table 12.

Table 12 Forest health agents and strategies

Category	Agent	Strategy
Bark Beetles	**Douglas-fir beetle** (1)	Aggressive suppression action.
	Spruce beetle(1)	Aggressive suppression action.
	Mountain pine beetle (2)	Salvage action.
	Western balsam bark beetle	Contain and ground-truth the extent of the infestation. Harvesting the current attack is a feasible means of control.
	Ips Engraver Beetle	Monitor stands for population build up. Dispose of slash in a timely manner.
Defoliators	**Western spruce budworm** (2)	Contain and treat moderate and severely defoliated high-value stands of Douglas-fir with B.t.k..
	Two year cycle budworm (2)	Containment, treat moderate and severely defoliated high-value stands with B.t.k..
	Forest Tent Caterpillar	Monitor outbreaks and re-foliation response of trees.
	Gypsy moth	Monitor with pheromone traps and eradicate known infested sites with B.t.k..
Rusts	**Comandra blister rust, Stalactiform blister rust, and Western gall rust** (2)	Contain and treat detected infestation areas.
Dwarf Mistletoe	Pl dwarf mistletoe	Aggressive Suppression action.
Root Diseases	Armillaria, Tomentosus	Monitor and treat as prescribed in best management practices.
Woody Tissue Feeders	Warren's root collar weevil	Contain and treat individual blocks to maintain stocking. Planting spruce near timber edges may discourage the weevil from entering the plantation.
Abiotic Injuries	Weather related	Salvage harvest merchantable timber within one year of the catastrophic event.
	Windthrow (2)	Aggressive Suppression action. Harvest Douglas-fir and spruce windthrow within one year of the event to reduce opportunities for bark beetle build-up.
	Wildfire (2)	Aggressive Suppression action.
Animal Damage	Hare and vole	Monitor and recommend treatment when required.

(1) Very high priority forest health agent (Bold text)
(2) High priority forest health agent (Bold text)

One of the key forest health strategies that can protect stands contributing to the mid-term timber supply is to treat Douglas-fir stands attacked by western spruce budworm (283 ha) and spruce stands attacked by spruce beetle (67 ha).

Climate change is expected to increase the frequency and intensity of severe wind-throw events and outbreaks of insects - particularly bark beetles[12], and pathogens [13]; undoubtedly leading to more challenging decisions regarding silviculture investments and priorities.

Table 13 provides links to sources for information on forest health.

[11] Quesnel Forest District, Quesnel Timber Supply Area Forest Health Strategy 2011-2012, May 2011, 26p.

[12] Carroll, A. 2012 Predicting Forest Insects Disturbance under Climate Change. http://www.for.gov.bc.ca/ftp/HFP/external/!publish/Web/FFESC/reports/Carrollfinalreport.pdf

[13] Woods, A.J., Heppner, D., Kope, H.H., Burleigh, J. and Maclauchlan, L. 2010. Forest health and climate change: A British Columbia perspective, The Forestry Chronicle, Volume 86, Number 4. 11p.

Table 13 Sources for information on forest health

Source	Link
Quesnel Forest Health Strategy	www.for.gov.bc.ca/hfp/health/TSA_strategies.htm
MFLNRO Forest Health Program	www.for.gov.bc.ca/hfp/health/index.htm
Forest health and climate change: A BC perspective	bcwildfire.ca/ftp/HFP/external/!publish/ClimateChange/FRPA/Workshop/Forest_Health_CC.pdf

4.6 Wildfire Management

The BC Wildfire Management Strategy [14] aims to encourage healthier ecosystems, reduce the risk of loss to communities, address climate change and enable more cost-effective fire response. The five strategies that aim to achieve these goals are to:

- Reduce the hazards and risks associated with wildland fire in and around communities and other high-value areas.
- Plan and implement careful use of controlled burning in appropriate ecosystems under suitable conditions to reduce hazards and risks and achieve healthy forests and grasslands (also see Section 4.7).
- Monitor wildfires occurring in areas where there is minimal risk to identified values and intervene when appropriate to reduce hazards and risks and ensure optimum use of fire suppression budgets and personnel.
- Ensure that plans adequately consider the management of wildland fire at all appropriate scales in order to reduce hazards and risks, achieve healthy forests and grasslands and ensure resource-efficient fire suppression.
- Develop a high level of public awareness and understanding about wildland fire and its management in order to garner support for proactive and resource-efficient wildland fire and fuels management (including policies, planning and on-the-ground actions).

Burn probability modelling is used help prioritize areas at risk, set objectives for wildfire risk reduction on the landscape, and support subsequent operational management planning over the next few years. The Wildfire Management Branch goals are to complete this initiative for all management units in BC by 2015.

4.6.1 Trends in Wildfire Impacts

Changing weather, climate and fuel types are expected to result in longer fire seasons, more area burned and more extreme wildfire behaviour. Reduced suppression success and shifting response priorities that focus on protecting interface values, will result in more areas and timber values lost to wildfire.

With over 7 million ha of hazardous fuels in full response zones provincially, (Hvenegaard, S., 2012) Wildfire Management Branch is not capable to respond to all wildfires in a major wildfire event. Consequently, wildfire response priorities may limit suppression actions to the protection of

[14] British Columbia Wildland Fire Management Strategy, September 2010, 21p.

communities and critical infrastructure during mass wildfire starts, often triggered by lightening. In these situations, protecting natural resource values will become a very low priority; as was experienced during the 2009 wildfire season when wildfire response was often focused entirely on interface fires. At fire intensities exceeding 4,000 kW/m most fire control efforts (direct fire control) are unlikely to be successful and may be limited to flank attacks or curtailed completely until extreme wildfire behaviour ameliorates (Hirsh, K., Martell, D. 1996).

