Golden TSA
Silviculture Strategy (Type 2)

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Summary

This report documents a forest-level modeling study that examines the implications of silviculture regime options proposed by the Columbia Forest District for implementation on the Golden TSA. The objective of the project is to provide strategic direction to the district silviculture staff in the design of their silviculture program.

Benefits are evaluated against the TSR base case

A silvicultural planning model was developed using the Woodstock (Remsoft, 1997) modeling language that is consistent with the current TSR model and base case for the TSA, and also fully represents the additional forest-level objectives and silvicultural activities required for silvicultural planning. The landbase and management parameters, described in *AAC Rationale for the Golden TSA* (January 2000), are the basis of the silviculture planning model implemented for this study. Using the TSR base case as the point of departure ensures that benefits from incremental silviculture are modeled in a management context consistent with the Chief Forester's assumptions when he set the AAC.

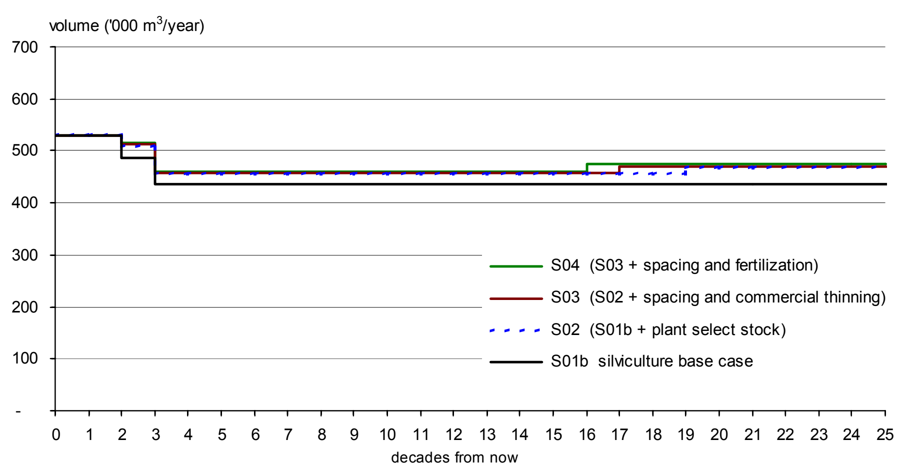
Quantity and quality objectives are evaluated

Scenarios were evaluated for their impacts on three forest-level management objectives: maximizing total timber supply, maximizing the supply of large dimension logs, and maximizing the supply of solid/clear wood.

28% increase in harvest in long term

Figure S-1 shows the timber supply impact of intensifying management. Planting select stock increases harvest levels by about 4.5%, starting in decade 3. This increase occurs because planting select stock increases the volumes available in later decades, releasing stands for harvest in decade 3 that under the silviculture base case (S01b) were being held to provide harvest volume later on. An additional 2.7% increment occurs beginning in period 17, when future managed stands planted with select stock become available for harvesting.

Figure S-1 Impact of planting select stock, commercial thinning, spacing and fertilization on the forecast harvest.

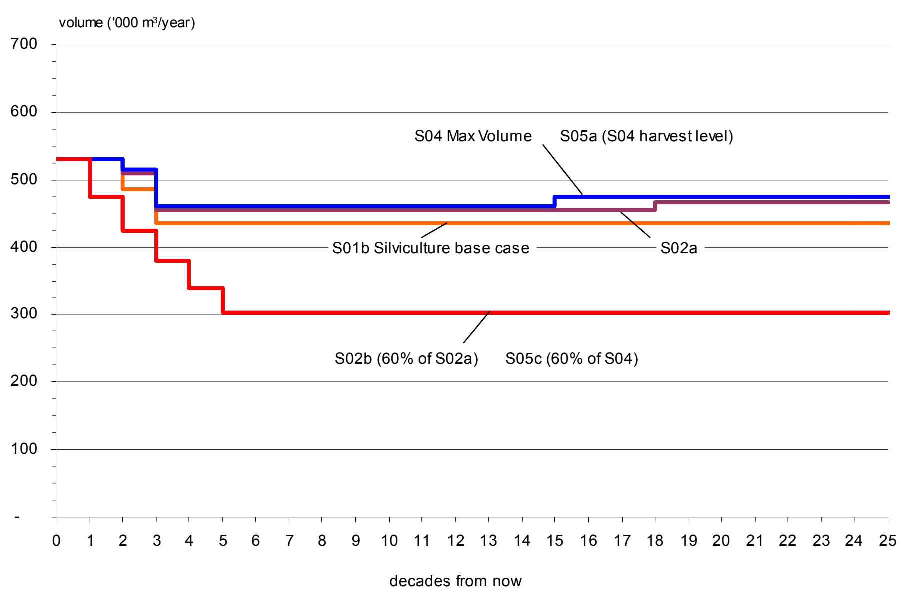


Commercial thinning regimes, including the juvenile spacing activities intrinsic to those regimes, increase the harvest by almost an additional 0.8% in the medium-term and by 0.9% in the long-term, compared to scenario S02. Spacing and fertilization increase the long-term harvest level by a further 0.9%.

The total increase in long-term harvest levels due to intensification of management (including genetic gain, spacing, commercial thinning and fertilization) is 9%, beginning in decade 16.

The model puts the highest priority on maximizing harvest levels in decade 2, then in the mid term (decades 3-16), and finally in the long term (decades 17-25). Thus the model uses commercial thinning to bring timber forward in the harvest queue in order to reduce falldown beginning in decade 2. Fertilization and genetic gain produce timber quantity benefits in the late mid term and early long term which are conveyed forward in the harvest queue by commercial thinning.

Figure S-2 Forecasts illustrating the tradeoff between maximizing volume and producing a mix of products.



It is clear that meeting the product mix objectives as currently defined for the Golden TSA requires sacrificing substantial volumes of fibre, if it is possible at all.

In this model only managed stands contribute to producing certain products. The yield model used to represent natural stands (VDYP) is unable to provide the piece size information needed, which prevents accurate portrayal of the product mix for the first 8 decades of the planning horizon.

The proportions of regenerated stands to which incremental silviculture treatments can be applied were constrained according to district experience—no more than 21% of regenerated area was available for treatment with incremental silviculture. In addition, to produce premium logs, stands must be grown to well past culmination age.

High-quality sawlogs with narrow growth rings

In the regimes used in this study, high quality logs with narrow growth rings, which comprise 50% of the clear wood objective, are produced only by regimes with late juvenile spacing. However not enough area is eligible for treatment with such regimes to meet the 50% objective.

The main limitations of the study are issues regarding the validity of the TASS managed stand yield tables, the difficulty of incorporating the silvicultural history in the landbase dataset, and the scope and accuracy of the representation of the silvicultural regimes in the model.

Production of product mix volumes is very limited in this model for two reasons. First, the objectives are defined such that 30% of the total harvest volume should consist of the clear wood product type, and half the total volume of the clear wood product must be in large, which constrains the amount of large sawlogs that can be produced. Second, in this model, high quality sawlogs are produced only from regimes that include juvenile spacing. Only scenarios S05a and S05c implement such regimes. These limitations may not accurately reflect management intent of district staff, and is something that should be discussed.

This study quantifies the change in productive capacity of the Golden TSA with intensification of management and alternative management objectives. It does not specify which management objectives should be pursued, and therefore does not prescribe a desirable intensity of forest management. Perhaps the most notable finding is the quantification of the tradeoff between objectives for volume production and product mix (Table 3-3, Fig. 3-19).

Prescriptive studies should follow confirmation of the descriptive model

The critical components of the physical production model (yield curves, silviculture history, and regime diagrams) should be confirmed before addressing the question of the appropriate level of silviculture investment.

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1.0 Introduction

This report documents a forest-level modeling study that examines the implications of silvicultural regime options proposed by the Columbia Forest District for implementation on the Golden TSA. The objective of the project was to provide strategic direction to district staff in designing a silviculture program.

A silvicultural planning model was developed that is consistent with the current TSR model and base case for the TSA[1]; and also fully represents additional forest-level objectives and silvicultural activities required for silvicultural planning.

The TSR base case is the appropriate "point of departure" for the silviculture analysis because it:

- reflects the management unit's current land base, inventory, growth and yield, and management practices;
- conforms to Ministry of Forests' conventions regarding harvest flow, and any departures from the standard harvest flow conventions that may have been deemed appropriate by the TSR;
- ensures that the silvicultural planning model is based on the timber supply assumptions for the TSA that the Chief Forester considered (or will consider) in setting the AAC for that TSA[2].

A major difference between the TSR analyses and this silviculture strategy analysis is the choice of forest-level model. The TSR uses the simulation model FSSIM while this analysis was undertaken with a linear programming (LP) model developed using the Woodstock (Remsoft, 1997) modeling language. The LP formulation was selected because of its flexibility and comprehensiveness in representing silviculture activities, its ability to incorporate complex and multiple objectives, and its facility and consistency with economic reasoning. The LP model is referred to in subsequent sections of this report as the Golden Silviculture Planning Model (GSPM).

Section 2.0 of this report describes the information requirements for the analysis with emphasis on changes to the TSR data base and additional information required for the silvicultural analysis. Section 3.0 describes the results of modeling the scenarios constructed to explore the implications of intensification of management. Section 4.0 reports the long-term silviculture strategy for the TSA and the silvicultural activities that are feasible in the first decade.

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[1] Golden Timber Supply Area Analysis Report, August 1998.
[2] Golden Timber Supply Area Rationale for AAC Determination, January 1, 2000.

The validity of this study depends substantially on the accuracy of the managed-stand yield tables, the representation of TSA's silvicultural history in the modeled landbase, and the specification and modeling of the silvicultural regimes. These limitations are discussed in Section 5.0.

2.0 Data and Management Assumptions

This section describes the data and assumptions used in this analysis that differ from those documented in TSR or are additional inputs that are required for the silvicultural analysis. Other forest management assumptions-- including forest cover requirements, utilization levels and standards, unsalvaged losses and green-up assumptions-- are unchanged from the TSR timber supply analysis.

2.1 The TSR2 Landbase

The TSR data set provided to the project team by Timber Supply Branch identified 451 856 ha of forested area (Table 2-1). Of this area, 166 614 ha of operable forest was categorized as the timber harvesting land base (THLB), and includes backlog NSR and Timber Licences (which revert to the Crown in the future). The remainder of the forested area was divided up into two categories: inoperable and operable excluded. Inoperable forest refers to forested area that is deemed inoperable due to physical or economic factors such as terrain and access. Inoperable forest is not available for harvesting but contributes to satisfying old forest cover requirements. Operable excluded forest includes areas that are physically and economically operable but have been made unavailable for harvesting due to other factors such as riparian management and environmental sensitivity. Operable excluded and THLB areas contribute to old growth and green-up forest cover objectives. For IRM areas only the THLB contributes towards achieving green-up and old growth forest cover objectives.

Table 2-1 Golden TSR2 analysis area.

Classification	Area (ha)
Current THLB	166 614
NSR	15 072
Timber Licences	4 000
Operable excluded	63 662
Inoperable	221 580
Total	451 856

In this analysis, roads, trails and landings have been treated in the same way that they were in TSR.

Roads, trails and landings were treated in the same way as in TSR. When area is harvested for the first time in the model, a specified percentage of the area harvested is removed from the THLB. Losses to roads and landings occur at a rate of 7% from harvested existing stands greater than 40 years.

2.2 Silviculture Analysis Units

The 24 analysis units defined for TSR were aggregated into 6 silvicultural analysis units (SAUs) deemed appropriate by District staff for the silviculture regimes contemplated for the TSA (see Table 2-2). Mean site index (metres at 50 years) for each SAU was calculated as the area-weighted average of the site indices of its constituent TSR analysis units.

Table 2-2 Definition of the silvicultural analysis units.

SAU # [1]	Composition	ITG	Site Index (m)	Area (ha)	Average SI [2] (m)
1	F,FS,SF,FC,S,FL	1-7, 21-25, 38-30	22+	18 78	23.7
2	F,FS,SF,FC,S,FL	1-7, 21-25, 38-30	17-21.9	41 20	19.3
3	C	9, 10	19+	67	20.5
4	C	9, 10	14-18.9	57	15.7
5	Fdecid, CH, H, B	8,11,12-20,26-27,31-34	14+	25 33	17.4
6	All species, low site indices			80 04	12.1
	Total			166 614	

Footnotes
1. SAUs for this study were defined by Pat Wadey, Columbia Forest District.
2. area-weighted average of the site indices of the TSR2 analysis units.

