North Coast LRMP: Government Technical Team

Final LRMP Recommendations Timber Supply Impact Analysis

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BRITISH COLUMBIA

Executive Summary

The North Coast Land and Resource Management Plan (LRMP) table has reached agreement on a range of land management issues. The LRMP government technical team interpreted aspects of the current agreement that could be assessed for both timber and ecological risks/benefits using the North Coast Landscape Model (NCLM; Morgan et al. 2002). The underlying basis of the NCLM is a spatial timber supply model (Fall 2003) that generates timber indicators and spatial time-series information of projected landscape states. Ecological indicators are also generated by the NCLM for interpretation by the environmental risk assessment team. Results from some temporal resource analysis experiments for general scenarios are presented in Morgan et al. (2003), and for some early land use scenario exploration in (Morgan et al. 2004).

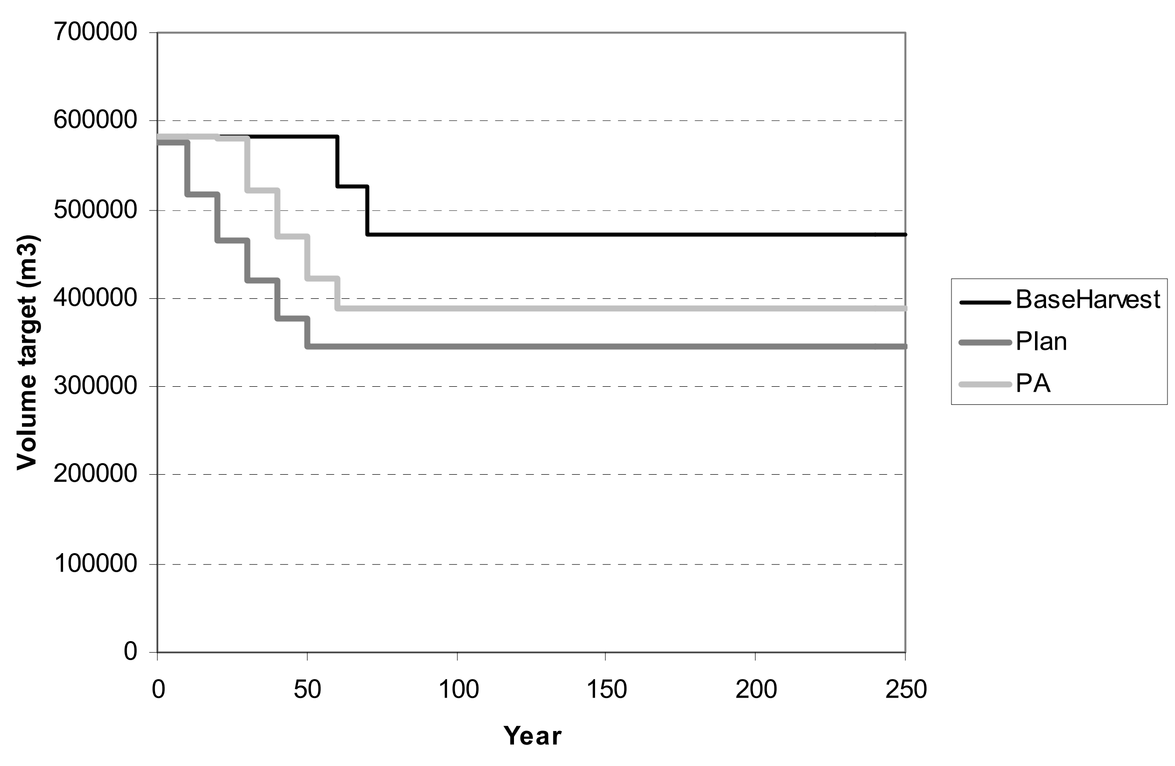
To help form a clear image of the plan impact on timber supply in the North Coast TSA, an assessment of timber supply impacts and harvest flows was undertaken on scenarios capturing the full plan, as well as sensitivities around the various plan components. Some of the concepts build on the temporal experiments made previously (Morgan et al. 2003; 2004). This document presents methods and results for these timber impact assessments.

The first set of assessments was designed to separate the effects due to differences between the NCLM spatial base case and the FSSIM analysis (BC Min. of Forests 2002) from the effects due to plan components. Differences from the FSSIM analysis include (i) spatial blocks; (ii) road access constraints and road construction; (iii) explicit adjacency; (iv) spatially-explicit riparian reserve zone THLB netdown; (v) frozen aging in most of the non-contributing landbase; and (vi) revised ages for old forest in certain site types (primarily pine, which is outside the THLB).

Key components of the plan that differ from the base case in terms of timber supply include (i) new protection areas; (ii) new visual zones and targets; (iii) forest cover requirements for ecosystem based management targets based on range of natural variability (coarse filter biodiversity); (iv) explicit aquatic and riparian THLB netdowns; and (v) explicit fine filter THLB netdowns for red and blue listed ecosystems, mountain goat winter range, and grizzly bear. We made a full harvest flow assessment for the spatial base case plus protection areas package, and used this is a reference for a range of sensitivity analyses around plan components, including the impacts due to Central Coast LRMP decisions that influence the North Coast TSA on Princess Royal Island. We then made a full harvest flow assessment of the full plan.

Overall, the current plan as captured by the above changes requires a maximum reduction of about 1% of the current harvest level in the first decade and of 27% of the current harvest long term harvest level (LTHL) (Figure 1). Hence little or no immediate reduction may be needed for one decade, but afterwards the drop to the long-term (in steps of at most 10%/decade) will have to occur over the following 50 years. With the protection areas package alone the current harvest level can be maintained for three decades, with a maximum reduction of about 17% of the current long-term harvest level (Figure 1).

Figure 1. Comparison of harvest flow from FSSIM (BaseHarvest), protection only (PA) and the full plan (Plan).



The language used to describe timber supply impact analysis is founded in the domain of timber harvesting. As a result, it is inherently biased towards describing things as they impact timber harvesting. An alternative description would describe how different resource management options benefit or impact other values such as wildlife, biodiversity, tourism, or communities. As well, the language is culturally biased and does not reflect some First Nations values or interests. Reframing the analysis description to be more culturally appropriate and to describe analysis in terms of other interests is beyond the current scope of this document. However, the intent is to inform all sectors and efforts have been made to describe analysis using more sector neutral language.

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Acknowledgements

The process used in conducting the experiments for the LRMP is known as collaborative modelling. This process requires input from a large number of people. Most of those listed below are domain experts that assisted with the development of conceptual models and model interpretation. The NC analysis team facilitates the participation of domain experts in an extended multi-disciplined team. This team has expertise in data management, spatial analysis, environmental risk assessment, decision support systems, timber Supply, inventory, operational forestry, operational biology and expertise in linking domain knowledge to LRMP decision-making. This team is co-ordinated and integrated with NC LRMP government technical team and the NC LRMP process. It evolved over several years with a great amount effort by all involved. It has a common vision of its purpose that promotes a positive professional environment that allows the collaborative modelling framework to succeed.

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Audience

This report is intended for the North Coast LRMP table, Government Technical Team, Forest Analysis Branch and Domain Experts.

1. Introduction

The North Coast Landscape model (NCLM; Morgan et al. 2002) was designed to project landscape state, forest age, composition, roads and ecological risk indicators through time under different forest management strategies. The NCLM is an extension of the "SELES Spatial Timber Supply Model" (Fall, 2002) developed with the BC Ministry of Forests, adapted to the North Coast timber supply area to address temporal landscape analysis questions relevant to the North Coast LRMP.