Due to the predicted extreme intensity of some MPB fuel fires, suppression success may be very limited until major weather changes occur. This was evident in the 2010 wildfires that affected the Cariboo.

Climate changes are expected to increase the frequency and intensity of wildfires[15]; undoubtedly leading to more challenging decisions regarding silviculture investments and priorities. Table 14 shows the expected impacts on wildfires due to climate change using a relatively conservative estimate of 25% increase in burned area each decade over the next 4 decades (i.e., into the mid-term period) and the projection of recently burned areas in the Quesnel TSA (62,200ha in the THLB since 2003). The projected total impact on the THLB is 404,200 ha, or over 60.6 million m^3 (at 150 m^3/ha).

Table 14 Expected impacts on wildfires due to climate change

Increase in Area Burned	Period	Area Burned (ha)
25%	2012 – 2022	77,700
50%	2022 – 2032	93,300
75%	2032 – 2042	108,800
100%	2042 – 2052	124,400

4.6.2 A Landscape Perspective

A landscape perspective on the likely occurrence and impacts of wildfire is critical to protecting the longer term viability of an adequate timber supply, as well as, non-timber values (e.g., habitat, properly functioning watersheds). A risk assessment is initially developed to identify hazards in proximity to key values across the landbase. Using the risk assessment, landscape-level fire management objectives (e.g., reduce fire size, reduce fire intensity) are prepared from which specific steps are identified to help "protect" timber supply – or at least make areas more resistant or resilient to wildfire.

The following steps can contribute to ameliorating aspects of wildfire management, such as burn probability, which can ultimately reduce the impacts of fire:

- Prioritize silviculture programs and ecosystem restoration (including BCTS FFT ITSLs) onto areas that align with landscape-level objectives to reduce wildfire risk to communities and other values, including timber.
- Ensure silviculture projects are located within areas of reduced fire risk and are strategically aligned in larger, more cohesive units that can be easily identified as a priority value for suppression.

[15] Woods, A.J., Heppner, D., Kope, H.H., Burleigh, J. and Maclauchlan, L. 2010. Forest health and climate change: A British Columbia perspective, The Forestry Chronicle, Volume 86, Number 4. 11p.

- Direct reforestation and pre-commercial thinning activities onto areas that can buffer both high value mid-term timber supply and silviculture investment areas by reducing the potential of crown fires and promoting more effective suppression techniques.
- Ensure that management unit timber objectives, silviculture regimes and standards, include a wildfire component that allows for modified harvesting or promotes the use of alternative species in areas forecasted with high or very high wildfire probability.
- Employ the strategic use of fire management activities based stocking standards (under development) and/or changes in practices (e.g. silvicultural activities as thinning, spacing with slash reduction, etc.).
- Support better integration of Ecosystem Restoration, Forests For Tomorrow and Fuel Management program planning to ensure that the right treatments are occurring in the right stands, and that they incorporate the historical and future patterns of open forest and grassland ecosystem expansion in the interior of BC.
- Build linkages between fire and forest management at the District stewardship level so that fire is recognized as part of the ecological process and a major driver on the landscape that is paramount for consideration in the planning process.

Key to this process is the continued development and use of fire management plans that address fire at both landscape- and stand-levels. If a fire management plan does not exist for a candidate silviculture activity, then the fire management planning program should be included to aid in the assessment and evaluation of silvicultural strategy options from a fire perspective.

4.6.3 General Considerations from a Fire Management Perspective

A spatially explicit product(s) for silvicultural activities is required to adequately plan for and protect values from the effects of fire. The tactical plan described in section 3 should be used to consider silviculture priorities in light of fire management plans and inform fire management plans (i.e., response priority) in light of planned silviculture treatments.

Table 15 illustrates the relationship between forest management activities and fire management where treatments are either promoted to reduce risk or caution is directed in high risk areas for treatments that require time to provide benefits. It describes silviculture treatment priorities given wildfire management considerations by using various Burn-P3 parameters to identify potential fire risk. This matrix is intended to assist prescribing foresters to consider fire risk when planning silviculture treatments. For example, a lower priority might be assigned to silviculture activities that are likely to contribute to the fire hazard or where there is a high probability that significant silviculture investments may be lost. Alternatively, a higher priority might be assigned to activities that mitigate the risk of loss due to wildfire.

Table 15 Forest management priorities for wildfire management

Treatments		Lower priority where…	Higher priority where…
Harvesting	Clearcut		• High values and high hazards exist; create fuel breaks
	Partial cut		• High risk interface area [(2)] identifies a need to treat fuels; mitigate risk
Silviculture	Enhanced Reforest	• Burn probability is highest; avoid lost silviculture investments	
	Alternate Reforest [(1)]		• Burn probability is highest; mitigate losses

Treatments		Lower priority where…	Higher priority where…
			and protect values
	Prescribed Burn / Ecosystem Restoration		• High values exist with high hazard and risk; treat fuels and improve forest health/habitat
	Spacing	• Burn probability is highest; avoid lost silviculture investments	
	Spacing & Cleaning		• High values exist to protect community and Infrastructure • High risk interface area (2) identifies a need to treat fuels; mitigate risk • Burn probability and fire intensity criteria are the highest; mitigate fuel loading
	Fertilization	• Burn probability is highest (except in interface); avoid lost silviculture investments	• Burn probability is highest within interface; avoid lost silviculture investments due to high fire extinguishment priority
Rehabilitate	Knockdown and site preparation		• High risk interface area (2) identifies a need to treat fuels; mitigate risk
	Plant and brush	• Burn probability is highest; avoid lost silviculture investments	

(1) encourage deciduous or other fire resistant species
(2) identified through a Community Wildfire Protection Plan (CWPP) or Provincial Strategic Threat Analysis (PSTA)

To illustrate how wildfire management might be considered to prioritize silviculture treatments, Figure 11 shows an example of two types of treatments: fertilization (green) and pre-commercial thinning (pink). Applying the direction in Table 15, would influence priorities accordingly:

1. Fertilization within the high burn probability and interface area is a lower priority.
2. Fertilization within the moderate burn probability and outside the interface is a higher priority.
3. Spacing and cleaning within the high burn probability and interface area is a higher priority.