2.3 Silvicultural State of the Landbase

The silvicultural state of a stand records the information needed to determine which silvicultural activities are immediately feasible (not including operational considerations such as harvesting restrictions, accessibility, terrain, or markets). For example, species mix, age, density, basal area, or crown closure may be the variables that the silviculturist considers when deciding how to treat a stand. These state variables change over time with the development of the stand (growth, competition, mortality) and with silvicultural actions (e.g., juvenile spacing).

The TSR timber supply analysis differentiates between stands that are in natural and managed states in order to assign appropriate yield curves. A silvicultural analysis requires a more complex definition of the silvicultural state of each stand in order to determine feasible management actions and appropriate managed stand yield curves.

However, describing the silvicultural state in terms of variables utilized by silviculturists may be appropriate for operational (tactical), program-level planning, but is too detailed for strategic planning with a forest-level model. For the purposes of this project, the silvicultural state of (aggregations of) forest stands was developed from the ISIS and MLSIS databases. The procedure used is described in Appendix A.

2.4 Management Practices

Harvesting operability responds to silviculture

Minimum harvestability criteria refer to the values of attributes such as age or volume per hectare, below which stands are considered to be economically inoperable. In this study, instead of assigning a minimum age for clearcut harvesting, minimum operable volumes were calculated from the height, diameter and volume criteria described in the TSR analysis report. Specifying minimum operable volumes rather than ages allows the model to harvest stands that have more than the required minimum volume per hectare, thus recognizing the benefits of management activities that increase growth.

Commercial thinning is single entry, at 3 possible ages

In addition to the harvesting methods included in the TSR analysis (clearcutting–conventional), this study explicitly models commercial thinning. The development of stands after commercial thinning was simulated with TASS, according to residual stand criteria (trees per hectare, target volume removal) and method (single entry, from below, leaving the largest well-spaced trees), which were developed in consultation with the District.

At the project workshop (September 2001) it was suggested that silvicultural regimes be defined to represent partial harvesting in landscape units that are otherwise "locked up" by biodiversity or habitat forest cover requirements. For example, such a regime could include commercial thinning to low densities leaving the residual stand to grow relatively old. Unfortunately it was not possible to do this within the scope of this study.

1st decade harvest profile is imposed on the model

The harvest profile for the first decade is imposed on the silvicultural model to ensure that silvicultural activities selected by the model reflect current operations. The distribution of the first-decade harvest shown in Table 2-3 was constructed from harvest data in forest development plans (FDP) for 1998-2003 completed by Licensees operating in the Golden TSA. The FDP data were utilized in the TSR analysis.

Table 2-3 Harvest profile (% volume harvested) in the first decade.

	% Total Harvest Volume	
Description	Past timber harvest	Annual timber harvest (FDP volume)
Age classes 8+	69	67
Age classes 6-7	17	15
Age classes <6	14	8
	100%	100%

Source: Golden Timber Supply Area Timber Supply Analysis Report, August 1998, p. 109.

Base case scenario assumes basic silviculture

The base case scenario for this study assumes basic silvicultural practices and models these practices in a manner identical to that of TSR timber supply analysis. The remaining scenarios of this study require the simulation of complex silvicultural regimes including spacing, pruning, fertilization and commercial thinning.

The term *establishment density,* as used in this report, refers to stand density at the free-growing stage, including planted trees and ingress. In this report this is sometimes also referred to as *plant and ingress*. The establishment densities used in this report reflect experience in the district, and not an idealized or target density. For example, district staff expect the result of planting at 1200 sph plus natural ingress to result in a free growing stand of 1400 sph.

Regime diagrams show the actions that can move a stand from one silvicultural state to another.

Alternative management regimes incorporating these incremental silvicultural activities and commercial thinning were specified for each SAU in consultation with District staff. Regime diagrams were constructed that define the alternative silvicultural states of each SAU and the feasible transitions between these states. These regime diagrams are useful for communicating the possible silvicultural states implied by alternative regimes, and for specifying yield tables required for stands in harvestable states. The regime diagrams for each SAU are included in Appendix B.

Managed stand yield tables are projected with TASS

Each harvesting activity represented in the regime diagrams requires a yield table corresponding to the silvicultural state of the harvested stand. Managed stand yield tables were created by Research Branch using TASS. Yield tables for existing natural stands (state N) were modeled using Batch VDYP. The yield tables for each SAU are included in Appendix E.

Costs and labour requirements for implementing the silvicultural treatments are listed in Table 2-4.

Table 2-4 Cost and labour assumptions for silviculture treatments.

Activity	$/ha	P-day/ha
plant	600	1.5
space	800	8.8
prune	1000	6
fertilize	250	1.2

Source: Golden TSA Interim Silviculture Strategy, March 31, 1999.

2.5 Select Stock and Genetic Gain

The benefits from planting select stock in the Golden TSA are evaluated in this study. The genetic gain for each planting mix specified by the District is listed in Appendix C.

Table C-1 Forecast genetic gain by silvicultural analysis unit.

SAU	% Gain
SAU01	12.1
SAU02	10.0
SAU03	12.7
SAU04	12.7
SAU05	10.6
SAU06	8.5

3.0 Analysis Results

This section presents the results of the analysis of eight scenarios designed to quantify the impact of silvicultural practices under different assumptions and objectives.

3.1 Scenarios

The following eight scenarios were used in this study. These scenarios are summarized in Table 3-1 and described in detail in Appendix D.

S01 *TSR2 Base Case*—This scenario reproduces the TSR2 base case in order to validate the data and model. The objective is to maximize priority-structured timber supply.

S01b *Silviculture Base Case* – TSR 2 base case assumptions with silviculture history land base and new analysis units and yield tables.

S02 *TSR2 Base Case plus Planting Select Stock*—This scenario assumes that select stock will be planted for species for which it is available, with genetic gains as described in Appendix C. The objective is to maximize priority-structured timber supply.

S02a *TSR2 Base Case plus Planting Select Stock "a"*—Assumptions as in S02. The objective is to maximize the product mix (see S05a for specifications) while maintaining the S02 harvest level

S02b *TSR2 Base Case plus Planting Select Stock "b"*—Assumptions as in S02. The objective is to maximize the product mix (see S05a for specifications) while allowing the harvest to decrease to 60% of the S02 harvest level.

S03 *TSR2 Base Case plus Commercial Thinning and Select Stock* – This scenario demonstrates the changes in the harvest forecast attributable to commercial thinning. The objective is to maximize priority-structured timber supply.

S04 *Optimal Management Scenario*– This scenario demonstrates the combined effects of all of the silviculture activities implied by the regimes defined for the TSA. It assumes an unlimited silviculture budget. The objective is to maximize priority-structured timber supply.

S05a *Product Mix Scenario A*– This scenario demonstrates the combined effects of all available silvicultural activities while maintaining the S04 harvest level. It assumes an unlimited silviculture budget, and attempts to meet the following product mix specified by the District:

Product	Target
Sawlogs, 27.5+ cm (total)	60% of harvest
High quality sawlogs, 27.5 cm, tight rings	50% of clear wood harvest
Clear wood, > 32.5 cm	30% of harvest
Fibre, 17.5-27.4 cm	residual

S05b not used

S05c *Product Mix Scenario C*–Identical to S05a, with the exception that the harvest level is allowed to decrease to 60% of the S04 harvest level.

Table 3-1 Scenarios used in this study.

	Scenario	Assumptions	Harvest-level objective or constraint	Product goal
S01	*TSR 2 base case*	TSR 2	maximum possible, priority-structured	volume
S01b	*Silviculture base case*	silviculture history land base, new AUs, new yields	maximum possible, priority-structured	volume
S02	*Silviculture base case + select stock*	+ select planting stock	maximum possible, priority-structured	volume
S02a	*product mix*	+ select planting stock	harvest volume ≥ S02	product mix
S02b	*relaxed volume requirement*	+ select planting stock	harvest volume ≥ 60% of S02	product mix
S03	*commercial thinning*	+ select stock + CT	maximum possible, priority-structured	volume
S04	*optimal management*	+ select stock + CT + fertilization	maximum possible, priority-structured	volume
S05a	*S04 + product mix*	all possible treatments, unlimited budget	maximum product volumes; total harvest volume ≥ S04	product mix
S05c	*S04 + product mix*	all possible treatments, unlimited budget	maximum product volumes; total harvest volume ≥ 60% of S04	product mix

3.2 Base Case

The TSR base case is the benchmark against which the effects of management are measured.

Only two silviculture activities are included in the base case – harvesting and planting, including basic silviculture. No incremental silviculture (spacing, pruning, or fertilization) or commercial thinning is included.

The base case is modeled for two reasons. It demonstrates the consistency of the silvicultural model used in this study with that used in TSR. With the validity of the silviculture model established, scenarios with intensified management or different management objectives can be compared to the base case results and differences can be quantified and attributed to management assumptions.

3.2.1 Base Case Harvest Forecast

Figure 3-1 compares base case harvest forecasts determined for this study with the TSR2 base case harvest forecast.

S01a represents base case assumptions applied to the TSR2 landbase

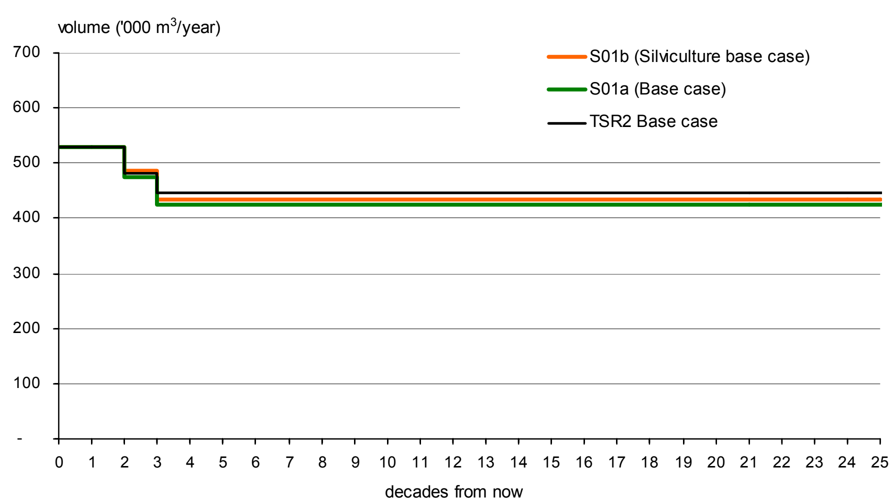
The harvest schedule labeled S01a corresponds to the base case management assumptions applied to the TSR2 landbase. It traces the TSR2 harvest schedule starting at the initial harvest level (January 2000 AAC), and declining by 8% in decade 3, followed by an additional 10% in decade 4. The decade 4 harvest level of 424 000 m^3 per year is 5% below that of TSR 2, and is maintained through to the end of the planning horizon.

S01b represents base case assumptions applied to the silvicultural history landbase

The harvest schedule labeled S01b corresponds to the base case management assumptions applied to the silvicultural history landbase (described in Appendix A). The silvicultural history landbase more accurately represents the silvicultural state of existing managed stands than does the TSR landbase. The S01b schedule closely follows the TSR2 schedule through decade 4. The decade 4 harvest of 435 000 m^3 per year is 2.5% below that of TSR 2, and is maintained out to the end of the planning horizon.

The differences between the S01a and TSR2 base case harvest schedules are due mainly to the differences in the definition of analysis units and associated yield tables.

Figure 3-1 Base case harvest forecasts.



Schedule S01b, based on the silvicultural history landbase, forecasts a harvest level that exceeds the S01a schedule in decades 4-25. This difference suggests that the existing managed stands in this study are assigned larger yields than are assumed in TSR2. S01b shows a slight increase over the TSR2 schedule in the early mid-term (decade 3) while under-performing TSR2 in the long term by about 2.5%. This is partly due to the model solution process, which assigns a high priority to maintaining the initial harvest level for as long as possible and mitigating the mid-term reduction, and assigns a lower priority on maximizing the long-term harvest level.

S01b is the silviculture base case harvest schedule

After consideration of these issues, schedule S01b was accepted as the basis for evaluating the effects of incremental silviculture, and will be referred to hereafter as the silviculture base case.