The analysis presented in this report reflects the NCLRMP Government Technical Team's (GTT) interpretation of the General Management Direction (GMD) in the NCLRMP planning table's recommendations. Being a technical interpretation of the GMD some planning table issues are not considered. For example, the analysis represents knowledge at a point in time, while implementation will be guided by best science and social direction, and new science based information will be incorporated into the land management as it becomes available. As well, adaptive management will be implemented that reflects social choice and would recognize that communities and economies are always in transition. In addition, there are a number of factors that could change the timber supply implications resulting from the GMD. These include, uplift in yields resulting from site index adjustment research and the area of the operable forest fluctuating due to changes in market conditions. Lastly, there is uncertainty in the nature and structure of forests due to natural disturbance, such as wind throw, wild fire, forest pathogens and insects.

Generally, many of the objectives from the LRMP can be met outside of areas designated for timber harvesting. Multiple objectives, such as wildlife habitat, riparian management and visuals can be met in the same place. The result is that objectives of the plan are not incremental; instead they are integrated and tightly spatially coupled, providing operational flexibility.

An assessment of current management ("spatial base case") was previously reported (Morgan et al. 2002), and this was used to provide a baseline for assessing alternate land-use scenarios in terms of timber supply and ecological risk. Timber supply impact is expressed as a percentage reduction of the harvest flow corresponding to the most recent FSSIM analysis (BC Min. of Forests 2002). A series of experiments was conducted to explore timber supply impacts relative to this baseline for a range of scenarios designed to help gain a better understanding of the decision space, interactions among policies, and most constraining elements (Morgan et al. 2003, 2004; Morgan 2004).

The current plan agreement includes variations of some of the components assessed in these temporal experiments, as well as some new refinements. Final plan analysis requires a more detailed timber supply assessment. We applied methods generally consistent with the approaches suggested by Fletcher (2004) to find a harvest levels that satisfy the following criteria (see Fall 2004):

(i) *Timber supply is sustainable*: The annual harvest target must be achievable in all periods of a 400-year time horizon, and long-term growing stock must be stable. If this is declining, harvests are higher than can be supported, while if it is lower, there are some harvest opportunities. We define "long-term" as 3-4 centuries, "stable growing stock" as effectively non-declining between years 200-400.

(ii) *No drops below long run*: The harvest target must be maintained at or above the long-run level. This condition may not always be desirable, in particular for management units that have conditions for which a drop in some periods below the long run may be necessary to achieve management objectives. In the North Coast TSA, however, this goal effectively captures the criteria that short and medium term management should not compromise long-term yields.

(iii) *Maximize short-term levels*: The maximum short-term harvest level, up to the current AAC, should be attempted and maintained as long as possible. This condition is designed to minimize short-term impacts, in particular if the current harvest flow must initially be reduced to meet objectives for a given land-use scenario.

(i) *Limit maximum drops between decades*: The maximum decline between subsequent 10-year planning periods is 10% of the period harvest target. This condition is designed to minimize the social and economic impacts of declining timber supply within any given decade.

2. Timber Supply Methods

Prior analysis showed that the variability between simulation runs was close to 0 (since the logging sub-model is mostly deterministic). In all simulation, we ran single-replicate simulations of 40 decades using a decadal time step.

Our goal is to provide information to domain experts (and by extension to the table and decision-makers) to gain understanding of the consequences of the final plan in its entirety and by sub-component. We need to estimate a reasonable harvest flow for each scenario (i.e. determine a timber supply impact), but due to the number of scenarios, it is not feasible to do a full analysis for each. However, more detailed harvest flow forecasting is needed for the full plan as well as the protection areas package alone.

We applied a procedure to perform a coarse timber supply impact analysis using the NCLM. We define the "direct" *timber supply impact* of a scenario as the difference in volume between the amount harvested in the base case and the amount that can be sustainably harvested when applying the scenario rules and using the same "shape" of harvest flow (i.e. a proportional change in harvest flow). The goal is not to do a full timber supply assessment, but rather to assess how the current harvest flow may need to be revised to maintain sustainability of timber resources and meet the scenario constraints. To achieve this, we designed a general experimental methodology that attempts to find the maximum harvest flow that has the same basic shape as the current harvest flow in terms of timing and magnitude of changes in timber supply over time. In other words, the experiment attempts to find the proportion p such that p is between 0 and 1 and a harvest level of p*(current harvest flow) can be sustained. The timber supply impact is then 1-p.

To support comparison with the spatial base case, we need to consider what is meant by "level growing stock". Nominally, this means growing stock with a slope of 0 over the long-term. However, on close examination, we find that the growing stock in the FSSIM base case and spatial base case declined slightly over the 3rd and 4th centuries. To account for this, we permit a maximum slope of –0.0004 (i.e. a maximum decline of 4% over the 3rd and 4th centuries, an average decline of 0.02%/year). For the purposes of the timber supply impact experiments, we use this as our threshold for "level growing stock".

An efficient binary search method was employed to quickly converge on the timber supply impact for each scenario (Fall 2004). Note that this method identifies an upper bound on timber supply impacts because it demonstrates that the modified harvest flow is sustainable using timber supply criteria. More detailed timber supply analyses could refine this and find the impacts could be reduced in some periods (but not all periods).

To make a more detailed timber supply assessment of the final plan, we used the methods outlined in (Fall 2004). This assessment is generated independent from the harvest flow from the recent FSSIM analysis (BC Min. of Forests 2002). It first involves estimating the maximum long-range sustainable yield. From this, the short term is incrementally increased, ensuring sustainability and the guidelines described in the previous section until no more increases are possible.

3. March 2004 Final Plan

The plan's GMD required some interpretation by the GTT to describe details of those components that could be assessed quantitatively by the NCLM. This section outlines the key components included in the timber supply analysis.

3.1 Changes to THLB

Note, as with all the results presented, amounts and impacts are expressed in reference to the entire North Coast TSA. The THLB used in the NCLM was based on a THLB inventory provided by the GTT. During simulation, areas are dynamically removed from the THLB to account for roads and landings. The Ministry of Forests aspatial analysis (MoF, 2002) included non-spatial THLB removals that are accounted for spatially in the NCLM. As a result, THLB area reported from the inventory and from the NCLM will differ slightly.

3.1.1 New protection areas

Protection areas amounted to 26,002 ha of THLB (out of 137,125ha) in the North Coast TSA, which is about 19.0% of the total TSA within the North Coast LRMP area. Table 1 presents some summary information by area, for areas with some current THLB (areas with less than 50ha of current THLB are grouped).

Table 1. Protection area information, presented in decreasing amount of THLB. Areas with less than 50ha of current THLB are grouped and areas with no current THLB are excluded.

Name	Total Area (ha)	Productive Forest (ha)	Current THLB (ha)
Kwinamass	33,359	16,742	4,760
JohnstonWest	31777	12,025	3,032
Khyex	47,833	11,660	2,855
Kitsault_DakRiver	8,405	3,832	1,344
Sparkling	30,857	7,594	1,280
Kitsault_IllianceRiver	9,648	5,193	1,154
QuaalRiver	18,507	5,936	1,109
KhtadaWest	15,812	3,895	840
MonktonNorth	11,035	6,846	828
Kitsault_LimeCreek	6,276	4,227	785
StagooSouth	10,874	5,311	781
Monkton	17,103	12,031	706
Pa_aatWest	4,866	2,762	554
UnionEast	6,238	3,398	518
StagooCentral	6,422	2,703	499
BishopBayHotsprings	1,625	1,312	498
Lowe_Gamble	14,375	5,715	435
Tuck_WoodworthLk	4,869	3,367	430
SparklingEast	5,315	1,521	371
Stagoo	12,455	6,005	325
Goschen_Dolphin_Spicer	7,028	3,563	272
BrownSouth	6,514	1,717	216
KingkownInlet	11,973	5,638	188
Porcher_HuntsInlet	6,224	3,175	167
Porcher_KitkatlaInlet	6,357	2,719	164
MonkeyBeach	1,072	881	138
PorcherInletWest	13,439	4,786	133
SouthKumealon	6,566	2,339	123
UnionPassage	761	605	112
Campania	16,819	4,387	111
AristazabalNorth_Karst	2,936	925	102
StagooNorth	9,807	3,616	97
AltyLake	2,260	666	88
Dundas	23,238	10,511	80
BrownNorth	9,146	4,177	76
Porcher_WelcomeHarbour	1,047	389	69
StairCreekEcoReserve	757	571	61
JohnstonEast	12,898	1,011	53
KingkownEast	572	324	50
Other (21 areas)	79,062	22,376	313

3.1.2 Aquatic and riparian management

Aquatic and riparian netdowns were applied explicitly. When included in a scenario, the 4.2% constant reduction on yields applied in the FSSIM analysis for riparian management was disabled. The total aquatic and riparian netdown was 4,200ha of THLB (3.1%) relative to the base case (Table 2). With new protection areas considered, a net of 2,565 ha is removed from the THLB (1.9%).