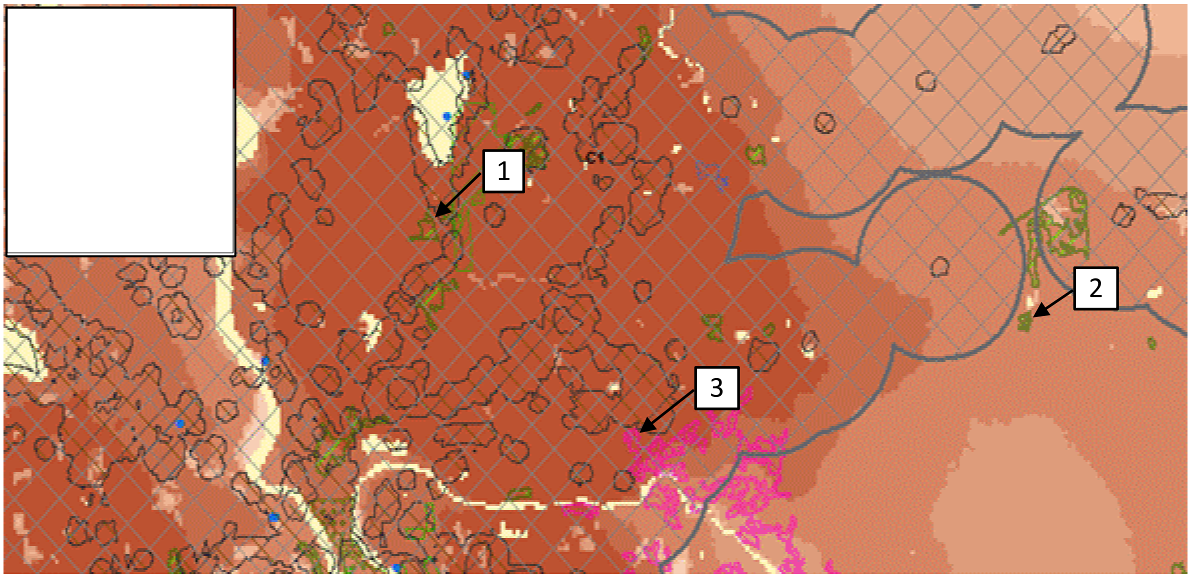


Figure 11 Map showing burn probability, interface areas and candidate treatment areas

Climate change is expected to increase the frequency and intensity of wildfires [16]; which will make decisions regarding silviculture investments and priorities much more challenging.

Table 16 provides links to sources for information on wildfire management.

Table 16 Sources for information on wildfire management

Source	Link
BC Wildland Fire Management Strategy	bcwildfire.ca/prevention/PrescribedFire/
Provincial Strategic Threat Analysis	ground.hpr.for.gov.bc.ca/maps/cariboo/index.htm
Cariboo Regional District Community Wildfire Protection Plan	www.crd-director.com/section.php?cid=163
Quesnel Community Wildfire Protection Plan	www.quesnelfire.ca/cwpp/
Burn-P3 Modelling	cfs.nrcan.gc.ca/pubwarehouse/pdfs/25627.pdf
Forest health and climate change: A BC perspective	bcwildfire.ca/ftp/HFP/external/!publish/ClimateChange/FRPA/Workshop/Forest_Health_CC.pdf
Innovative Timbre Sale Licences (ITSL) – Stand Selection Policy	www.for.gov.bc.ca/hcp/fia/landbase/fft/ITSL-FLTC-Stand-Selection-Policy-20120920.docx.
Silvicultural Regimes for Fuel Management in the Wildland Urban Interface or Adjacent to High Landscape Values	www.for.gov.bc.ca/ftp/HFP/external/!publish/LBIS_web/Guidance/FFT%20guidance%20-Silvicultural%20Regimes%20for%20Fuel%20Management%20in%20the%20WildLand%20Urban%20Interface_V2.3.pdf

4.7 Ecosystem Restoration

In fire-maintained ecosystems of BC's interior, decades of fire suppression and the absence of prescribed burning has contributed to trees encroaching into areas that were historically grassland, as well as, increased tree densities in areas previously considered to be open forests. This type of

[16] Woods, A.J., Heppner, D., Kope, H.H., Burleigh, J. and Maclauchlan, L. 2010. Forest health and climate change: A British Columbia perspective, The Forestry Chronicle, Volume 86, Number 4. 11p.

ecological change reduces ecosystem resiliency to climate change pressures and contributes to many other negative trends.

The current ecosystem restoration plan[17] established a grassland benchmark used to facilitate the restoration of open-grassland habitat and legally established under the Cariboo-Chilcotin Land Use Plan. The ecosystem restoration plan also prioritized locations for restoration treatments, including prescribed burning and /or mechanical thinning. Most priority areas identified for treatment are located within the western part of the TSA.

Ecosystem restoration is not a direct, obvious or significant strategy to mitigate the falldown in mid-term timber supply and was therefore not included with this analysis. However, there may be instances where stands currently outside of the THLB could undergo certain restoration treatments, such as partial harvesting or commercial thinning, to return them to an open forest or even grassland condition. In this case, if the timing is appropriate, these harvested volumes might then contribute to the mid-term timber supply.