Figure 3-2

Figure 3-2 shows the composition of the base case harvest by leading species. In decade 1 the mix of species harvested is controlled by the harvest profile specified by the District (section 2.4). In subsequent decades it is determined by the model. Species are not directly constrained in the harvest profile but the age classes specified in the harvest profile differ in species composition.

Figure 3-2 Composition of harvest by leading species, silviculture base case.

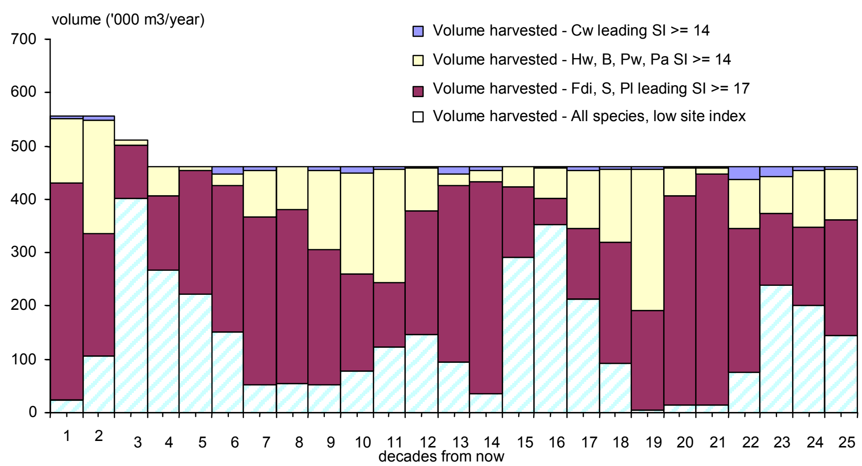


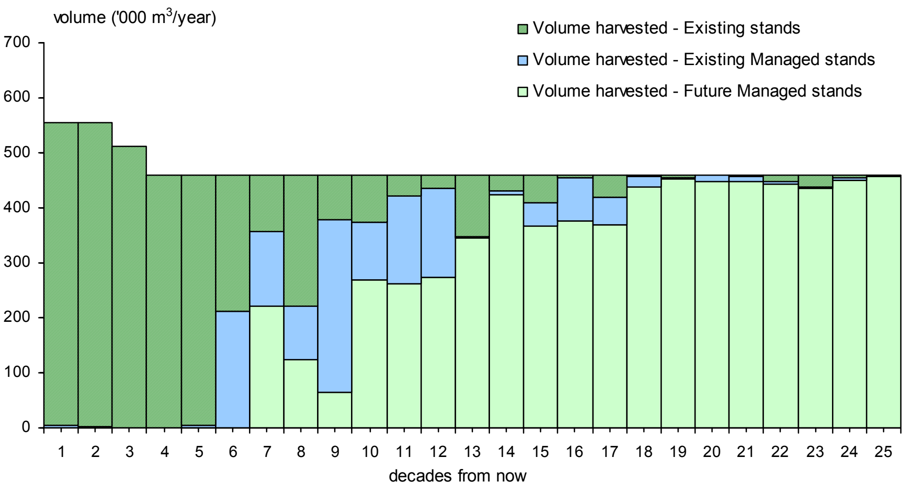
Figure 3-3

Figure 3-3 shows the composition of the base case harvest in terms of natural stands, existing managed stands, and future managed stands. The harvest is composed entirely of existing stands until decade 6, and the transition to managed stand is not complete until decade 16.

Response framework

In this study *short-term* refers to decades 1 and 2. M*id-term* refers to the period between decade 3 and the end of the transition to managed stands (decade 16), when the *long-term* period begins.

Figure 3-3 Composition of harvest by existing natural and managed stands, silviculture base case.



Figures 3-4, 3-5

The composition of the harvest by product mix and diameter limit are plotted in Figures 3-4 and 3-5, respectively. Both figures show only the composition of the harvest from managed stands, since yields from natural stands are not differentiated by grade or diameter due to limitations of the yield model. Note also that the quadratic mean diameter of the harvested managed stands, plotted against the right-hand axis on Figure 3-5, remains relatively constant after decade 5 - between 20-25 cm - out to the planning horizon.

Figure 3-4 Composition of harvest (managed stands) by product mix objective, silviculture base case.

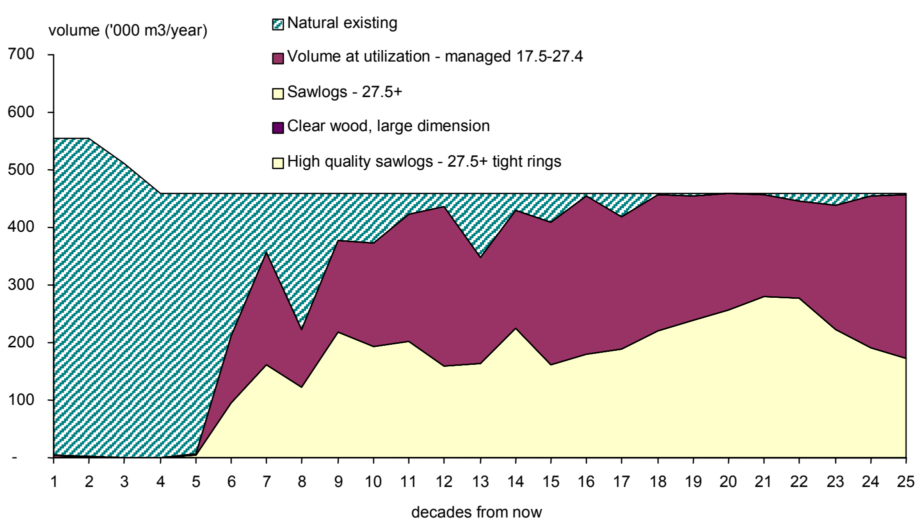


Figure 3-5 Composition of harvest (managed stands) by dimension, silviculture base case.

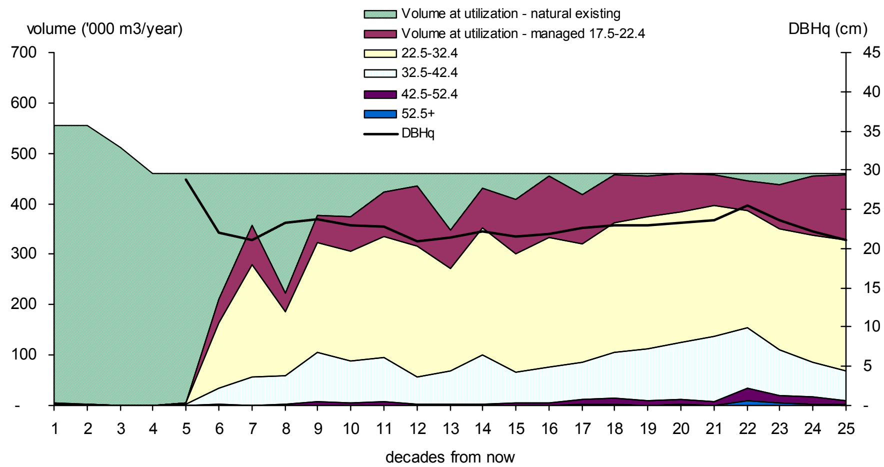
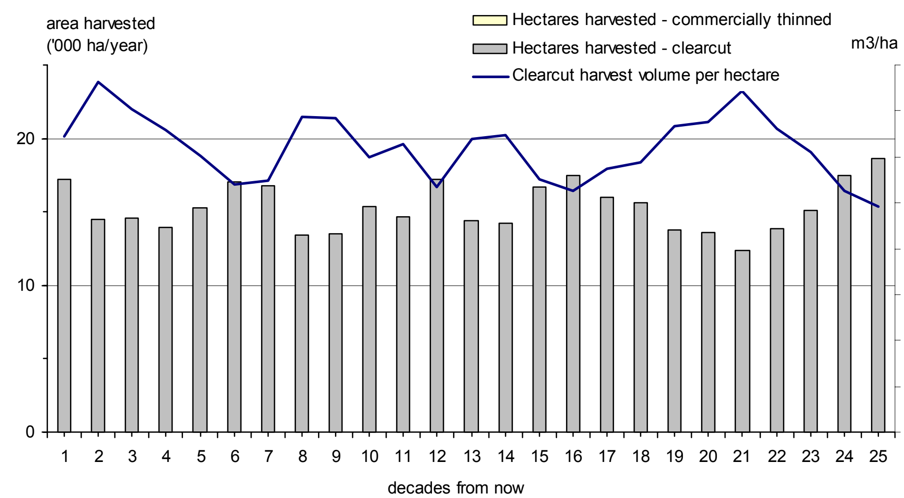


Figure 3-6

Figure 3-6 shows the area harvested on (left-hand axis), and the harvest volume per hectare (right-hand axis). Volume per hectare harvested declines over the first 7 decades. The trend in volume per hectare is somewhat erratic, increasing when harvest is concentrated in hectares of SAU06. Note that there is no commercial thinning in the base case.

Figure 3-6 Total area and volume per hectare harvested, silviculture base case.



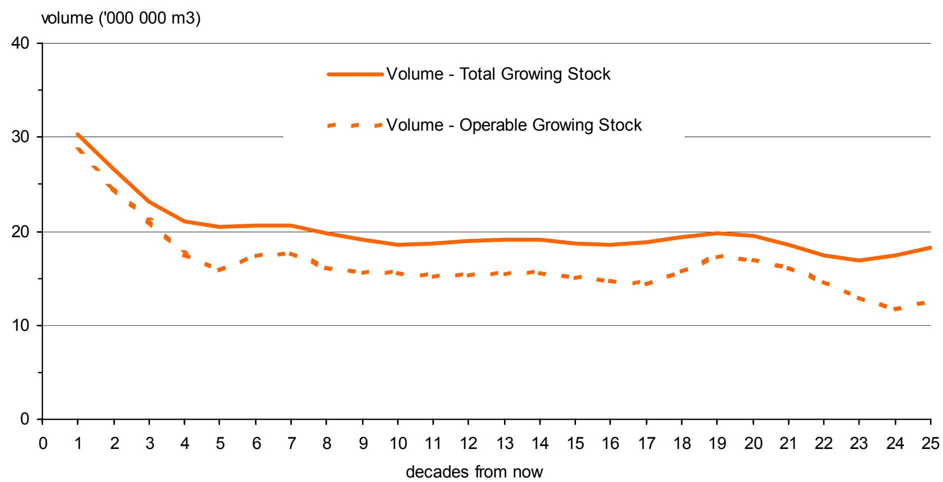
3.2.2 Changes in the Silvicultural State of the Base Case

Stable inventory indicates sustainable LTHL, as in Fig. 3-7

Figure 3-7 shows the volume of total and operable growing stock over the planning horizon. Initially, most of the growing stock is operable. During the first

5 decades harvesting increases the area of forest that is younger than minimum harvestable size and age, and the operable growing stock diverges from the total growing stock curve. At the initially high levels of harvesting, growing stock inventory levels decline, after which they stabilize. The relatively stable inventory levels in the long-term indicate that the long-term harvest level (LTHL) is sustainable.

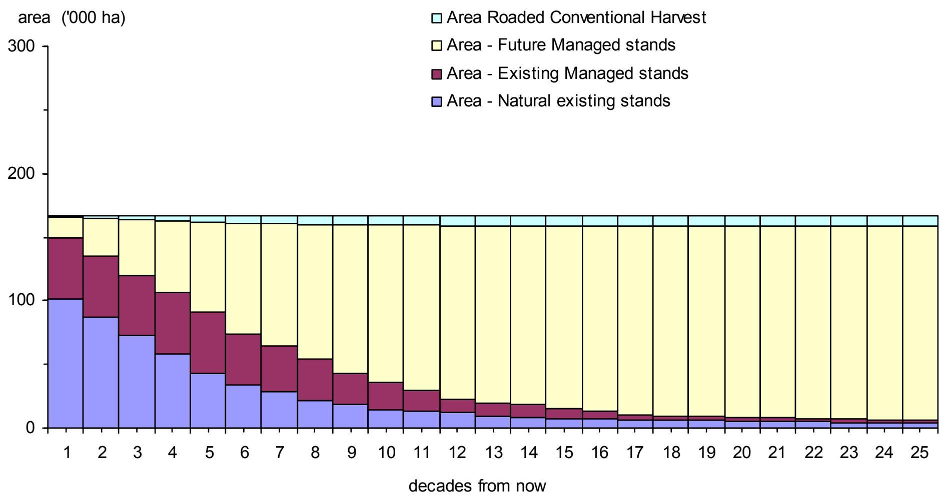
Figure 3-7 Total and operable growing stock, silviculture base case.