Table 2 Aquatic and riparian netdowns, showing total area of each type, the target area to protect, amounts in non-contributing and THLB, and net amount of THLB reserved to meet target relative to the base THLB.

Type	Area	Target	NC	THLB	THLB Reserved
estuary	1,150	1,035	1,061	89	58
floodplain	17,980	16,182	14,161	3,819	2,795
wetland	67,207	59,268	65,908	1,298	888
lakes	11,528	8,070	10,862	666	460
Total	97,864	84,554	91,992	5,872	4,200

The Plan for aquatic and riparian does not fully account for all base case aquatic and riparian objectives. As a result, a sensitivity analysis was done to ensure that, at a minimum, the base case riparian management requirements were met. This was done by identifying the difference between the 4.2% yield reductions applied in the base case and the per cent impact of the aquatic and riparian GMD in the recommendation plan on the LTHL.

Small stream buffers were not included in the final recommendation plan. The total THLB in stream buffers is 4,082 ha for fish bearing and 325 ha for non-fish bearing streams. Total non-contributing area in stream buffers is 80,574 ha total and 34,200 ha of productive forest for fish bearing, and 61,556 ha total and 27,907 ha of productive forest for non-fish bearing streams. A sensitivity analysis was conducted to include small stream buffers with a target of 70% of all 50m buffers, which netted out an additional 2,781 ha of THLB (about 2.0%, but about 1.5% net of new protection areas).

3.1.3 Fine filter wildlife management

Fine filter netdowns were also applied explicitly. When included in a scenario, the 1% constant reduction on yields applied in the FSSIM analysis for the Identified Wildlife Management Strategy (IWMS) was disabled. The total fine filter was 4,662 ha of THLB relative to the base case, with no aquatic and riparian netdowns (Table 3). With new protection areas considered, a net of 3,631 ha is removed from the THLB. Netdowns were done by type in the order shown.

When aquatic and riparian and fine filter are both applied, aquatic and riparian netdowns were applied first (and so the values reported in section 3.1.2 applied to any case with aquatic and riparian netdowns). In this case, the fine filter netdowns are reduced (Table 3) to 3,886 ha gross and 3,226 ha net.

Table 3 Fine filter netdowns (with and without aquatic and riparian netdowns), showing total area of each type, the target area to protect, amounts in non-contributing and THLB, and net amount of THLB reserved to meet target relative to the base THLB.

Type	Area	Target	NC	THLB	THLB Reserved with aquatic and riparian	THLB Reserved no aquatic and riparian
Red listed ecosystems	760	760	510	250	121	250
Blue listed ecosystems	592	414	490	102	12	28
Goat class 1	18,059	16,253	16,714	1,345	452	452
Goat class 2	44,439	39,995	42,129	2,310	985	993
Grizzly class 1	22,142	22,142	19,047	3,095	2,274	2,892
Grizzly class 2	130,636	65,318	115,596	15,041	41	47
Total	216,628	144,883	194,485	22,144	3,886	4,662

3.1.4 Central Coast decisions on Princess Royal Island

Princess Royal Island overlaps with the Central Coast LRMP and North Coast TSA (but is outside the North Coast LRMP). Recent agreements on the Central Coast LRMP propose protection for a significant portion of Princess Royal Island. The base FSSIM analysis included netdowns for an area surrounding Laredo Inlet (Spirit Bear) based on an earlier Central Coast agreement. We performed several sensitivity analyses to assess the impacts of the new protection areas on Princess Royal Island. These new areas amount to 5,114ha of THLB (about 3.7%).

3.2 Forest Cover rules

3.2.1 Forest cover requirements for ecosystem base management targets

One component of the ecosystem-based management (EBM) approach proposed in the plan is a set of forest cover targets for coarse filter biodiversity to maintain levels of old forest based on an assessment of historical rates of natural disturbance. By applying the range of natural variability (RONV) concept, different site types have specific ages at which “old” conditions are assumed to be met (Table 4), as well as different percentages of the area that would be expected to be old over time (Holt and Sutherland 2003). The landbase was partitioned into “higher risk” and “lower risk” site types. The site types, a combination of biogeoclimatic ecosystem classification subzone variant and analysis unit, were ranked by area in ascending order. The first 60% of the rank, corresponding to site types with the smallest areas, were assigned as higher risk due to their rarity. The last 40% of the rank, the site types with the largest areas, were assigned a lower risk due to their commonality. The lower risk site types have minimum old forest targets based on meeting 30% of the RONV levels (Table 4), while the higher risk site types have targets based on meeting 70% of the RONV levels (Table 5). In addition to meeting targets within each site type, targets were also set by site type within each landscape unit. The table also proposed additionally meeting reduced targets by watershed, but we found this to be non-constraining in an earlier assessment (and since it slowed model run time substantially, we omitted this set of rules in the final analysis).

Table 4. EBM coarse filter biodiversity targets for lower risk sites (30% of range of natural variability estimates), over entire plan area (i.e. within entire site type) and by LU (20% of RONV).

		Min. Percentage		Forest affected (ha)	
Site Type	**Old Age**	**Plan**	**LU**	**THLB**	**Productive**
CedarHigh	260	49	35	0	0
CedarMed	150	27.3	18.2	13,764	26,191
CedarLow	130	27	18	40,744	591,215
HemBalHigh	260	21	14	5,268	6,679
HemBalMed	150	23.7	15.8	29,153	50,483
HemBalLow	150	21	14	33,251	201,636
SpruceHigh	260	21	14	1,230	2,800
SpruceMed	260	23.7	15.8	3,831	7,216
SpruceLow	260	23.4	15.6	2,226	7,465
Cottonwood	260	0	0	0	0
Total				129,470	893,713

Table 5. EBM coarse filter biodiversity targets for higher risk sites (70% of range of natural variability estimates), over entire plan area (i.e. within entire site type) and by LU (50% of RONV).

		Min. Percentage		Forest affected (ha)	
Site Type	**Old Age**	**Plan**	**LU**	**THLB**	**Productive**
CedarHigh	260	49	35	1,355	1,748
CedarMed	150	63.7	45.5	624	1,521
CedarLow	130	63	45	1,170	12,896
HemBalHigh	260	49	35	1,036	2,646
HemBalMed	150	55.3	39.5	2,081	4,233
HemBalLow	150	49	35	137	533
SpruceHigh	260	49	35	551	1,400
SpruceMed	260	55.3	39.5	232	1,216
SpruceLow	260	54.6	39	170	2,284
Cottonwood	260	0	0	302	1,700
Total				7,657	30,180

3.2.2 Modified visual objective zones.

Changes were made to both the mapping of visual zones as well as forest cover targets, based on new scenic area mapping and table discussions (Table 6 vs. Table 7).