Difficulties will arise when attempting to fit natural ranges of variability into modern concerns of a changing climate. Climate change concepts must then be applied as best as possible into restoration processes.

Table 17 provides links to sources for information on ecosystem restoration.

Table 17 Sources for information on ecosystem restoration

Source	Link
Provincial Ecosystem Restoration Strategy	www.for.gov.bc.ca/hra/Restoration/index.htm
Cariboo-Chilcotin Grasslands Strategy and Cariboo-Chilcotin Ecosystem Restoration Plan	www.ilmb.gov.bc.ca/slrp/lrmp/williamslake/cariboo_chilcotin/news/files/reports/grasslands_strat/index.html
Ecosystem Restoration Guidelines	www.env.gov.bc.ca/fia/documents/restorationguidelines.pdf

4.8 Enhanced Retention

In a previous AAC rationale[18], the Chief Forester encouraged district staff and licensees to resolve ways to implement forest stewardship recommendations[19] operationally. This eventually led to the development of an enhanced retention strategy[20] to provide guidance in selecting and distributing conservation legacy areas (CLA) during the salvage of MPB impacted pine leading stands.

The enhanced retention strategy presented a combination of stand- and landscape-level recommendations, supporting maps to identify areas suitable for CLAs, and recommended best management practices (BMP) which provide guidance for selecting additional CLAs. It was also expected that forest stewardship plans (FSP) would reflect these management practices. CLAs are tracked spatially through RESULTS as reserves on the WTP layer.

[17] B.A. Blackwell & Associates Ltd., Cariboo-Chilcotin Ecosystem Restoration Plan: Grassland Benchmark, November 2007, 47p. (plus maps)

18 Quesnel Timber Supply Area – Rationale for Allowable Annual Cut (AAC) Determination, Effective October 1, 2004, Larry Pedersen, Chief Forester.

[19] BC Ministry of Forests, Forest Science Program, Forest Stewardship in the Context of Large-Scale Salvage Operations: An Interpretation Paper, Technical Report 19, 2004, 18p.

[20] Quesnel Forest District Enhance Retention Strategy Committee, Quesnel Forest District Enhanced Retention Strategy for Large Scale Salvage of Mountain Pine Beetle Impacted Stands – Release 1.0, February 2006.

In this silviculture strategy, CLAs were modelled as a forest cover constraint for the first 30 years. These areas should be identified to ensure that planned silviculture treatments will not conflict with accessing these areas for harvesting in the future. Otherwise, no silviculture treatments are recommended within CLAs.

By encouraging heterogeneity across the landscape, enhanced retention strategies should improve the resiliency of forest ecosystems in the face of changing climate [21] .

Table 18 provides links to sources for information on the enhanced retention.

Table 18 Sources for information on enhanced retention

Source	Link
Forest Stewardship in the Context of Large-Scale Salvage Operations	www.for.gov.bc.ca/hfd/pubs/docs/tr/tr019.pdf
Quesnel Forest District Enhanced Retention Strategy	www.for.gov.bc.ca/dqu/policies/

4.9 Secondary Structure

Section 43.1 of the Forest and Range Practices Act Forest Planning and Practices Regulation requires forest licensees to protect secondary structure (i.e., understory advanced regeneration and non-pine canopies) in MPB affected areas. Harvesting in areas with little to no secondary stand structure and retaining areas with good densities of high-quality secondary stand structure is expected to improve the mid-term timber supply as areas with suitable secondary structure should develop into merchantable stands sooner than if they were clearcut and reforested. Secondary structure is typically considered during operational planning. Suitable stands are either excluded from proposed cutblocks or harvested in a way that protects the understory regeneration.

Since protecting secondary structure is a legal requirement, licensees are expected to incorporate results and strategies into their respective FSPs. However, a formal process for reporting these areas was not clearly identified.

Ideally, stands protected with secondary structure would be identified within CLAs as described above (section 4.8). Accordingly, these areas should be identified to ensure that planned silviculture treatments will not conflict with accessing these areas for harvesting in the future. Otherwise, no other silviculture treatments are considered within these stands.

Since areas temporarily protected for secondary structure will ultimately be harvested, they were considered within the THLB in this analysis and no further constraints or treatments were applied.

Table 19 provides links to sources for information on protecting secondary structure.

Table 19 Sources for information on protecting secondary structure

Source	Link
Mid-Term Timber Supply assessment	www.for.gov.bc.ca/hfp/mountain_pine_beetle/mid-term-timber-supply-project/secondary%20stand%20structure_summary_june_11.pdf
Silviculture Survey Reference Documents	www.for.gov.bc.ca/hfp/silviculture/Silviculture_Surveys.html

[21] Gayton, D., and P. Lara Almuedo. 2012. Post-disturbance management of biodiversity in BC forests. BC Journal of Ecosystems and Management 13(1):1–9.

4.10 Watershed Management

Changes in hydrology can be estimated by equivalent clear cut area (ECA) and road density. Significant increases in ECA, road density, kilometres of road ditches, and numbers of stream crossings, increase the risk of increased peak flows and impacts on channel morphology. Risk can be reduced by accelerating hydrological green-up and an increased emphasis on maintaining vegetation within riparian ecosystems. This is especially important for all fish-bearing streams, wetlands, fishery-sensitive watersheds and community watersheds.

Assessment of watershed risk requires a sound understanding of watershed hazards or the likelihood of events taking place (e.g., landslide, high peak flows) and the values or consequence that are at risk (e.g., fish/fish habitat, highways or life & limb). Recently, a GIS-based watershed risk analysis[22] prioritized management activities based on their potential positive or negative influence of watershed risk. This risk analysis was used to designate “priority watersheds” and flag stands that warrant consideration for silviculture or other treatments that provide both increased timber supply benefits and decreased watershed risk.