Some poor site fir and spruce is never harvested

Figure 3-8 tracks the change in silvicultural state of the THLB over the planning horizon. At the end of the first decade, the THLB is composed of 101 521 ha natural existing stands, and 63 902 ha of existing and future (regenerated by the model) managed stands. The Timber Licences are harvested and regenerated as managed stands by the end of decade 1, and the areas of natural stands and existing managed stands are steadily reduced as harvesting and regeneration convert them to future managed stands. Note that at the end of decade 25 approximately 4 342 ha of natural stands have not been harvested. These natural stands are predominantly poor site fir and spruce.

Figure 3-8 Aggregate silvicultural state, silviculture base case.



The model considers the objectives over the entire planning horizon

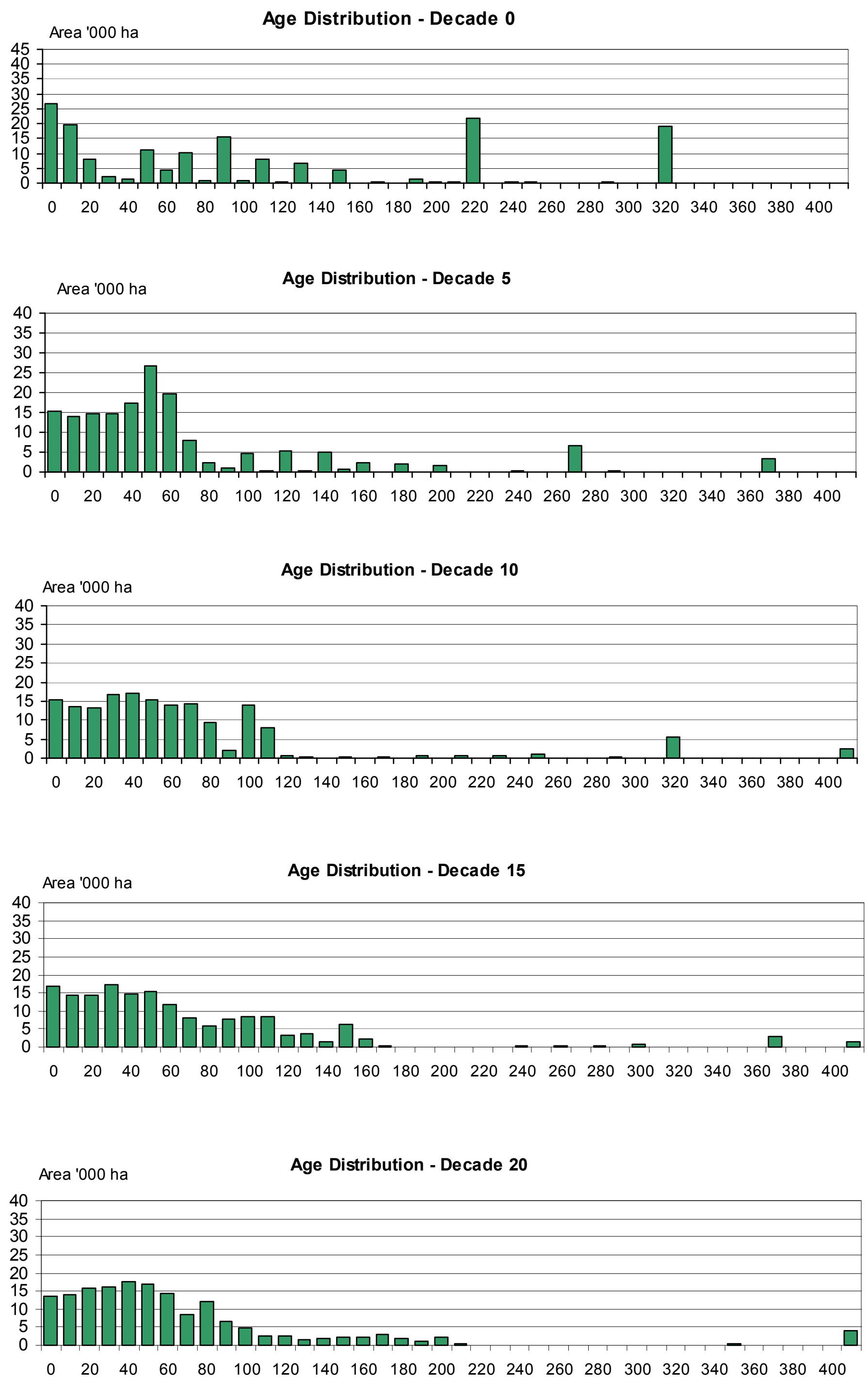
The model does not harvest these low productivity stands because it is structured to select stands for harvesting such that timber supply is maximized across the entire planning horizon. Two factors come into play here. First, some low site stands may contribute most to the objective by being retained to satisfy seral stage requirements rather than by being harvested. Second, the model is choosing hectares to harvest in a way that will maximize productivity of the land base, i.e., it chooses hectares to harvest to convert productive sites to shorter rotations and second growth yield curves as soon as possible. Focusing harvesting on more productive stands with shorter rotations increases the productivity of the THLB and increases timber supply over the planning horizon. Note that in practice it might be necessary to also retain some good site stands to satisfy seral stage requirements, an important departure from the assumptions of the model.

Simulation models, such as FSSIM, use a simple harvest rule, such as oldest first, and do not consider the future implications of harvesting a stand. This is a significant difference between simulation and LP models and underlines the importance of having a clear objective when forecasting timber supply.

By decade 25, most of the hectares older than 230 years are poor site fir and spruce

Table 3-9 shows the progression of the age class distribution of operable timber on the TSA over the planning horizon. Age class 400 includes all stands 400 years or older, although the model tracks stands for 700 years before converting them to the regenerating state. By decade 25, almost all of the stands age class 230 or older, are poor site fir or poor site spruce.

Figure 3-9 Distribution of operable area for total inventory, silviculture base case.



3.3 Management for Timber Quantity

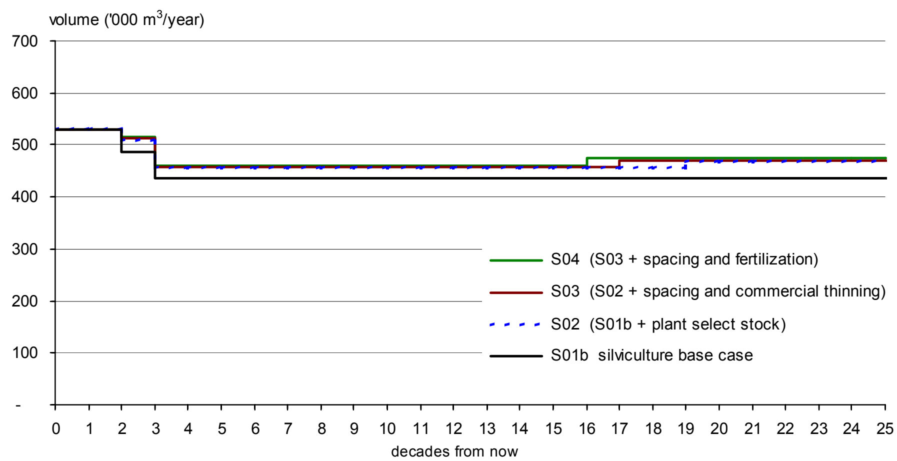
This section presents the results of incorporating incremental silvicultural activities (including planting, spacing, pruning and fertilization) and commercial thinning into the silvicultural planning model, and explores the implications of alternative levels of expenditure.

3.3.1 Select Stock, Commercial Thinning and Intensive Silviculture Scenarios

S02, S03, and S04 maximize volume of timber harvested, and assume unlimited silviculture budget

Figure 3-10 shows the incremental benefits from planting select stock (S02), commercial thinning (S03) and spacing and fertilization (S04) relative to the silviculture base case (S01b). These scenarios were implemented with the management objective of maximizing the quantity of timber harvested, and assumed an unlimited silviculture budget.

Figure 3-10 Impact of planting select stock, commercial thinning, spacing and fertilization on the harvest forecast.



Planting select stock increases timber supply by 5%

Planting select stock (scenario S02) increases timber supply by about 4.5% starting in decade 3 (Fig. 3-10). This increase occurs because planting select stock increases the volumes available in later decades, thus releasing stands for harvest in decade 3 that under the silviculture base case (S01b) were being held to provide harvest volume later on. An additional 2.7% increment occurs beginning in period 17, when future managed stands planted with select stock become available for harvesting.

Commercial thinning increases timber supply by 0.8%

Commercial thinning regimes, including the juvenile spacing activities intrinsic to those regimes, increase the harvest by almost an additional 0.8% in the medium-term and by 0.9% in the long-term, compared to scenario S02.[3] Total increase in timber supply volume attributed to planting select stock (S02) and commercial thinning (S03) is about 5.2% in the medium-term and about 8% in the long-term.

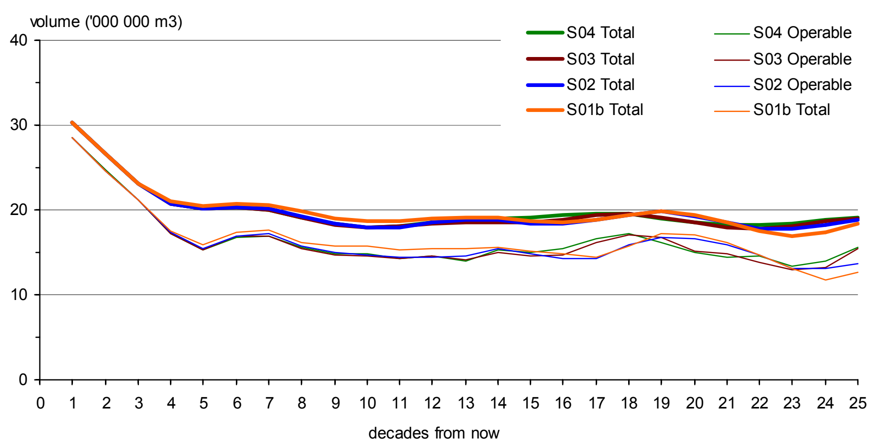
In accordance with the model's schedule of priorities, commercial thinning is used to bring harvest forward to increase the mid-term harvest levels. In the long term, the increment from commercial thinning may be due to reducing the effect of forest cover constraints and allowing stands to be harvested closer to their culmination ages.

Spacing and fertilization increase timber supply by about 0.6% more

Implementing spacing and fertilization regimes, in addition to select stock and commercial thinning regimes, returns a further increment of 0.6% starting in decade 3 and increasing to almost 0.9% in the long term. The total increase relative to the silviculture base case from the intensification of management (plant select stock, space and fertilize, commercial thin) is almost 9%, beginning in decade 16.

Figure 3-11 plots the total and operable growing stock level for each of the scenarios. The criterion for sustainability (of timber supply) noted in the discussion of the base case, that total and operable growing stock should be non-declining in the long term, is met.

Figure 3-11 Total and operable growing stock forecasts with intensification of management.



Both total and operable growing stock increase with intensification of management— inventory levels for the select stock scenario are higher than the base case and the scenarios that include spacing and fertilization regimes lift

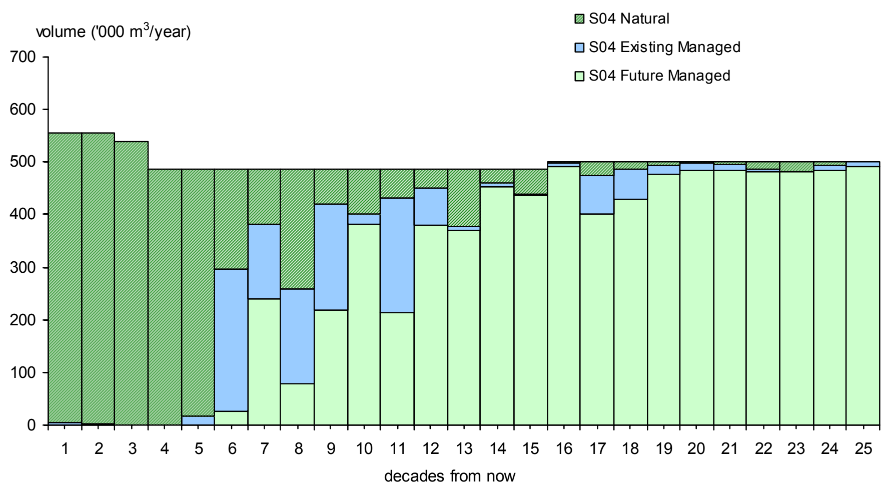
[3] Unless otherwise described, all increment percentages in this report are calculated with reference to the silviculture base case harvest level (S01b).

inventory levels higher. Commercial thinning has little effect on growing stock, except to reduce operable growing stock in decades 4-15.