Table 6 New forest cover rules for visual objectives

VQO	Forest Cover rule	Forest affected (ha)	
		THLB	Productive
Preservation	Max. 1% of forest shorter than 7 metres	0	0
Retention	Max. 4% of forest shorter than 7 m	14,896	75,251
Partial retention	Max. 10% of forest shorter than 7 m	15,252	93,469
Modification	Max. 16% of forest shorter than 7 m	16,109	107,625
IRM	Max. 33% of THLB shorter than 3 m	89,367	637,046

Table 7 Previous forest cover rules for visual objectives (from FSSIM analysis and spatial base case)

VQO	Forest Cover rule	Forest affected (ha)	
		THLB	Productive
Preservation	Max. 1% of forest shorter than 7 metres	844	3,984
Retention	Max. 5% of forest shorter than 7 m	9,230	52,719
Partial retention	Max. 15% of forest shorter than 7 m	13,570	74,793
Modification	Max. 25% of forest shorter than 4 m	20,414	94,295
IRM	Max. 33% of THLB shorter than 3 m	92,988	697,955

3.4 Scenarios

To explore the final plan package, we designed a set of analyses to assess each key component separately, and then combined into a full package.

3.4.1 Spatial base case

To develop the spatial base case, we started from the FSSIM analysis (Ministry of Forests, 2002). The first step was to set up an aspatial base case for the NCLM that matches the assumptions and behaviours of the FSSIM analysis. That is, no spatial rules were applied, so no spatial constraints or patterns can influence the results. No new harvest flows were produced, but rather a comparison was made between the FSSIM and NCLM results for growing stock, areas/volumes harvested, mean volume/ha harvested and mean age/ha harvested. The two results sets matched almost precisely (see Morgan et al. 2002 for results and more detailed description).

The NCLM was designed to allow spatially explicit analysis of patterns and landscape trends. Based on discussions with Ministry of Forests and North Coast Forest Licensees the "spatial base case" incorporated the following changes to the base set of assumptions and behaviours:

(a) Access constraints: The North Coast has been stratified into conventional and helicopter-accessible stands. The helicopter analysis units (defined in the LRMP timber supply analysis based on operability) contribute to 18.7% of the THLB, and are harvested strictly by helicopter, while some of the conventional analysis units are also harvested by helicopter at times. Using this information, we have defined a heli-access zone as the area in the heli-analysis units plus any areas further than 1km from an existing or proposed mapped road. This heli-access zone contributes to 45.3% of the THLB, more than double the area of the heli-analysis units alone. This is captured in the North Coast Landscape Model (NCLM) using a "heli-access zone" layer. To capture access, we set an upper limit of 2km from access (road or the ocean) as the maximum distance a block can be placed for ground-based access. In addition, preference for block selection declines starting at 200m (relative to other factors). That is, stands within 200m of access have the same preference and this declines linearly to 0 at 2,000m. Spur roads are constructed to blocks and area accessible is updated dynamically during processing. In the heli-access zone we apply a maximum distance of 5,000m from access, and no roads are created as a result of treatment. Access restrictions have the effect of influencing the order in which stands are harvested, and so may have timber supply consequences.

(b) Block size: The logging model is capable of applying a uniform block size distribution (e.g. 5-20ha) or a target block size distribution such as is specified in the Biodiversity Guidebook (Anon. 1995). Based on analysis of clear-cut block sizes in the North Coast (Eng 2002), we model a target block size of 5-20ha (selected from a uniform distribution, giving a mean of 12.5ha). Using a spatial block size has the effect of modifying the order in which cells are harvested (e.g. the model cannot cut old single-cell blocks across the district).

(c) Explicit adjacency (3m greenup): Greenup adjacency was approximated in FSSIM using implicit forest cover rules. For spatial adjacency, we define the spatial distance as 100m with a greenup height of 3m. That is, no harvest can take place next within 100m of areas under 3m in height.

(d) Spatially-explicit netdown of the riparian reserve zone: In the base LRMP analysis, the Riparian Reserve Zone (RRZ) was netted out of the landbase contributing to timber supply by applying a 7.49% reduction in area across the landbase. This was modelled as such due to the lack of data for stream classification, and as a result, means that area was netted out in locations that may have not been in RRZs. In the spatial model, we can be more specific about where the reductions will actually be made. Since riparian reserves will in practice be near waterways, we estimated stream locations using a hydrological flow model (Fall and Morgan, 2000) that computes catchment size from an elevation grid. We then replaced the 7.49% average netdown for RRZs with an explicit removal of 100% of the THLB in cells with estimated streams within them (with catchments > $1km^2$) and slopes < 20%.

(e) Frozen NC: the ages in the non-contributing were held constant (to offset the fact that we don't model natural disturbance) everywhere except in the Ohl, Anyox and Stagoo landscape units (since there is substantial regeneration after fume-kill from an early mining operation in the area).

(f) Age update: It was identified that inventory ages for certain site types were underestimated (A. Banner pers. comm.), and so a decision was made to increase the ages in some specific cases to age class 9 (250 years). Stands of age class 7 (120-140 years) in the following analysis units were updated: Cedar Low (including marginally operable and heli low) and Pine. Stands of age class 8 (140-250 years) in the following analysis units were updated: Cedar Medium (including heli medium), Cedar Low (including marginally operable and heli low), HemBal Medium (including marginally operable), HemBal Low (including marginally operable), and Pine. The update from age class 7 to 9 affected 7,814 ha of forest (4,174 ha productive forest; 123 ha of THLB). The update from age class 8 to 9 affected 12,792 ha of forest (7,751 ha of productive forest; 654 ha of THLB).

A comparison was made with the spatial base case to assess these components individually and in combination.

3.4.2 Timber impacts relative to spatial base case

A number of scenarios were designed to assess sensitivity of changes relative to the base case. In these cases, the highest harvest flow as a proportional change to the base harvest flow was found as described in section 2. The following scenarios were assessed:

- Protection areas package: same as spatial base case, but with new protection areas.
- Protection areas package, but applying aspatial rules: to help separate impact of spatial effects from plan proposals.
- Protection areas package, with aspatial rules except still applying access constraints: to illustrate contributing of access constraints on modifying harvest ordering and resulting impacts on timber supply.
- New visuals: application of spatial base case plus new visuals (but not new protection areas).
- Protection areas package, plus new visuals
- Full plan: protection areas package, new visuals, ecosystem base management rules, aquatic and riparian netdowns and fine filter netdowns.
- Full plan, but applying aspatial rules.

3.4.3 New harvest flow for protection areas package (PA)

To assess a new harvest flow, first a sustainable long-term harvest level (LTHL) was found, and then the short-term harvest flow was increased according to the methods outlined in section 2 to determine a new flow. The only influence the current harvest flow has on obtaining a new flow is to set the harvest level for the starting period.

3.4.4 Timber impacts relative to protection areas (PA) scenario

A wide range of sensitivity analyses were run to assess the impacts of plan components, or combinations of components, using the following scenarios. Timber impacts for these assessments are expressed in terms of a reduction over the harvest flow for the protection areas package. All of the scenarios include the new protection areas package.

- Central Coast protection areas: additional effect of including Central Coast protection areas.
- New visuals.
- EBM targets.
- Aquatic and riparian netdowns.
- Fine filter netdowns.
- Combinations of visuals, EBM, aquatic and riparian, fine filter: almost a complete factorial experiment of combinations of 2 or more of the plan components.
- Full plan (visuals + EBM + aquatic and riparian + fine filter).
- Full plan plus Central Coast protection areas.

3.4.5 New harvest flow for full plan (Plan)

As with the protection areas package, first a long-term harvest level was found, and then a complete new harvest flow that attempts to maintain the short term as long as possible, and then step down to the long-term in a controlled manner.