Priority watersheds were identified as basins and sub-basins that are:

- high risk to fish and fish habitat
- high risk to social values, and
- high equivalent clearcut area (ECA) (>30% based on the methodology implemented within the risk analysis).

In addition to the watersheds identified in the GIS-based approach, the district included the Bazaeko River as a priority watershed because of the associated MPB impact and anticipated future ECAs. Over one third of the total area for the TSA was identified as being with a priority watershed.

The original intent was to incorporate watershed priorities into this silviculture strategy analysis, but after a series of discussions, it was decided to simply describe the silviculture treatments impacts on ECA in general terms. Table 20 describes how these treatment impacts can be used to prioritize stands for tactical and operational planning.

Table 20 Silviculture impacts on ECA

Treatment	Impact on ECA	Rationale
Fertilizing	Positive	Fertilizing will increase the growth rates of treated stands, and reduce the time to canopy closure, thus potentially expediting hydrological recover of ECA areas. This is expected to have a positive impact towards reducing ECA.
Spacing and Fertilizing	Negative	Though fertilizing is anticipated to have a beneficial impact, removal of stems will lengthen time to canopy closure and thus slow hydrologic recovery.
Shortened Rotation	Negative	Increased % of landbase in a non-recovered condition due to the reduction in rotation age will keep ECA levels higher.
Knockdown and Plant (salvage)	Negative in short- term; Positive in the mid-term.	Increased ECA due to the additional salvage harvest. Negative impact is shorter term (5-10 years), however it does result in an expedited recovery in the mid-term (i.e. >10 years)
Commercial Thinning	Nil	Assuming that Commercial Thinning maintains a stocked stand and decent crown closure, the impacts of removing individual trees should (in theory) not increase or decrease the amount of ECA within a priority watershed. As a result the anticipated impact is considered nil.

[22] Forsite Consultants Ltd. 2012. Cariboo GIS-Based Watershed Risk Analysis . Ministry of Forests Lands and natural Resource Operations.

Planting	Positive	Where there are NSR areas, for example, just doing planting will help increase the rate of recovery and earlier reduction in ECA.

Climate change is expected to have many important effects on watershed processes that in turn will affect values such as water quality, water supplies, slope stability, and terrestrial and aquatic habitats [23]. Developing effective responses to these effects will likely involve local-level strategies. Table 21 provides links to sources for information on watershed priorities.

Table 21 Sources for information on watershed priorities

Source	Link
Cariboo Watershed Risk Analysis	ftp://ftp.geobc.gov.bc.ca/pub/outgoing/Cariboo%20Watershed%20Risk%20Assesment/Cariboo%20Watersheds%20Risk%20Analysis%20Report%20Final_Mar2012.pdf
Fisheries Sensitive Watersheds	www.env.gov.bc.ca/wld/frpa/fsw/index.html

4.11 Wildlife Habitat

The Identified Wildlife Management Strategy (IWMS) provides direction, policy, procedures and guidelines for managing species at risk and regionally important wildlife. Legal objectives are also established for ungulate winter ranges (UWR) for mule deer and wildlife habitat areas (WHA) for American White Pelican, Data Sensitive Species, Northern Caribou and Mountain Caribou. The Cariboo-Chilcotin Land Use Plan (CCLUP) identified grizzly bear habitat, high value wetlands for moose and critical fish habitat.

Many species at risk and those of management concern are negatively affected by roads which will increase significantly to salvage MPB. Given the vulnerability of forest-dependent species and large areas of MPB impacted timber, increased emphasis on managing road impacts is warranted.

While this analysis incorporated landbase netdowns and forest cover constraints to address UWRs, WHAs and critical fish habitat, it did not incorporate any further constraints associated with the additional wildlife species identified in the CCLUP.

Based on predictive ecosystem mapping, the BC Ministry of Environment (MoE) has been working to create habitat models for moose, mountain caribou, northern caribou, mule deer, elk, white-tailed deer, grizzly bear, marten, lynx, three-toed woodpecker, and northern goshawk. Draft habitat maps from these models were not available in time for inclusion with this analysis however, our results may later be incorporated back into the habitat model to identify areas where silviculture treatments might benefit or degrade habitat.

No direct linkages appear to exist between these wildlife habitat strategies and the silviculture treatments explored in this project. However, prescribing foresters should consider how these designated habitat areas might be impacted by the silviculture treatments and prioritize them accordingly.

Wildlife trees are managed through results and strategies stipulated in FSPs, the Chief Forester's guidance, licensee discretion and stewardship principles. While MPB impacts can enhance the

[23] R.G. Pike, T.E. Redding, R.D. Moore, R.D. Winkler, and K.D. Bladon. 2010. Compendium of forest hydrology and geomorphology in British Columbia. FORREX Forum for Research and Extension in Natural Resources (Chapter 19 Climate Change Effects on Watershed Processes in British Columbia).

availability of wildlife trees and CWD, at least in the short- to medium-terms, actions such as salvage, road building, and safety issues associated with roads, replanting and stand tending can result in the loss of non-pine wildlife trees and CWD. These features are also vulnerable to intense fires promoted by large areas of dead pine and climate change. Strategies to retain coarse woody debris and wildlife trees through time should be considered when planning silviculture treatments.

Climate change will likely impact wildlife habitat through increased forest disturbance reducing live structure while creating additional dead trees. This may be mitigated by treatments designed to reduce risk of damage from wildfire or pests.

Table 22 provides links to sources for information on wildlife habitat.