Transition to managed stands occurs earlier

Figure 3-12 shows the transition in the timber supply from natural stands to managed stands. Comparing this figure with the base case transition plotted in Figure 3-3, with the intensification of management, the transition is completed slightly earlier (decade 16 versus decade 17). Also, continued management (especially repeat fertilization) of existing managed stands has increased the yield from these stands, allowing the initial harvest of future managed stands to be delayed from decade 5 to decade 6.

Figure 3-12 Composition of harvest forecast by existing natural and managed stands, maximum intensive management scenario (S04).



Clearcut vs commercial thinning

Figure 3-13 compares the area harvested by clearcutting versus commercial thinning. Overall, very little commercial thinning occurs because of the scarcity of suitable stands. The greater amounts of commercial thinning in decades 14 and 15 allow the model to increase the harvest of future managed stands in decades 9-10 (Fig. 3-12).

Figure 3-13 Total area and volume per unit area of the forecast harvest, maximum intensive management scenario (S04).

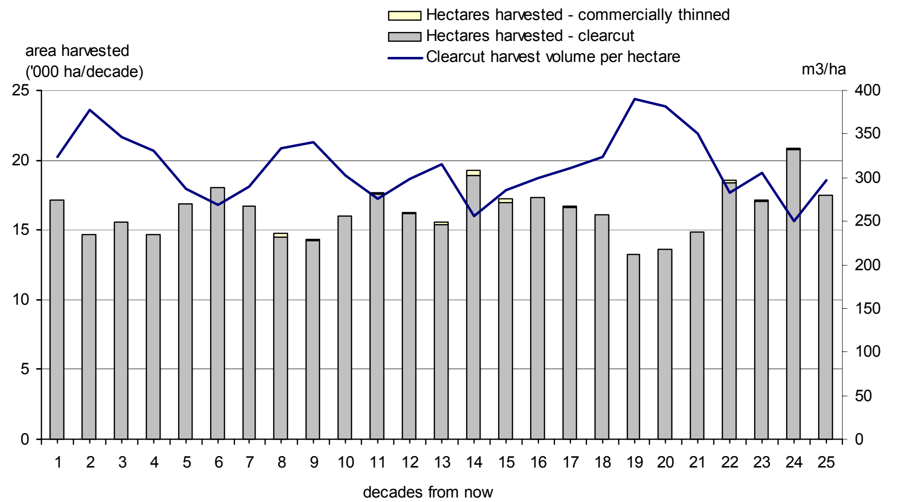


Figure 3-14 Composition of harvest by diameter limit

Figure 3-14 shows the composition by diameter limit of the harvest from managed stands. Comparing this figure with the equivalent base case Figure 3-5, it is apparent that the largest increment is in smallest diameter category, i.e., stems with dbh exceeding 17.5 cm (the TSR lower limit) and less than 30 cm.

Figure 3-14 Composition by dimension of forecast harvest of managed stands, maximum intensive management scenario (S04).

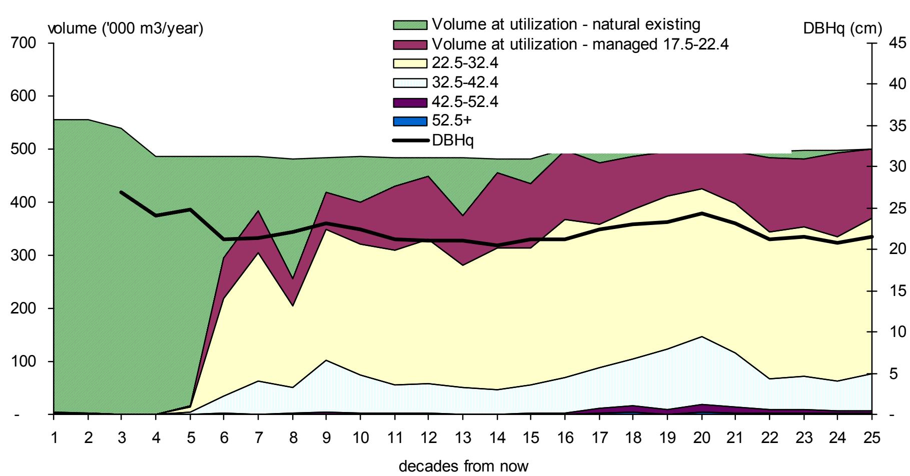
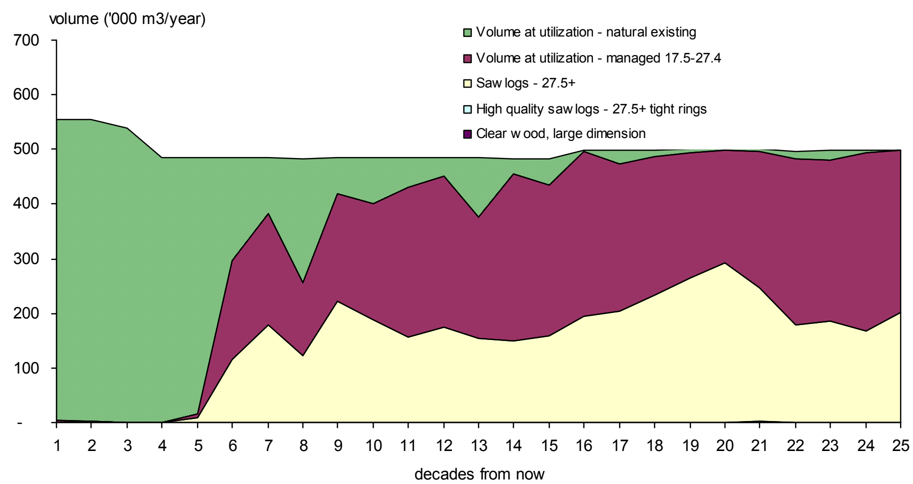


Figure 3-15 Composition of harvest by product mix

Figure 3-15 shows the composition by product objective of the harvest from managed stands. Comparing this figure with the equivalent base case Figure 3-4, there is no discernable shift in product objective for the regimes implemented by the model. This result was expected, since the objective of this scenario was to maximize harvest volume.

Figure 3-15 Composition of the harvest forecast by product mix, maximum intensive management scenario (S04).



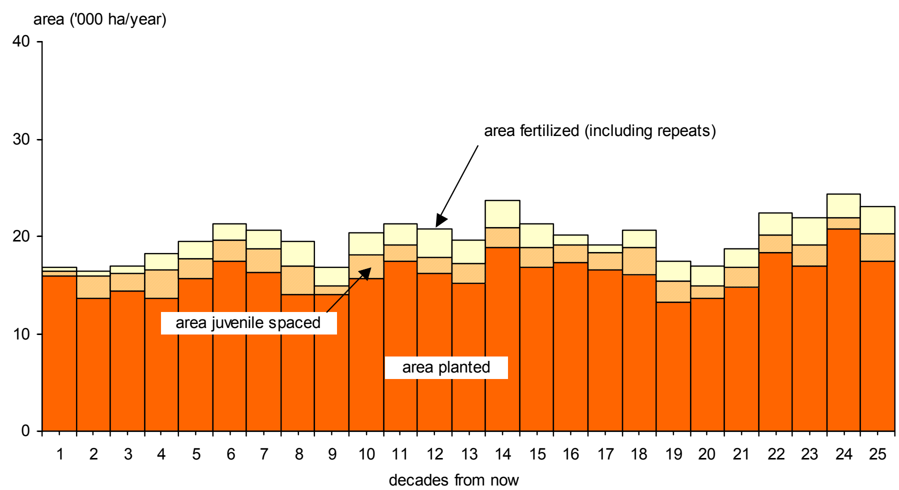
3.3.2 Optimal Management for Maximizing Harvest Quantity

Figures 3-16, 3-17, and 3-18 show the area treated, costs of treatment and the associated direct employment benefits for scenario S04, the optimal management for maximizing harvest volume scenario. Note that the amount of planting is shown in these figures, but is not a function of incremental silviculture.

About 2000 ha is spaced, and 2000 ha fertilized annually

The area fertilized and the area spaced increase very rapidly after decade 1, from an initial 424 ha per year in decade 1 to an average of over 2 000 ha per year in subsequent decades (Fig 3-16).

Figure 3-16 Treatment area forecast, maximum intensive management scenario (S04).



Average annual costs for spacing and fertilization are about $150 000 and $50 000 respectively.

The cost of spacing and fertilization (Figures 3-17) and the silviculture employment outputs of these programs (Figures 3-18) follow a similar pattern. The average annual costs of spacing and fertilization are about $150 000 and $50 000 respectively.

Figure 3-17 Treatment cost forecast, maximum intensive management scenario (S04).

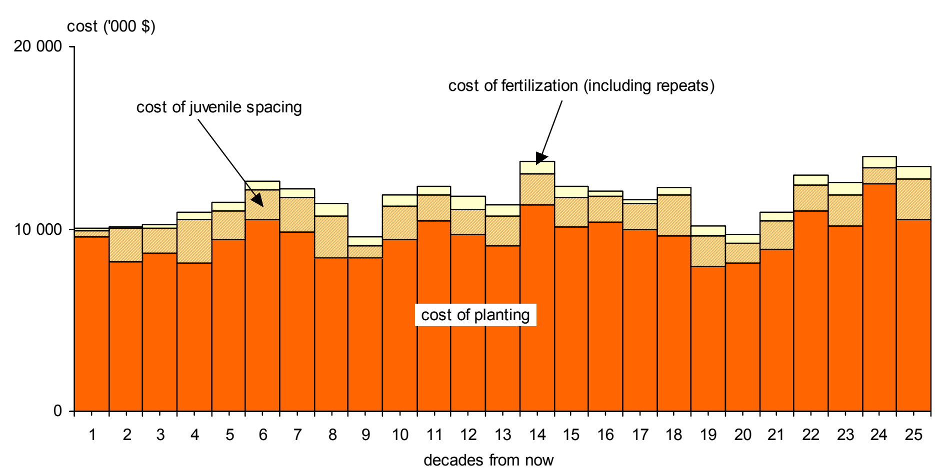


Figure 3-18 Silviculture direct employment forecast, maximum intensive management scenario (S04).

The regimes implemented to achieve the quantity benefits described in this section are discussed in Section 4.

3.4 Management for Product Objective

This section presents the results of scenarios[4] that explore ways to achieve the District's product mix objectives (Table 3-2)[5]. We were investigating two effects with these scenarios. First, we were interested in determining the marginal gain in product volumes attributable to investing in "incremental" treatments (spacing, commercial thinning, fertilization, and pruning). Second, we wanted to know how much the total harvest volume would have to be reduced to produce the product mix without investing in incremental treatments, i.e., using only basic reforestation.

Two types of scenarios were analyzed. In scenarios S02, S02a, and S02b the only possible incremental treatment was the use of select planting stock. In scenarios S04, S05a and S05c all treatments (select planting stock, spacing, commercial thinning, fertilization, pruning) were available to be used. All scenarios maximize the product mix objective throughout the entire planning horizon.

In Scenarios S02 (select stock only) and S04 (all treatments) the objective was to maximize the volume harvested.

In Scenarios S02a and S05a the objective was to achieve the product mix while maintaining the S02 and S04 harvest levels respectively, or in other words to achieve the product mix objective without reducing the total volume cut.

In Scenarios S02b and S05c the objective was to achieve the product mix while allowing total harvest volume to be reduced to 60% of the S02 and S04 harvest levels respectively. This approach was developed to explore the trade-off between maximizing volume and achieving product mix objectives.

Table 3-2 Product mix objectives for the Golden TSA.