3.4.6 Timber impacts relative to full plan (Plan) scenario

Some final sensitivity assessments were made to compare the effect of non-spatial rules, of including the Central Coast protection areas, and to compare the protection areas package (PA) scenario with respect to the harvest flow for the entire plan.

4. Results

All results include unsalvaged losses (USLs) of 10,084 m^3/year along with harvest levels (including results reported from the FSSIM analysis) because new USLs need to be estimated for each scenario based on THLB netdowns and assumptions regarding implementation of EBM rules in response to natural disturbance. Leaving USLs in results is equivalent to assuming that these losses decline in proportion to timber impacts. An alternative assumption may be that losses change in proportion to changes in THLB size. Also, due to uncertainty in data and methods, we have chosen to maintain accuracy at the expense of precision by rounding timber impacts to the nearest percent point.

4.1 Spatial base case

See Morgan et al. 2003 for results and more details. The following is a brief summary.

(a) Access constraints: Applying an access constraint had a modest effect on the growing stock and timber supply indicators. There is currently approximately 33,204ha (24%) of THLB that is currently further than 2km from access (5km for heli-access). This becomes available gradually as road development occurs, and so changes the order of harvesting from that possible when access constraints are omitted. This reduced the mean age harvested in the first period relative to the FSSIM analysis (Ministry of Forests 2002) by almost 40 years different in the first decade, leading to lower volumes/ha (a mean of approx. 2% less than FSSIM). Using a volume-based harvest target, this leads larger areas harvested (an increased mean of almost 16ha/year), slightly lower total growing stock (mean of 1.5% less than FSSIM) and merchantable growing stock (mean of 4.8% less than FSSIM), and an advancement in the trend of merchantable growing stock

(b) Block size: Using spatial blocks had a moderate impact on timber supply. As with access, the primary cause is that the mean age harvested is lower than in the FSSIM version in the early decades, since isolated, small patches of old forest are harvested more gradually over time than when using single-cell blocks. This decrease in age causes a decrease in the mean volume/ha harvested.

(c) Spatial adjacency: Contrary to most management units where we have assessed the effect of explicit adjacency, in the NCLM it has little effect on timber supply indicators. This is partly due to the spatial pattern of the THLB, which has a very high edge-area ratio, resulting in a much lower impact than in management units with more contiguous THLB. It is also related to the relatively productive forest in the district, where the 3m greenup height is reached at fairly young ages (between 10 and 20 years for most analysis units). Volume harvested and growing stock do not change much when this feature is added. If we look at the amount of area constrained by adjacency we see why. Initially less than 2,500ha is constrained and this declines and remains below 1,500ha for the rest of the horizon. Note that the available forest declines from over 100,000ha to an average of about 33,000ha over time (i.e. adjacency locks up less than 5% of the THLB that might otherwise be available).

(d) The THLB layer with an explicit riparian reserve zone removal was 236 ha smaller than the THLB derived using the spatial averaging of RRZ netdown as in the FSSIM analysis. A total of 11,441ha of THLB were shifted as a result of this procedure. To assess the likely impact, we computed the area of each AU overall in two THLB layers. Using the spatially-explicit RRZ left most of the AU amounts the same. There was a shift of about 1,978ha between AU classes, mainly due to increases to Cedar and HemBal medium thinned/low AUs and decreases to Spruce, Cottonwood and HemBal high/med. In terms of percentage, the largest increases are in Cedar High (3.8%) and HemBal medium thinned (3.1%), while the largest decreases are in Spruce medium (-10.4%), Spruce high (-8.0%), Cottonwood (-7.8%) and Spruce low (-3.3%). In terms of area, the largest increases are in Cedar low (1,034ha) and HemBal low (639ha), and the largest decreases are in Spruce medium (-877ha), HemBal medium (-473ha), Spruce high (-339ha) and Spruce low (-322ha). The general trend is a shift to more Cedar and less Spruce and Cottonwood in the THLB.

(e) Combined effects (Spatial Base Case): Combining the aspatial base case scenario with access constraints, spatial block sizes, spatial adjacency, and spatially-explicit riparian reserve zone integrates the effects of the various spatial components. The mean age harvested in the first periods is less than the FSSIM analysis (by 37-years in first decade), leading to lower volumes/ha (a mean of approx. 5.1% less than FSSIM). With an area-based harvest target, the initial lower stand ages leads to lower volumes achieved rather than an increase in area harvested (Morgan et al. 2003). The difference results in a reduction of overall harvest by approximately 18,800m^3/year on average (4.0%). The long-term difference in growing stock from the FSSIM analysis is about 0.4% less for total growing stock, and 2.2% less for merchantable growing stock.

Our examination of the effect of road access constraints and block size showed that timber supply seems to be moderately sensitive to these spatial features. Each spatial feature individually resulted in an increase in area harvested and a modest decline in growing stock as a consequence of relatively younger, lower volume stands being harvested (Morgan et al. 2003). Combining these options resulted in a broadly additive effect in the spatial base case.

4.2 Timber impacts relative to base case

Table 8 shows the reduction in THLB and timber supply impact of the component sensitivity analysis, with respect to the base harvest flow (Ministry of Forests 2002). The protected areas result in a reduction of about 17% of the overall harvest level (somewhat less than the 19% reduction in THLB due to differences in productivity between protection area are remaining THLB) and the full plan results in a reduction of about 27%. Applying non-spatial results leads to less than a 1% difference. Visuals have a somewhat higher impact with the protection areas than in the base case because visually sensitive areas are disproportionately outside the protection areas.

Table 8. Timber supply impact sensitivity analysis results for scenarios compared against base case.

Scenario	Percent THLB Reduction	Timber supply impact
Protection areas package (PA)	19.0%	17%
PA with aspatial rules	19.0%	17%
PA with aspatial rules, except for access	19.0%	17%
PA + new visuals	19.0%	19%
New visuals	0%	1%
PA + new visuals + EBM	19.0%	27%
PA + new visuals + EBM + Aquatic and riparian	20.8%	25%
Full Plan (protection areas, new visuals, EBM, aquatic and riparian, fine filter)	23.2%	27%
Full Plan with aspatial rules	23.2%	26%

4.3 New harvest flow for protection areas package (PA)

A long-term harvest level of 387,290 m^3/year was found to be sustainable over the long run (18% reduction over base case long-term). The new harvest flow effectively supports 3 decades at the current initial harvest flow (with a minor drop in the 3rd decade), before making drops of 10% in the 4th – 6th decades and one final drop of 7.4% in the 7th decade to the LTHL (Table 9).

Table 9. Comparison of base harvest flow, constant reduction harvest flow (17% reduction over base) and new harvest flow for protection areas package

Decade	*Base Harvest Flow	PA 17% Reduction		PA Flow		
		*Flow	Difference	*Flow	Difference	% Difference
10	583,708	484,523	99,185	583,708	0	0%
20	583,708	484,523	99,185	583,708	0	0%
30	583,708	484,523	99,185	580,060	3,648	1%
40	583,708	484,523	99,185	522,054	61,654	11%
50	583,708	484,523	99,185	469,849	113,860	20%
60	583,708	484,523	99,185	423,134	160,574	28%
70	526,346	436,908	89,438	387,290	139,056	26%
Thereafter	472,084	391,867	80,217.	387,290	84,794	18%

* Non recoverable loss (10,084m^3 in the base case) has not been removed from volumes reported.

4.4 Timber impacts relative to protection areas (PA) harvest flow

Table 10 shows the reduction in THLB and timber supply impact of the component sensitivity analysis, with respect to the protection area package flow presented above.

Table 10. Timber supply impact sensitivity analysis results for scenarios relative to protection areas package harvest flow (PA). All have the new protection areas plus the identified additional components.