Table 22 Sources for information on wildlife habitat

Source	Link
Identified Wildlife Management Strategy	www.env.gov.bc.ca/wld/frpa/iwms/index.html
Ungulate Winter Ranges	www.env.gov.bc.ca/wld/frpa/uwr/index.html
Fisheries Sensitive Watersheds	www.env.gov.bc.ca/wld/frpa/fsw/index.html
CCLUP	ilmbwww.gov.bc.ca/slrp/lrmp/williamslake/cariboo_chilcotin/index.html
Quesnel SRMP	www.ilmb.gov.bc.ca/slrp/srmp/north/quesnel/index.html

4.12 Recreation

Whereas the CCLUP does not establish objectives specifically for recreation, there are three related objectives:

- maintain visual quality objectives for scenic areas
- maintain visual quality objectives for lakeshore management zones
- maintain a 50 meter management zone on either side of designated trails

As well, the CCLUP final report provides further direction on significant recreation corridors and a tourism sector strategy that considers access and visual quality. The SRMP proposes objectives and strategies for recreation corridors and trails, backcountry recreation areas and scenic areas.

In this analysis, modelling approaches to address the legal objectives for scenic areas, lakeshore management zones and designated trails were incorporated as either forest cover constraints or a landbase netdown. No changes were incorporated to incorporate recreation activities within the silviculture treatment scenarios.

While direct linkages do not appear to exist between recreation plans and the silviculture treatments explored in this project, prescribing foresters should consider any recreation features that may be affected either positively or negatively.

Climate change is not expected to have any direct impacts on recreation features. It is more likely that these values will be affected indirectly through increased forest disturbance and changes in ecosystem processes such as increased stream temperatures and the subsequent impacts on fish. In some cases treatments to address these processes may be available and should be considered in tactical and operational planning.

Table 23 provides links to sources for information on recreation values.

Table 23 Sources for information on recreation values

Source	Link
CCLUP	ilmbwww.gov.bc.ca/slrp/lrmp/williamslake/cariboo_chilcotin/index.html
Quesnel SRMP	www.ilmb.gov.bc.ca/slrp/srmp/north/quesnel/index.html
(Archived) Recreation Corridor Management Strategy	archive.ilmb.gov.bc.ca/slrp/lrmp/williamslake/cariboo_chilcotin/docs/rec_cor.html

4.13 Range Management

The MFLNRO range program allocates and administers, through range use plans, hay cutting and grazing agreements as well as grazing leases on Crown range across the Province. A formal range management strategy or plan is currently unavailable for the TSA.

While direct linkages do not appear to exist between range management activities and the silviculture treatments explored in this project, prescribing foresters should consider how these treatments might affect or be affected by range activities. For example, cattle use within riparian areas and newly planted areas will continue to be a concern for managing both habitat and timber supply. Silviculture treatments could help to retain and enhance existing barriers to cattle accessing these riparian areas.

Table 24 provides links to sources for information on the range program, BC Cattlemen's association and the Guide Outfitters Association of BC.

Table 24 Sources for information on the range management

Source	Link
MFLNRO Range Program	www.for.gov.bc.ca/hra/index.htm
BC Cattlemen's Association	www.cattlemen.bc.ca/default.htm
Guide Outfitters Association of BC	www.goabc.org/

4.14 Invasive Plants

The MFLNRO addresses invasive plant management through operational inventory, survey, treatment, and monitoring activities, and the development of new biological control agents for effective long-term control and rehabilitation of heavily infested areas. To prevent the introduction or spread of prescribed species of invasive plants, the MFLNRO reviews operational plans to ensure that invasive plant concerns are adequately addressed by the plan holder before approval .

Millennium Ecosystem Assessment [24] has identified invasive alien species as a major threat to the resilience of ecosystems in the presence of climate change. Given the substantial environmental and economic costs associated with the risk of biological invasion, prescribing foresters should pay considerable attention to the management of invasive plant species, especially under projected climate change scenarios.

While direct linkages do not appear to exist between invasive plant strategies and the silviculture treatments explored in this project, prescribing foresters can contribute to the program by reporting

[24] Millennium Ecosystem Assessment, 2005. Ecosystems and human well-being: multiscale assessments, 4: OisLAND press, London.

invasive plant sightings and where appropriate, collaborating with the Invasive Species Council of BC and the MFLNRO on specific treatment and research initiatives[25].

Table 25 provides links to sources for information on strategies for addressing invasive species.

Table 25 Sources for information on invasive species

Source	Link
MFLNRO Invasive Alien Plant Program	www.for.gov.bc.ca/hra/plants/
Invasive Species Council of BC	www.bcinvasives.ca/
Cariboo Chilcotin Coast Invasive Plant Committee	www.cccipc.ca/

4.15 Tree Improvement and Seed Transfer

The Forest Genetics Council of BC is appointed by B.C.'s chief forester to guide the full range of forest genetic resource management activities, including tree improvement (tree breeding and seed orchards), genetic conservation, genecology, climate-based seed transfer, and seed-use policy in the province. The Council provides a forum for stakeholder representatives to set goals and objectives, and to oversee the development and delivery of business plans to fulfill them. The annual FGC Business Plan outlines the activities and budgets of the seven subprograms that constitute the provincial forest genetic resource management program.

Direct linkages between tree improvement and the silviculture treatments explored in this project exist where planting is a component of the silviculture treatment (e.g., rehabilitation scenario). In these cases, planting trees germinated from select seed can significantly increase volume production that contributes to addressing mid-term timber supply issues. Prescribing foresters commonly use of select seed in normal operations so no further considerations are expected in adapting these practices for the silviculture treatments or actions described above.

Climate based seed transfer is one of the key features of BC's overarching Climate Change Adaptation Strategy. Planting seedlings adapted to future climates (assisted migration) is recognized as a key strategy to address climate change, as it will help maintain healthy, productive forests, and ensure capture of gains obtained from decades of selective breeding.