Product	Stand type	Minimum average stand diameter (cm)	% of total harvest
Sawlogs	Existing and future managed stands	27.5+	60
Clear wood, large dimension sawlogs	Existing stands Existing and future managed stands	32.5+	30
High quality sawlogs, tight rings	Future managed stands	32.5+	50% of clear wood large dimension sawlog harvest
Fibre	Existing stands Existing and future managed stands	17.5+	10

[4] The full set of scenarios used in this study is described in Section 3.1 and Appendix D
[5] Columbia Forest District. 1999. *A framework for determining timber product objectives, associated management regimes and efficient expenditure of enhanced silviculture resources within Golden TSA*. Unpublished report, Ministry of Forests. Ministry of Forests. 2000. Interim Silviculture Strategy, Nelson Forest Region—Golden TSA. Unpublished report.

S02b and S05c:
Max product mix objective

The harvest from the various product mixes was not maximized directly by the model. Comparing the S02a and S05a runs shows the marginal value of using incremental activities to achieve product mix objectives. The S02a run constrained the harvest level to be equal to S02. The S05a run constrained the harvest level to be equal to S04.

Scenario	Description
S02a	planting only, product mix goals, maintain S02 harvest level
S05a	all treatments, product mix goals, maintain highest possible (S04) harvest
S02b	planting only, product mix goals, maintain at least 60% of S02
S05c	all treatments, product mix goals, maintain at least 60% of S04

Table 3-2
Tradeoff between fibre volume and clear wood sawlog volume

Under strategies constrained to maintain volume production, there are only small and subtle opportunities for using incremental silviculture treatments to increase the production of high quality products. Table 3-3 shows the product mix objective percentages attained for each scenario. As expected, product mix volumes increased as the minimum required harvest level was relaxed. Clear wood volume can only be obtained from SAU1, SAU2, SAU3, and SAU4. Table 3-4 represents the clear wood percentages obtained from volume at utilization. The percent of harvest volume from clear wood sawlogs increased from 0% for scenario S02a to 4.33% for scenario S02b. A similar pattern was found for scenarios involving incremental silviculture treatments. The percent of harvest volume from clear wood sawlogs increased from 0% for Scenario S04 to 2.9% in S05c The harvest volume percent from high quality sawlogs increases from 0% (for all previous run except S05a) to 1.5%.

Production of product mix volumes is very limited in this model for two reasons. First, the objectives are defined such that 30% of the total harvest volume should consist of the clear wood product type, and half the total volume of the clear wood product must be in large, which constrains the amount of large sawlogs that can be produced. Second, in this model, high quality sawlogs are produced only from regimes that include juvenile spacing. Only scenarios S05a and S05c implement such regimes. These limitations may not accurately reflect management intent of district staff, and is something that should be discussed.

Table3-3 Percent of harvest volume by product and log size, by scenario.

	Percent of Total Harvest				
	Target %	**S02a**	**S02b >= 60% S04**	**S05a = S04 (max)**	**S05c >= 60% S04**
Products					
Fibre, 17.5-27.4 cm	**10**	54.1	21.8	37.3	24.6
Sawlogs, 27.5+ cm (total)	**60**	45.9	73.9	62.0	72.4
HQ Sawlogs, 32.5 cm, tight rings	**<=30**	0.0	0.0	0.4	1.5
Clear wood, > 32.5 cm	**<=30**	0.0	4.3	0.7	2.9
Total	100	100	100	100	100
Diameter limits (cm)					
17.5-22.4		22.7	9.2	13.5	9.9
22.5-32.4		56.6	37.3	52.0	38.8
32.5-42.4		17.8	33.5	29.7	33.1
42.5-52.4		2.2	15.7	4.2	13.4
52.5+		0.6	4.3	0.6	4.8
		100	100	100	100

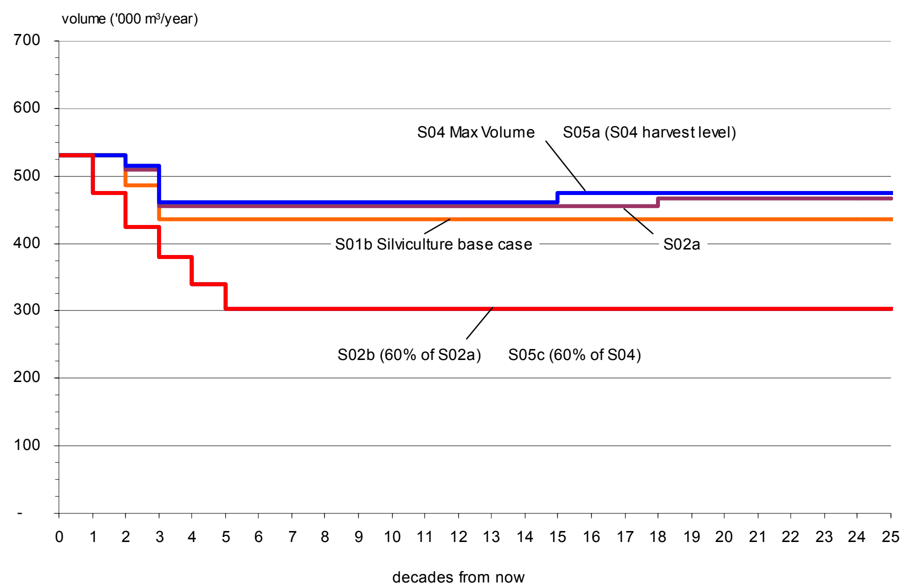
Table 3-4 Percent (%) clear wood from volume at utilization for SAU1, SAU2, SAU3, and SAU4.

Stand Age	Percent (%) clear wood from volume at utilization SAU1 SAU2	SAU3 SAU4
130	1.1	0
140	2.5	0.1
150	4.2	2
160	5.9	4
170	7.5	6.1
180	9.6	8.2
190	11.5	10.3
200	12	12
210	12	13.3
220	12	14.1
230	12	14.6
240	12	14.9
250-350	12	15

Figure 3-19 Trade-off between harvest and product mix objectives

Figure 3-19 shows the trade-off between harvest level and product mix objectives. For both S02b and S05c the total harvest level declines by the maximum amount allowed (60%) in trying to meet product mix objectives.

Figure 3-19 Harvest forecast corresponding to product mix targets.



It is clear that meeting the product mix objectives as currently defined for the Golden TSA requires sacrificing substantial volumes of fibre, if it is possible at all., because of the need to use very long rotations to achieve the product mix objectives.

In the regimes used in this study high quality tight-ring logs, which comprise 50% of the clear wood objective, are produced only by regimes with late juvenile spacing. However not enough area is eligible for treatment with such regimes to meet the 50% objective.

Figure 3-20
Average age of harvested stands

In order to attain the sawlog production objectives the model must harvest existing older stands. Figure 3-20 illustrates the average harvest age from scenarios S02a, S02b, S05a and S05c.

Figure 3-20 Average age of harvested stands (scenario S02 and S05).

The model harvests existing stands early in the planning horizon to convert the silvicultural state of hectares from existing to managed. The average harvest age declines between periods 4 to 8 as the area of existing stands declines. The model then implements managed-stand regimes with longer rotations to produce high quality products, causing the steady increase in harvest age in scenarios S02b and S05c from period 9 to the end of the planning horizon.

Percent of harvest from various diameter classes is shown in Table 3-2. Relaxing the minimum harvest level requirement and maximizing product objectives allows the model to the choose higher harvest ages needed to produce high quality logs. Both S02b and S05c have more then 50% of the harvest from stands with a diameter greater than 32.5 cm.

4.0 Recommendations for Management

Section 3.0 described the potential productive capacity of the Golden TSA under different management objectives, and also described the effect of intensified management on indicators of the state of the forest. This section of the report identifies the specific regimes selected by the model to achieve the three management objectives embodied by scenarios S04, S05a, and S05c, which were:

S04, Optimal Management Scenario– This scenario demonstrates the combined effects of all of the silviculture activities implied by the regimes defined for the TSA. It assumes an unlimited silviculture budget. The management objective is to maximize priority-structured timber supply.

S05a, Product Mix Scenario A– This scenario demonstrates the combined effects of all of the silviculture activities implied by the regimes defined for the TSA. It assumes an unlimited silviculture budget. This scenario attempts to meet the product mix specified by the District while maintaining the S04 harvest level.

S05c, Product Mix Scenario C– This scenario demonstrates the combined effects of all of the silviculture activities implied by the regimes defined for the TSA. It assumes an unlimited silviculture budget. This scenario attempts to meet the product mix specified by the District while allowing the harvest to decrease by as much as 60% from the S04 harvest level.

The silviculture strategy has two parts—the strategic plan that schedules silviculture (including harvesting) for 25 decades and the tactical plan that implements the strategic plan in the first decade. The strategic plan identifies the regimes selected by the model as contributing maximally to achieving the management objectives, while the tactical plan applies these optimal regimes to the silvicultural opportunities available in the first decade.

4.1 Long-Term Silvicultural Strategy

The strategic plan is reported in Table 4-1. This table shows the total areas scheduled for treatment over the planning horizon[6] by SAU (01 - 06), establishment density (planting and ingress to 1400, 3500, and 7500 sph) and scenario (S04, S05a, and S05c). For each establishment density, the table shows total area regenerated, the area available for incremental silviculture (specified by the district silviculturists), and the sum of the areas scheduled for treatment over the planning horizon by regime.

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[6] The planning horizon for this study was 250 years. However, because of computational intensity required to solve the linear programming model, the planning horizon was shortened to 20 decades for objectives S05a and S05c.

Table 4-1 Total area scheduled for each silvicultural regime by management objective and SAU. Percent values represent the proportion of total area regenerated that was treated by incremental silvicultural activities for each establishment (plant and ingress) density.