Scenario	Percent THLB Reduction	Timber supply impact
Central Coast protection	22.7%	4%
New visuals	19.0%	3%
EBM	19.0%	10%

Aquatic and riparian	20.8%	-1%
Fine filter	21.3%	3%
New visuals + Aquatic and riparian	20.8%	1%
New visuals + Fine filter	21.3%	6%
New visuals + EBM	19.0%	11%
Aquatic and riparian + Fine filter	23.2%	1%
EBM + Aquatic and riparian	20.8%	10%
EBM + Fine filter	21.3%	12%
New visuals + Aquatic and riparian + FF	23.2%	4%
New visuals + EBM + Aquatic and riparian	20.8%	9%
New visuals + EBM + Fine filter	21.3%	13%
EBM + Aquatic and riparian + Fine filter	23.2%	11%
Full Plan (protection areas, new visuals, EBM, aquatic and riparian, fine filter)	23.2%	12%
Full Plan + Central Coast protection	26.9%	17%

A sensitivity conducted to assess the influence of the aquatic and riparian netdown (3.1% of THLB) relative to the spatial base case, independent from the effect of yield reductions, showed that the netdown resulted in an impact of 3.9%. Hence there is a 0.3% less than the 4.2% yield reduction applied in the FSSIM analysis. This difference is partly because stream buffers were not included in the netdown. Other analysis results showed that yield reductions in this analysis have a 1:1 impact on timber supply. Hence, if the yield reductions for scenarios with explicit aquatic and riparian were increased by 0.3% so that this component has the same impact in the base case as the FSSIM yield reduction, then the timber impacts would increase by the same amount.

This 0.3% difference between the FSSIM yield reduction and the spatially explicit netdown does not fully explain why the “Aquatic and riparian plus protection areas” scenario in the above table has an increase of 1% over the protection area scenario. First, since yield reductions are applied to all volumes harvested, we expect the impact to be constant. That is, the yield reductions included in the PA scenario has an impact of 4.2% on the resulting flow. However, there is substantial overlap between the protection areas and the aquatic and riparian netdowns. The netdown alone is about 3.1% of the base THLB, and about 1.9% net of protection areas. That is, the netdown decreases by about 39%, which is much higher than expected relative to a reduction of 19% of base THLB due to protection areas. Hence the 3.9% impact of the aquatic and riparian netdown transfers less than proportionally (with an expected impact closer to 3.0% relative to the PA scenario, not 3.9%).

4.5 New harvest flow for full plan (Plan)

A long-term harvest level of 345,765 m^3/year was found to be sustainable over the long run (26.8% reduction over base case long-term). The new harvest flow effectively supports 1 decades at the current initial harvest flow (with a minor initial drop of about 1%), before making 4 drops of 10% in the 2nd – 5th decades and one final drop of 8.5% in the 6th decade to the LTHL (Table 11). While the constant reduction scenario leads to a 27% loss of timber supply across all periods, the detailed flow results in a gradually increasing loss from 1% in the first period to 41% in the 6th, which then declines again to the LTHL impact level of 27%.

Table 11. Comparison of base harvest flow, constant reduction harvest flow (26.8% reduction over base) and new harvest flow for full plan.

Decade	*Base Harvest Flow	Plan 26.8% Reduction *Flow	Difference	Plan Flow *Flow	Difference	% Difference
10	583,708	427,520	156,188	575,500	8,208	1%
20	583,708	427,520	156,188	517,950	65,758	11%
30	583,708	427,520	156,188	466,155	117,553	20%
40	583,708	427,520	156,188	419,539	164,169	28%
50	583,708	427,520	156,188	377,739	205,969	35%
60	583,708	427,520	156,188	345,765	237,944	41%
70	526,346	385,507	140,839	345,765	180,582	34%
Thereafter	472,084	345,765	126,320	345,765	126,320	27%

* Non recoverable loss (10,084m^3 in the base case) has not been removed from volumes reported.

4.6 Timber impacts relative to full plan (Plan) harvest flow

Table 12 shows the reduction in THLB and timber supply impact of the sensitivity analysis with respect to the plan flow presented in the previous section. As before, there is little or no effect of applying spatial rules (to verify this, we also created a harvest flow for the full plan with aspatial rules, which coincided with the flow in Table 11).

Table 12. Timber supply impact sensitivity analysis results for scenarios relative to full plan harvest flow.

Scenario	Percent THLB Reduction	Timber supply impact
Full Plan with aspatial rules	23.2%	0%
Full Plan + Central Coast protection	26.9%	6%
Protection areas package (PA)	19.0%	-13%
Full Plan + Stream buffers	24.6%	1%

4.7 Comparison Final Plan, PA and FSSIM Results

Figure 2 compares the harvest flows from the FSSIM analysis, the coarse timber supply impact analysis (PA17 for the protection areas package with a 17% impact, and Plan27 for the full plan with a 27% impact), and the detailed harvest flow analysis (PA and Plan; Table 9 and Table 11).

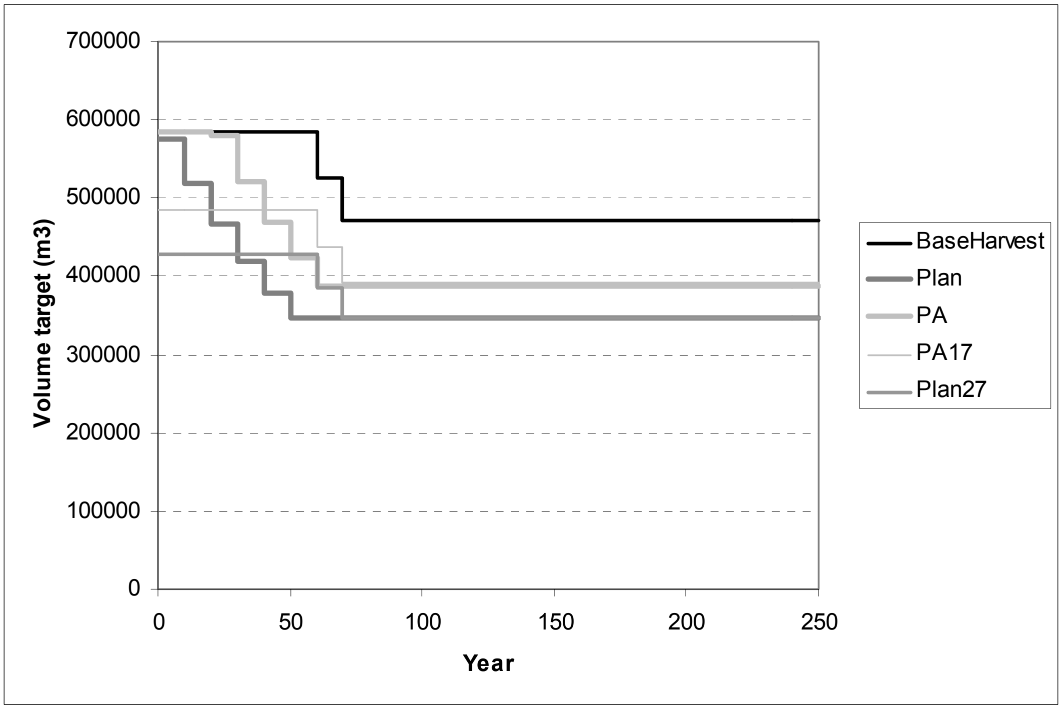

Figure 2. Comparison of harvest flow from FSSIM, 17% timber supply impact in (PA), 26.8% impact (Plan) and detailed flow assessment (PA and Plan).