Table 26 provides links to sources for information on tree improvement and seed transfer.

Table 26 Sources for information on tree improvement and seed transfer

Source	Link
Forest Genetics Council of BC	www.fgcouncil.bc.ca/
MFLNRO Tree Improvement Branch	www.for.gov.bc.ca/hti/index.htm
Climate Change Adaptation Strategy	www.for.gov.bc.ca/het/climate/actionplan/index.htm
Forest Stewardship Action Plan for Climate Change Adaptation	www.for.gov.bc.ca/ftp/HFP/external/!publish/ClimateChange/Adaptation/MFLNR_CCAdaptation_Action_Plan_2012_final.pdf

[25] Numerous tools are available including an App to report invasives, e.g., http://www.bcinvasives.ca/special-events/fight-against-invasive-species-right-at-your-fingertips

4.16 Forest Inventory

The MFLNRO's forest inventory program includes both forest inventory and stand growth modelling sub-programs. Data and models produced by this program are used to characterize current, and forecast future, forest condition. This includes the recently completed LVI product used to represent the state of the forest in the western half of the TSA. Validation of this product is occurring in 2013/2014.

While direct linkages do not appear to exist between the forest inventory and the silviculture treatments explored in this project, information derived from this program is critical to the design of silviculture regimes. Reliability of the forest inventory demands continuous updates to reflect changes in the forest from harvesting, silviculture, pests, fire and other catastrophic events.

To address the impacts of climate change a concerted effort to capture baseline information and relate it to climate variables and growth is needed. This is an area that requires further direction to inform modeling and future yield projections.

Table 27 provides links to sources for information on the forest inventory program.

Table 27 Sources for information on the forest inventory program

Source	Link
Forest Inventory Strategic Plan	www.for.gov.bc.ca/hts/vri/

5 Recommendations

With any forest level analysis and planning process, opportunities for improvement are recognized throughout the process. This section provides recommendations to improve data sources, analysis approaches, or other issues that could lead to improvements in the next forest-level analysis. This section offers suggestions for special funding initiatives or needs for a full-phase approach to manage a specific issue (e.g., best management practices for dry-belt Douglas-fir stands).

New developments in silviculture practices and strategies are sometimes listed as adaptive management documents[26] prepared under the Forests for Tomorrow (FFT) program, as well as, standard operating procedures for undertaking Type 4 analyses (currently being developed).

5.1 Recommendations for Implementing Strategies

Enhanced Basic Silviculture

Despite the obvious gains, it is unlikely that enhanced basic silviculture will become a viable silviculture strategy until a better understanding of how the current appraisal system can be used to incorporate enhanced basic costs in the silviculture allowance for the stumpage calculation. We recommended that a task force be established to develop guidance of how enhanced basic silviculture can be incorporated into the silviculture allowance used in the stumpage calculation of the current appraisal system.

Rehabilitation

When licensees assess areas for harvest, they make decisions to harvest or not harvest after considering costs and the potential recoverable revenue. Currently, there is no process to track the no harvest decisions. Having such a system in place would flag areas as potential rehabilitation candidates. We recommend that a process be developed to report no harvest decisions to help identify candidates for rehabilitation.

5.2 Recommendations for Data Gaps and Information Needs

Further information and research are needed to support or refine silviculture strategies for the Quesnel TSA. Recommendations for these data and research needs are described below.

Forest Inventory

The forest inventory for this analysis was based on an amalgamation of a several separate projects completed over many years, using three distinct standards: Forest Inventory Projection (FIP), Vegetation Resource Inventory (VRI) and Landscape Vegetation Inventory (LVI). All forest-level analyses rely most heavily on the forest inventory to assign the operable landbase, determine an appropriate starting inventory and describe how existing stands develop through the short and mid-terms. Given the dynamic nature of our forests, it is unreasonable to expect this inventory to provide an accurate depiction of stands at a large scale. However, the modifications described below should improve these estimates for developing tactical plans.

Updating the forest inventory with disturbance impacts from harvesting, fire, insects and disease is clearly essential for estimating forest conditions at the beginning of a harvest forecast as well as for applying stand regeneration assumptions. Moreover, silviculture strategies typically require key forest

[26] www.for.gov.bc.ca/hcp/fia/landbase/fft/adaptive_management.htm

attributes (e.g., species composition, age and stand density) to determine stands that are eligible for various treatments. The forest update process, therefore, is a very important component of these analyses that currently requires much effort to complete; mostly due to poor or missing data that is highly complex and often disjointed. We recommend that the ministry work to strengthen the inventory update process to reflect available RESULTS data and impacts from natural disturbances (e.g., harvesting, fire, insects, disease) wherever possible.

The current standards for undertaking forest-related inventories aim to provide reasonable estimates at a management unit level (small scale). Less emphasis is placed on estimating stand boundaries and attributes appropriate at larger scales. Consequently, unique stands, such as those with repressed pine or insufficient stocking, are often overlooked. Identifying these unique stands in the forest inventory would help in developing silviculture strategies for tactical plans.

While the LVI is designed to be appropriate for strategic-level analyses, it is not an appropriate source for developing tactical plans. Besides the general uncertainty associated with data accuracy, the detailed features of this raster dataset create a significant challenge for spatially representing candidate treatment areas. Instead, we recommend using the VRI and applying adjustments to account for MPB impacts.

In this analysis, yield projections for the post-attack regenerating stands were assumed to regenerate like their original natural stand but were adjusted to remove attacked trees and to include a 20-year regeneration delay. Improving yield assumptions for understory regeneration by identifying where it exists and how it develops, would enhance how some strategies (e.g., rehabilitation) are applied.

Forest Health Impacts

It quite apparent from the results of this analysis that assumptions used to model MPB impacts have profound effects on forest dynamics – particularly assumptions for percent mortality, shelf-life and understory regeneration.