Silvicultural Regime	Regime #	Decades 1-25 **S04** (ha)	Decades 1-20 **S05a** (ha)	Decades 1-20 **S05c** (ha)
SAU01: ITG 1-7, 21-25, 28-30, Average SI=23.76				
Total area regenerated to 1400 sph	1001	4 343	3 993	3 304
Area available for incremental silviculture		2606 (100%)	2396 (100%)	1982 (100%)
Plant and ingress to 1400 sph, CT, clearcut	1005	81 (3%)	120 (5%)	101 (5%)
Plant and ingress to 1400 sph, prune, clearcut	1002	-	739 (31%)	141 (7%)
Plant and ingress to 1400 sph, prune, CT, clearcut	1003	-	1183 (50%)	1484 (75%)
Area available for incremental silviculture but not treated		**2525 (97%)**	**354 (15%)**	**1726 (13%)**
Total area regenerated to 3500 sph	1007	50 669	46 589	38 548
Area available for incremental silviculture		**0**	**0**	**0**
Total area regenerated to 7500 sph	1008	17 372	15 973	13 216
Area available for incremental silviculture		10423 (100%)	9584 (100%)	7930 (100%)
Plant and ingress to 7500 sph, JS to 900 sph at height < 10m, clearcut	1009	2278 (22%)	443 (5%)	297 (4%)
Plant and ingress to 7500 sph, JS to 900 sph at height < 10m, prune, clearcut	1010	-	4591 (48%)	4323 (55%)
Plant and ingress to 7500 sph, JS to 1400 sph at height < 10m, clearcut	1011	5995 (58%)	316 (3%)	204 (3%)
Plant and ingress to 7500 sph, JS to 1400 sph at height < 10m, CT, clearcut	1015	1300 (12%)	137 (1%)	130 (2%)
Plant and ingress to 7500 sph, JS to 1400 sph at height < 10m, prune, clearcut	1012	-	308 (3%)	161 (2%)
Plant and ingress to 7500 sph, JS to 1400 sph at height < 10m, prune, CT, clearcut	1013	-	1750 (18%)	399 (5%)
Plant and ingress to 7500 sph, JS to 1800 sph at height < 10m, clearcut	1017	110 (1%)	306 (3%)	204 (3%)
Plant and ingress to 7500 sph, JS to 1800 sph at height < 10m, CT, clearcut	1018	-	147 (2%)	130 (2%)
Plant and ingress to 7500 sph, JS to 1800 sph at height = 10m, clearcut	1020	110 (1%)	814 (8%)	1464 (18%)
Area available for incremental silviculture but not treated		**630 (6%)**	**772 (8%)**	**617 (7%)**
SAU02: ITG 1-7, 21-25, 28-30, Average SI=19.32				
Total area regenerated to 1400 sph	1021	7 032	6 211	5 243
Area available for incremental silviculture		1406 (100%)	1242 (100%)	1259 (100%)
Plant and ingress to 1400 sph, fert, clearcut	30211	-	-	-
Plant and ingress to 1400 sph, fert, prune, clearcut	30221	-	204 (16%)	488 (39%)
Plant and ingress to 1400 sph, fert, prune, late fert, clearcut	30222	-	399 (32%)	304 (24%)
Plant and ingress to 1400 sph, late fert, clearcut	30213	-	8 (1%)	48 (4%)
Plant and ingress to 1400 sph, CT, late fert, clearcut	3024	28 (2%)	22 (2%)	55 (4%)
Plant and ingress to 1400 sph, cyclic fert, clearcut	30212	1305 (93%)	318 (26%)	187 (15%)
Plant and ingress to 1400 sph, CT, clearcut	1024	27 (2%)	178 (14%)	176 (14%)
Area available for incremental silviculture but not treated		**46 (3%)**	**112 (9%)**	**0 (0%)**
Total area regenerated to 3500 sph	1026	82 038	72 467	58 097
Area available for incremental silviculture		**0**	**0**	**0**
Total area regenerated to 7500 sph	1027	29 378	24 846	19 919
Area available for incremental silviculture		18127 (100%)	14908 (100%)	11951 (100%)
Plant and ingress to 7500 sph, JS to 900 sph at height < 10m, clearcut	1028	157 (1%)	487 (3%)	570 (5%)
Plant and ingress to 7500 sph, JS to 900 sph at height < 10m, fert, clearcut	3028	1591 (9%)	-	-
Plant and ingress to 7500 sph, JS to 900 sph at height < 10m, fert, prune, clearcut	30291	-	1216 (8%)	955 (8%)
Plant and ingress to 7500 sph, JS to 900 sph at height < 10m, fert, prune, cyclic fert, clearcut	30292	-	5385 (36%)	3609 (30%)
Plant and ingress to 7500 sph, JS to 1400 sph at height < 10m, clearcut	1030	157 (1%)	538 (4%)	660 (6%)
Plant and ingress to 7500 sph, JS to 1400 sph at height < 10m, CT, clearcut	1032	62 (0%)	614 (4%)	334 (3%)
Plant and ingress to 7500 sph, JS to 1400 sph at height < 10m, fert, clearcut	3030	15241 (84%)	3098 (21%)	1148 (10%)
Plant and ingress to 7500 sph, JS to 1800 sph at height < 10m, fert, clearcut	3034	0 (0%)	774 (5%)	531 (4%)
Plant and ingress to 7500 sph, JS to 1800 sph at height < 10m, fert, CT, clearcut	30361	0 (0%)	3 (0%)	124 (1%)
Plant and ingress to 7500 sph, JS to 1800 sph at height < 10m, clearcut	1034	219 (1%)	1100 (7%)	904 (8%)
Plant and ingress to 7500 sph, JS to 1800 sph at height < 10m, CT, late fert, clearcut	30362	481 (3%)	224 (2%)	85 (1%)
Plant and ingress to 7500 sph, JS to 1800 sph at height = 10m, clearcut	1038	219 (1%)	1100 (7%)	2077 (17%)
Area available for incremental silviculture but not treated		**0 (0%)**	**370 (2%)**	**954 (8%)**
Existing managed, Plant and ingress to 7500 sph, JS to 1400 sph at height < 10m, CT, clearcut	1030	10	-	1 829
SAU03: ITG 9-10, Average SI=20.5				
Total area regenerated to 1400 sph	1039	122	111	89
Area available for incremental silviculture		37 (100%)	33 (100%)	27 (100%)
Plant and ingress to 1400 sph, CT, clearcut	1040	23 (63%)	22 (66%)	15 (55%)
Area available for incremental silviculture but not treated		14 (37%)	11 (33%)	12 (45%)
Total area regenerated to 3500 sph	1042	1 427	1 299	1 038
Area available for incremental silviculture		**0**	**0**	**0**
Total area regenerated to 7500 sph	1043	489	445	356
Area available for incremental silviculture		293 (100%)	267 (100%)	213 (100%)
Plant and ingress to 7500 sph, JS to 1800 sph at height < 10m, clearcut	1044	231 (79%)	57 (21%)	34 (16%)
Plant and ingress to 7500 sph, JS to 1800 sph at height = 10m, clearcut	1047	29 (10%)	155 (58%)	146 (69%)
Area available for incremental silviculture but not treated		**33 (11%)**	**55 (20%)**	**33 (15%)**

Table 4-1 (cont'd)

SAU04: ITG 9-10, Average SI=15.7				
Total area regenerated to 1400 sph	1048	78	84	60
Area available for incremental silviculture		16 (100%)	17 (100%)	12 (100%)
Plant and ingress to 1400 sph, CT, clearcut	1050	2 (12.5%)	10 (59%)	7 (58%)
Area available for incremental silviculture but not treated		**14 (87.5%)**	**7 (41%)**	**5 (42%)**
Total area regenerated to 3500 sph	1053	907	977	701
Area available for incremental silviculture		**0**	**0**	**0**
Total area regenerated to 7500 sph	1054	311	335	240
Area available for incremental silviculture		187 (100%)	201 (100%)	144 (100%)
Plant and ingress to 7500 sph, JS to 1400 sph at height < 10m, clearcut	1055	144 (77%)	26 (13%)	23 (16%)
Plant and ingress to 7500 sph, JS to 1400 sph at height < 10m, CT, clearcut	1057	27 (15%)	29 (14%)	9 (6%)
Plant and ingress to 7500 sph, JS to 1400 sph at height = 10m, clearcut	1059	4 (2%)	94 (47%)	82 (57%)
Area available for incremental silviculture but not treated		12 (6%)	52 (26%)	30 (21%)
SAU05: ITG 8,11,12-20,26-27,31-34, Average SI=17.4				
Total area regenerated to 1400 sph	1061	10 549	8 738	6 192
Area available for incremental silviculture		**0**	**0**	**0**
Total area regenerated to 3500 sph	1062	49 231	40 777	28 894
Area available for incremental silviculture		**0**	**0**	**0**
Total area regenerated to 7500 sph	1063	10 549	8 738	6 192
Area available for incremental silviculture		6330 (100%)	5243 (100%)	3715 (100%)
Plant and ingress to 7500 sph, JS to 1400 sph at height < 10m, clearcut	1064	5499 (87%)	3271 (62%)	2449 (66%)
Area available for incremental silviculture but not treated		**831 (13%)**	**1972 (38%)**	**1266 (34%)**
SAU06: All ITG's, All SI's not captured in SAU01-SAU05				
Total area regenerated to 1400 sph	1066	8 238	6 763	2 910
Area available for incremental silviculture		**0**	**0**	**0**
Total area regenerated to 3500 sph	1067	96 107	78 900	33 946
Area available for incremental silviculture		**0**	**0**	**0**
Total area regenerated to 7500 sph	1068	32 951	27 051	11 639
Area available for incremental silviculture		19770 (100%)	16231 (100%)	6983 (100%)
Plant and ingress to 7500 sph, JS to 1400 sph at height < 10m, clearcut	1069	14675 (74%)	8776 (54%)	4084 (58%)
Area available for incremental silviculture but not treated		**5095 (26%)**	**7455 (46%)**	**2899 (42%)**

The percentage values shown in parentheses indicate the proportion the area represents of the total area available for incremental silviculture. For example, for SAU01 under scenario S05a, an area of 739 ha was assigned to the regime *plant and ingress to 1400 sph, prune, clearcut*. This area represents 31% of the 2 396 ha available in SAU01 under scenario S05a for incremental silviculture at this establishment density.

The proportion of harvested area to be regenerated to each establishment density (1400, 3500, 7500 sph) was determined *a priori* based on the experience of District staff, and is shown in the regime diagrams (Appendix B). Total area regenerated includes planting. The average areas treated annually for all SAUs across the planning horizon (decades 1-25 for scenario S04; decades 1-20 for S05a and S05c) are shown in Table 4-2.

Table 4-2 Average areas treated annually, by management objective scenario.

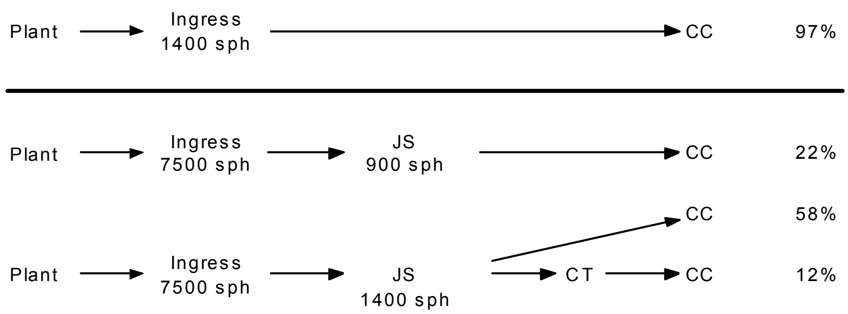
Average area treated annually (ha/yr)	S04	S05a	S05c
Planted	1607	1721	1152
Spaced	194	179	135
Pruned	-	79	59
Fertilized	75	64	42
Commercial-thinned	8	22	24

SAU01: ITG=1-7, 21-25, 28-30, Average SI=23.67

S04

For management objective S04 (to maximize volume production without regard to product mix) the dominant regime employed on SAU01 comprises stand establishment (planting plus ingress) at a density of 7500 sph and subsequent spacing where operationally feasible to 1400 sph (58%). Under this volume-maximizing scenario (S04) very little area (3%) established at 1400 sph is scheduled for incremental silviculture (Fig. 4-1).

Figure 4-1 Dominant regimes for SAU01, scenario S04 (maximum volume).

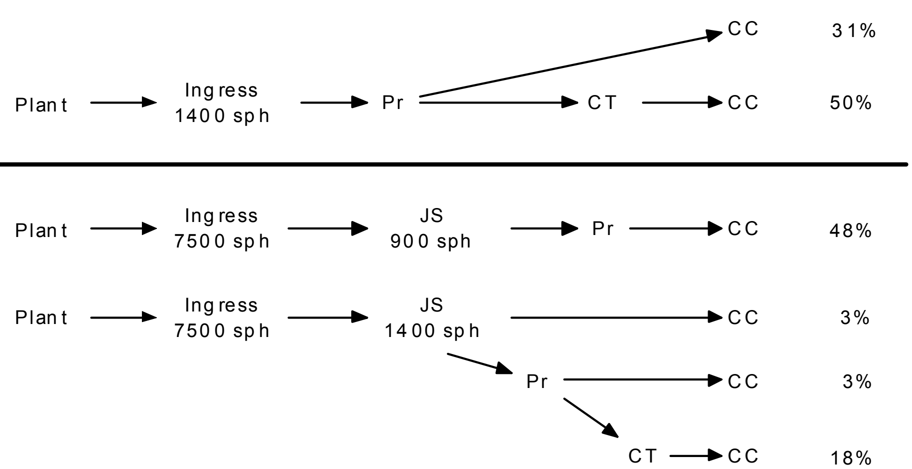


S05a

For management objective S05a (maximize product mix while maintaining the S04 harvest level) the dominant regimes include pruning (Fig. 4-2). Over 81% of the stands established at a density of 1400 sph will be pruned (no spacing), including 50% that will also be commercial-thinned.

The dominant regime for stands established at 7500 sph includes early spacing to 900 sph and pruning (over 48% of the total).

Figure 4-2 Dominant regimes for SAU01, scenario S05a (product mix at maximum volume).

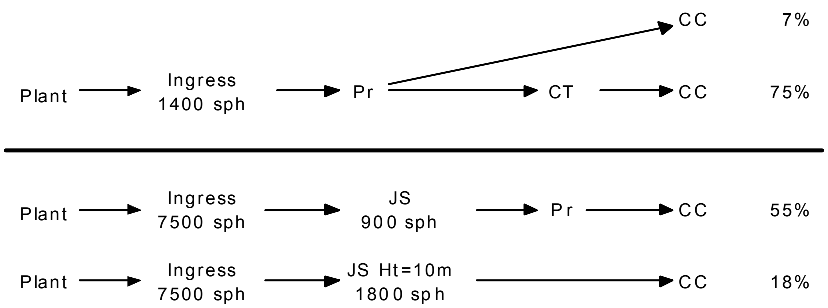


S05c

For management objective S05c (maximize product mix while allowing the harvest level to decrease from the S04 harvest level), the dominant regimes also include pruning (Fig. 4-3). When stands are established at 1400 sph, over 75% of the regenerated area will be pruned (no spacing) and commercial-thinned, with another 7% just pruned.