The following graphs compare timber supply indicators for the FSSIM (Base harvest), full plan, and protection areas package scenarios. The total THLB growing stock (Figure 3) and merchantable growing stock (Figure 4) show how the protection areas reduce the initial growing stock in the THLB. The plan results in lower growing stock over all periods (due to a smaller THLB), but the difference from the base case is less over the mid and long-term than the short term, due to the EBM constraints resulting in some stands remaining older in the THLB. The constant reduction scenarios maintain slightly higher growing stock over the mid term than the corresponding detailed harvest flow scenarios because of higher short-term harvest levels in the latter.

The plan results in lower areas harvested except in the first period and at year 150 due to relatively lower volumes/ha in those periods (Figure 5, Figure 6). Age of stands harvested is slightly lower in the plan, but follows a similar trend to the base harvest flow, dropping from fairly old stands (~350 years) to ~150 year old stands between years 120-150 (Figure 7). This change corresponds to a shift from harvesting in predominately unmanaged stands to predominately managed stands (Figure 8).

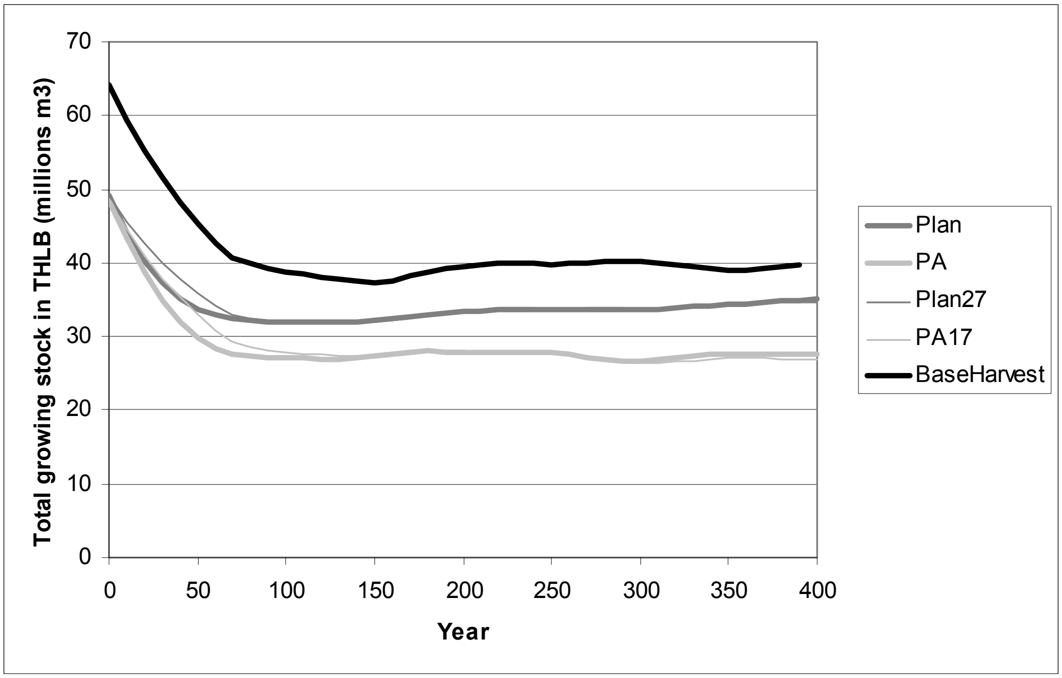

Figure 3. Total growing stock in millions of m^3.

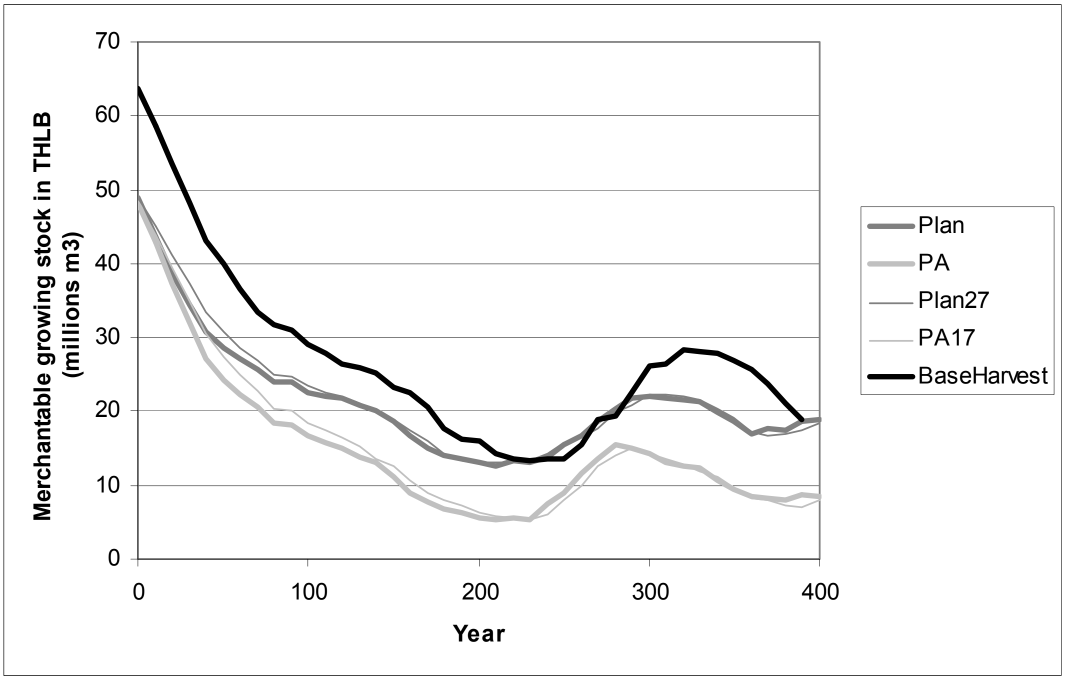

Figure 4. Merchantable growing stock in millions of m^3.