Estimates of tree mortality from fire, insects and disease are based on a combination of overview flights and ground assessments in both old and young stands. These data are essential for adjusting stand yield predictions for the current inventory and projecting future growth, as well as, estimating non-salvaged losses. Live volume estimates in MPB-impacted stands played a significant role in defining the mid-term harvest level in this analysis. Confirmation of live volume estimates on MPB-impacted stands is highly recommended.

Site Index

Site index is a key variable for projecting the growth of existing and future managed stands. The SIBEC data used in this analysis provides average site indices for specific ecosystems at the site series level (as identified using ecosystem or biophysical mapping). In comparison to a site index adjustment project[27], the SIBEC estimates show consistently higher estimates of productivity for managed stands.

Applying averages across the forest causes some loss of resolution at a stand-level, particularly on the extreme sites (for both moisture and nutrients). As a result, some candidate stands may actually be inappropriate for specific treatments. Improving site index estimates across a full spectrum of site series and verifying the ecosystem mapping would enhance future silviculture strategies.

[27] JS Thrower and Associates, 2007.

To ensure that Quesnel TSA volumes are not being overestimated by SIBEC and extreme sites are identified, we recommend ongoing monitoring of managed stand yields against predicted yields.

Past Incremental Silviculture Treatments

Ideally, silviculture strategies would incorporate past treatments to ensure that appropriate stands are selected for future treatments (e.g., multiple fertilization). As a minimum, the tactical plan should include the spatial extent of past treatments to improve how operational plans are prepared. Unfortunately, spatial and attribute data for past incremental silviculture treatments is not readily available and must be captured or derived through a combination of methods. We recommend streamlining the process for retrieving information on past incremental silviculture treatments and verifying that the data is accurate and complete.

Genetic Worth

Tree improvement and seed transfer guidelines play a significant role in the transition and long-term periods of the harvest forecast. Provided adequate seed supply is maintained, benefits will be realized as volume gains, increased survivability linked to assisted migration, and reduced forest health impacts. We recommend continued support for the tree improvement program and that genetic gains are closely monitored and applied in future forest-level analyses.

Product Profiles

In this analysis, product profiles were based on rather general assumptions. Future silviculture strategies could be improved by exploring opportunities with identified models (.e.g., SYLVER) and tracking harvested products over time. Alternatively, product profiles could be derived separately based on the species and age class distributions from the harvest forecast.

Studies on product profiles and harvested material are also valuable to inform criteria used to assign minimum harvest age, which can have a profound impact on mid-term harvest levels and future product profiles. As this has a major influence on mid-term harvest levels, we recommend further investigation of the linkages between desired product profiles, minimum merchantability and harvest ages.

Riparian Management

Riparian buffers were used as spatial netdowns to the operable landbase. Areas identified for riparian management were derived by buffering classified linear and polygon features for stream, lakes and wetlands. Since the classification was completed in 2005, it is very likely that better information is now available from various sources. While this may be a lower priority than other initiatives, updating riparian management areas would improve identification of treatable areas for silviculture strategies.

Road Network

In this analysis, landbase netdowns for existing and future roads were done aspatially. Improving estimates of average road widths (i.e., non-forest area) could improve the landbase netdown process. Moreover, a current and classified road network with associated widths could potentially improve future modelling of silviculture strategies by aggregating stands into treatment blocks or assigning roads to harvest blocks and assigning more detailed economic criteria such as haul distance.

Retention Areas

Section 4.4 discusses aspects of landscape-level biodiversity that will be negatively impacted over the next decade. Mapping the current retention areas would help to identify deficiencies and focus priorities for additional retention and silviculture treatments.

5.3 Recommendations for Modelling Approaches

Defining Treatment Areas

Among other objectives, this project aimed to provide products that will support operational implementation of the strategy. The tactical plan described above generates a map based on a combination of the model's spatial selection of stands treated and the associated forest inventory polygons. Tactical plans for future silviculture strategies could likely be streamlined by first aggregating polygons through blocking or by implementing more spatial controls within the model.

5.4 Recommendations for Related Plans and Strategies

General

Approaches for aligning with or at least considering related plans and strategies are discussed in section 4. In most cases, it is not clear how these initiatives should be integrated. A key to coordination is a consistent map base for all values. Everyone involved with these strategies needs to work with appropriate agencies to align or integrate strategies (particularly forest health, wildfire and wildlife) into a coordinated map base where queries to promote multiple objectives, or to avoid or mitigate risk, can be derived.

As emphasized in section 3.3, prescribing foresters using the tactical plan from this analysis to assist in preparing operational plans should carefully consider the related plans and strategies.

Links in section 4 to sources for information on related plans and strategies should be periodically updated for this report (or on the FFT website) to ensure that none have broken and that new initiatives are incorporated.

Access

It is well-accepted that harvest levels in the Quesnel TSA will soon be reduced to less than half the current uplift AAC of 4 million m^3/yr; lasting 3 or 4 decades. During this period, one of the challenges will be maintaining access throughout the TSA. This is disconcerting because some activities (e.g., fertilization) require well-maintained road systems for hauling the fertilizer products. Road access is also a key consideration in deciding fire-fighting priorities.

By far, the best way to maintain road systems is by supporting economic opportunities over the landbase. This provides a clear benefit to silviculture strategies that would otherwise require road maintenance to be added to treatment costs.

5.5 Recommendations for Monitoring

This plan is intended to be periodically updated using results from ongoing implementation efforts and better data as it becomes available.

A monitoring program should be developed to ensure outputs meet expectations over time. This should also examine how appropriate the input assumptions were for each strategy and recommend whether they should be revised for a future silviculture strategy.