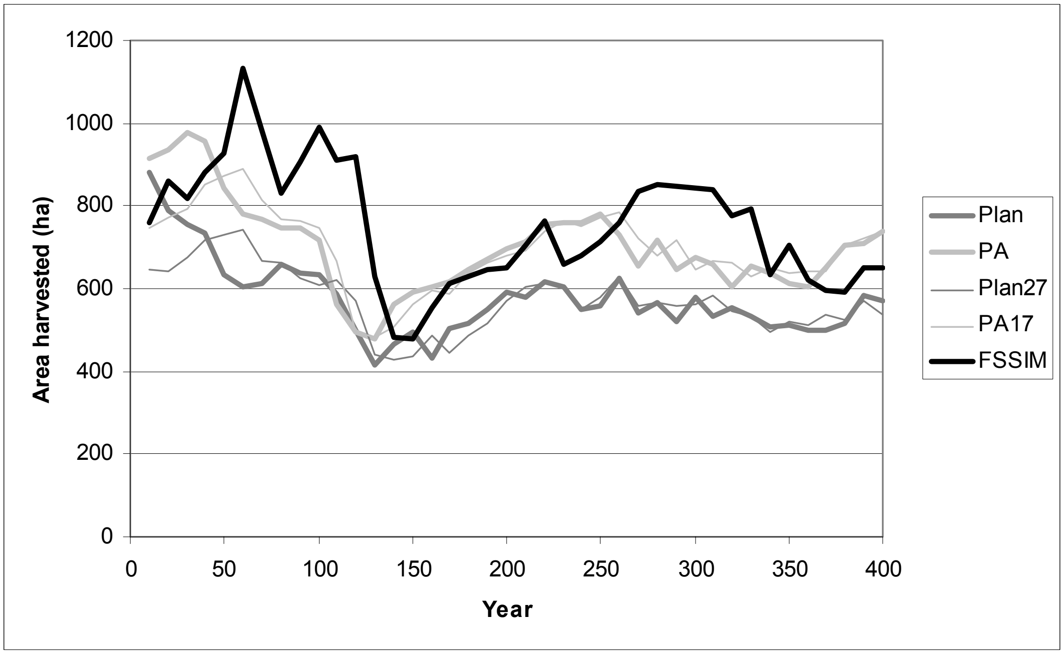

Figure 5. Area harvested in hectares

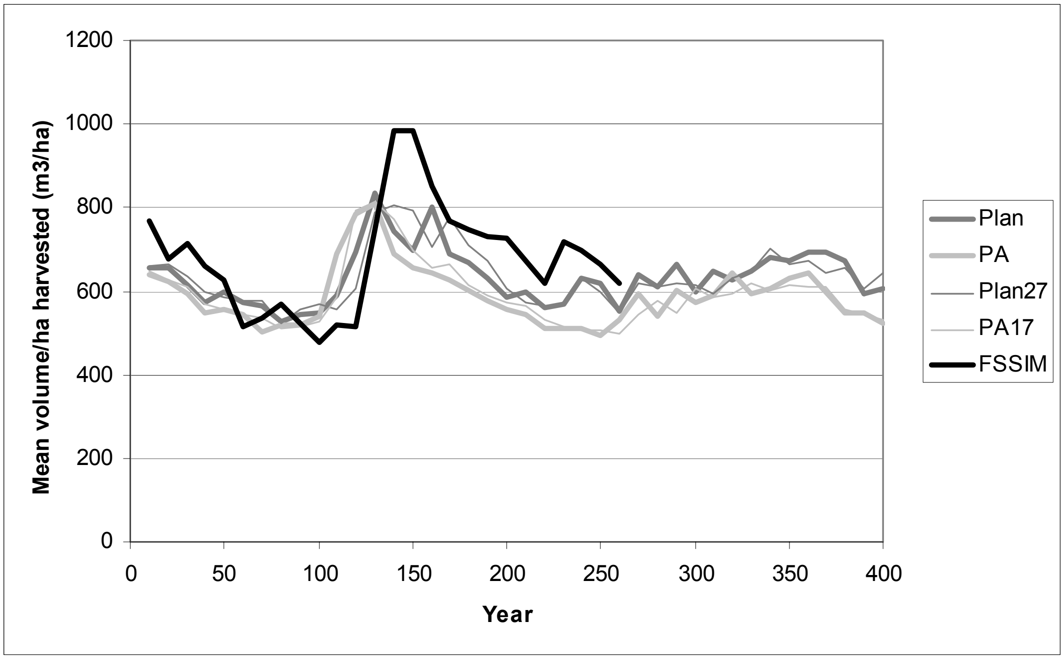

Figure 6. Mean volume per hectare harvested in m^3/ha.

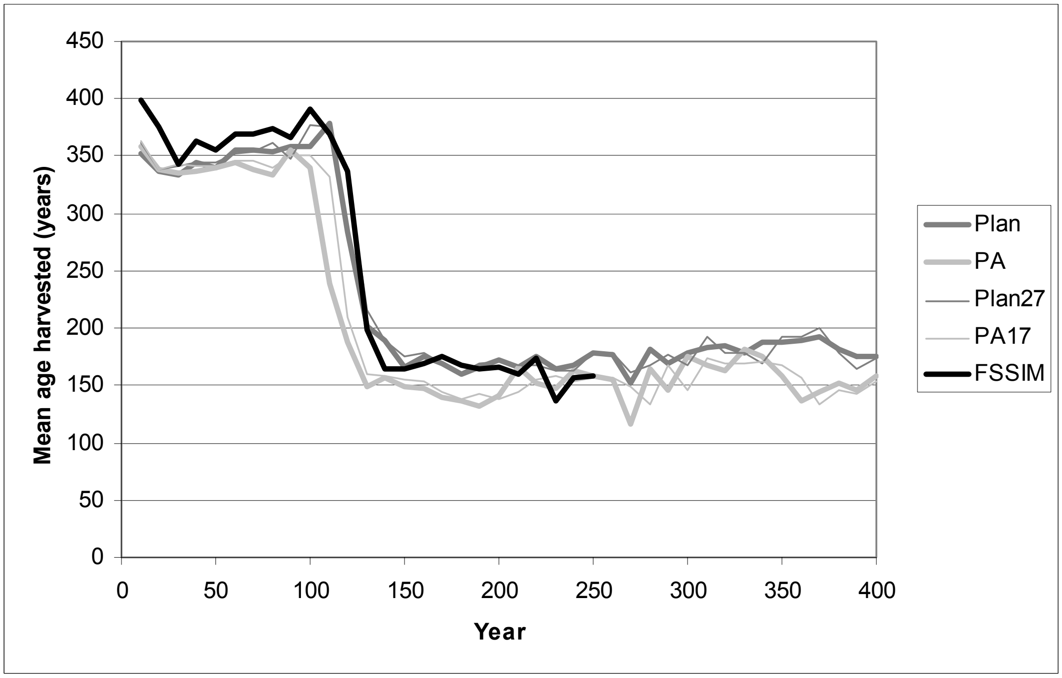

Figure 7. Mean age harvested in years/ha.

Figure 8. Proportion of harvest in unmanaged (Old) and managed stands over time in the final plan harvest flow.

5. Discussion

The overall impact for the plan is estimated to be approximately 27% in the long run (Table 11). Accounting for non-recoverable losses proportional to reduction in THLB in the plan flow doesn't affect this estimate, nor does inclusion of an increased yield reductions (of 0.3%) to increase the effect of aquatic and riparian to be equal to the impact in the base case. The current harvest level can effectively be maintained (1% drop) for 10 years before a series of 10% steps is required down to the long term level. Since maintaining the current harvest level requires the steps down to the long-term level to initiate sooner than in the base case, the impact over the FSSIM harvest flow is larger than 27% in the mid-term (i.e. the impact can be less in decades 1-3, more for decades 4-7 and 27% in the long term; Table 11). Spatial harvesting effects (e.g. block size, access, adjacency) don't affect these results.

The plan impacts from individual components can be roughly separated by examining the impacts of incrementally adding components from the base case to the full plan in the following order (Table 8): protection areas (+17%); new visuals (+2%); EBM rules for late seral requirements (+8%); aquatic and riparian, but not streams (-2%); fine filter (+2%). Note that due to overlaps and interactions among components, one must interpret individual contributions with caution.

In the plan scenario, growing stock and mean age harvested rose slightly over the long run (Figure 3 and Figure 7), indicating that the primary constraint on harvest flow is not long-term growing stock, but mid-term availability. As the growing stock for the protection areas package is fairly flat (Figure 3), this indicates that the cause is due to the other plan components (EBM, visuals, aquatic and riparian, and fine filter). The constraints limiting harvest showed that there is a harvest availability bottleneck around years 190-240 in many scenarios (data not shown), just after the shift to second growth harvesting (Figure 8). At this point, harvesting must rely entirely on second growth, and the system is quite sensitive to anything that reduces second growth availability at this time. In particular, differences in harvest order can cause stands to be harvested with older/younger min. harvest ages or higher/lower regeneration productivity. These differences can ameliorate or exacerbate this bottleneck, and may result in some minor counter-intuitive results (e.g. access constraints in the aspatial protection areas package scenario actually had a lower timber impact relative to no access constraints, but this difference is masked by rounding in Table 8). This is one reason why impact levels have been rounded to the nearest percentage. It also suggests that further examination of harvest order rules (i.e. other than relative oldest-first) during plan implementation may help refine results. In particular, careful planning of harvest order to meet targets in the time period associated with the bottleneck may help reduce long-term impacts of the plan. However, as the growing stock for the plan scenarios is only rising gradually (Figure 3), only minor reducing in impact can be expected.

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