The dominant regime when stands are established at a density of 7500 sph includes early spacing to 900 sph and subsequent pruning (over 55% of the total established at 7500 sph). Under S05c, the area spaced late in the rotation accounts for 18% of the total area regenerated at 7500 sph.

Figure 4-3 Dominant regimes for SAU01, scenario S05c (product mix, reduced volume requirement).

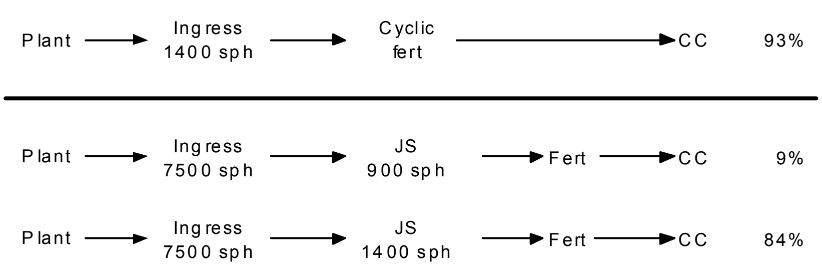


SAU02: ITG=1-7, 21-25, 28-30, Average SI=19.32

S04

For management objective S04 (to maximize volume production without regard to product mix), the dominant regimes employed on SAU02 include fertilization (Fig. 4-4). Most of the stands established at 1400 sph are treated with regimes that include cyclic fertilization (93% of the total area established at 1400 sph). The dominant regime for stands established at 7500 sph is early spacing to 1400 sph, and fertilization (84% of the total area established at 7500 sph).

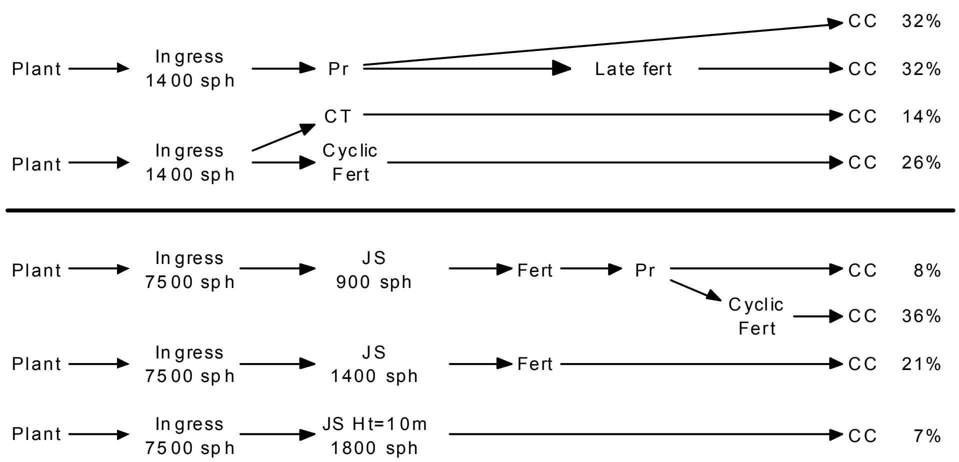
Figure 4-4 Dominant regimes for SAU02, scenario S04 (maximum volume).



S05a

The dominant regimes chosen when the objective is S05a (maximize product mix while maintaining the S04 harvest level) include pruning and fertilization (Fig. 4-5). The dominant regimes for an establishment density of 1400 sph include fertilization and pruning (48%). Regimes that include fertilization also dominate when establishment density is 7500 sph. Much of the fertilized area is also pruned at this density.

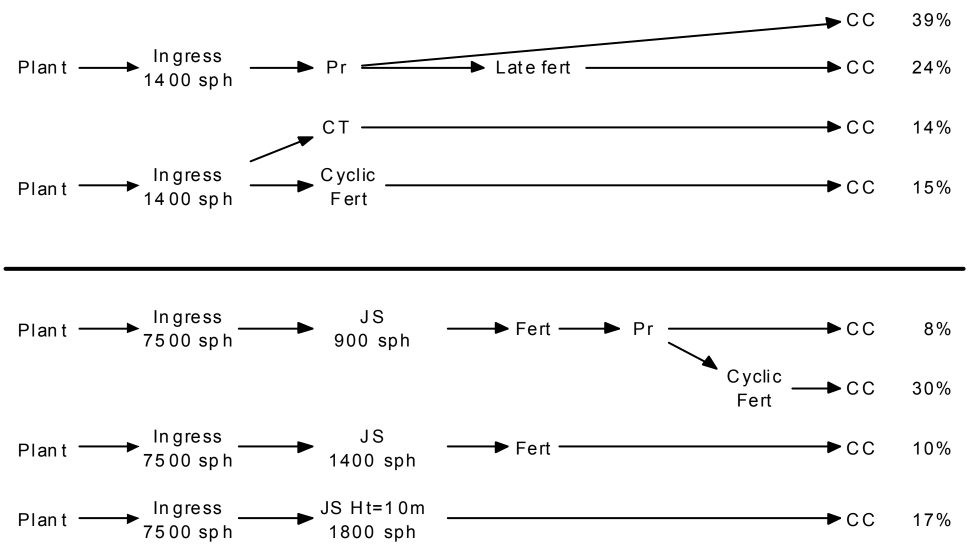
Figure 4-5 Dominant regimes for SAU02, scenario S05a (product mix at maximum volume).



S05c

For management objective S05c (maximizing product mix while allowing the harvest level to decrease from the S04 level) the dominant regimes include pruning and fertilization (Fig. 4-6). About 63% of the stands established at 1400 sph are fertilized and pruned. Regimes that include fertilization and pruning also dominate stands established at 7500 sph. Under S05c, the area spaced late accounts for 17% of the total area regenerated at 7500 sph.

Figure 4-6 Dominant regimes for SAU02, scenario S05c (product mix, reduced volume requirement).



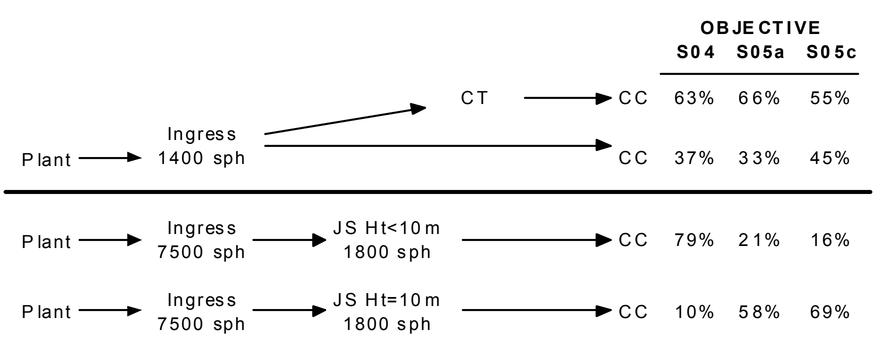
Regardless of objective and ingress allowed, over 92% of the total area regenerated was treated with incremental silviculture activities.

SAU03: ITG=9-10, Average SI=20.5

S04, S05a, S05c

The only incremental activity for stands established to 1400 sph is commercial thinning, regardless of objective (Fig.4-7). About half to two-thirds of the area available for incremental silviculture is treated with commercial thinning, depending on objective. However, for stands established at 7500 sph, most stands are treated with juvenile (early) spacing (79%) when the objective is to maximize volume production (S04), whereas late spacing is used when the objective is to maximize product mix (58% and 69% for S05a and S05c, respectively). When the objective is volume production only 10% of the area is treated with late spacing.

Figure 4-7 Dominant regimes for SAU03, all scenarios.



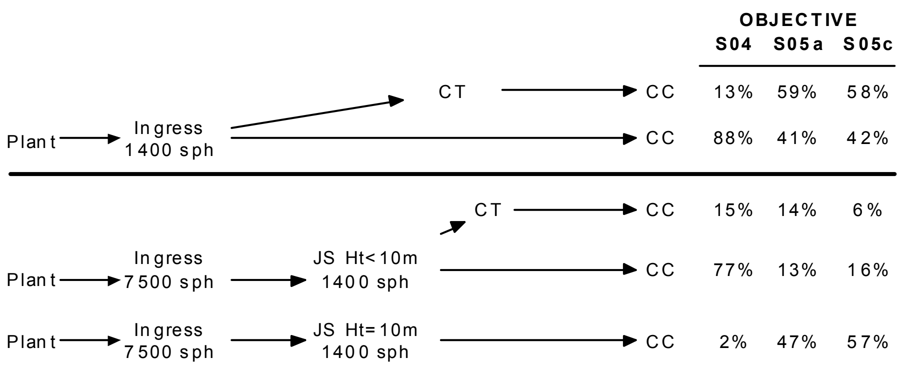
SAU04: ITG=9-10, Average SI=15.7

S04, S05a, S05c

The only incremental activity for stands established at 1400 sph is commercial thinning, regardless of objective (Fig. 4-8). Changing the objective from maximizing volume production (S04) to maximizing product mix (S05a, S05c) increases the amount of commercial thinning from 13% to almost 60%.

The dominant regimes implemented for stands established at 7500 sph comprise early spacing when the objective is S04 (77%), and mainly late spacing for the product mix objectives (47% and 57% for S05a and S05c respectively). Very little area is spaced late in the rotation when the objective is volume production (S04).

Figure 4-8 Dominant regimes for SAU04, all scenarios.



SAU05, SAU06

In silviculture analysis units SAU05 and SAU06, the only incremental silviculture regime specified was juvenile spacing of stands established to 7500 sph. Regardless of the management objective, more than half the area regenerated to 7500 sph was treated in this way.

Summary of Long-Term Strategy

The regimes chosen by the model identify appropriate management strategies for each silvicultural analysis unit and management objective scenario (Table 4-3, 4-4, 4-5). It is important to remember that the model chooses to implement regimes according to their contribution to the management objective (e.g., maximizing volume, or maximizing product mix), but that the regimes themselves were defined *a priori* by district staff and consultants. Note that in the high-density regimes used in this study, spacing always precedes fertilization—if a regime with fertilizing is chosen by the model, spacing will also be chosen.

Table 4-3 Incremental silvicultural regimes for maximizing volume production (scenario S04).

Silvicultural Analysis Unit	Establishment density (sph)	Regime
SAU01	1400	<no incremental silviculture>
	7500	Juvenile spacing to 900 or 1400 sph
SAU02	1400	Cyclic (15 yr) fertilization
	7500	Juvenile spacing to 1400 sph, followed by fertilization
SAU03	1400	Commercial thinning
	7500	Juvenile spacing to 1800 sph
SAU04	1400	Commercial thinning
	7500	Juvenile spacing to 1400 sph
		Juvenile spacing to 1400 sph, then commercial thinning
SAU05	1400	<no incremental silviculture>
	7500	Juvenile spacing to 1400 sph
SAU06	1400	<no incremental silviculture>
	7500	Juvenile spacing to 1400 sph

Table 4-4 Incremental silvicultural regimes for maximizing product mix while maintaining S04 harvest level (scenario S05a).

Silvicultural Analysis Unit	Establishment density (sph)	Regime
SAU01	1400	Pruning, commercial thinning
		Pruning
	7500	Juvenile spacing to 900 sph, pruning
		Juvenile spacing to 1400 sph, pruning, commercial thinning
SAU02	1400	Fertilizing, pruning, late fertilizing
		Fertilizing (cyclic)
		Fertilizing, pruning
	7500	Juvenile spacing to 900 sph, fertilizing, pruning, cyclic fertilizing
		Juvenile spacing to 1400 sph, fertilizing
SAU03	1400	Commercial thinning
	7500	Late spacing to 1800 sph
		Juvenile spacing to 1800 sph
SAU04	1400	Commercial thinning
	7500	Late spacing to 1400 sph
		Juvenile spacing to 1400 sph, commercial thinning
		Juvenile spacing to 1400 sph
SAU05	7500	Juvenile spacing to 1400 sph
SAU06	7500	Juvenile spacing to 1400 sph

Table 4-5 Incremental silvicultural regimes for maximizing product mix with reduced volume production (scenario S05c).

Silvicultural Analysis Unit	Establishment density (sph)	Regime
SAU01	1400	Pruning, commercial thinning
	7500	Juvenile spacing to 900 sph, pruning
SAU02	1400	Fertilizing, pruning
		Fertilizing, pruning, late fertilizing
		Fertilizing (cyclic)
		Commercial thinning
	7500	Juvenile spacing to 900 sph, fertilizing, pruning, fertilizing
		Juvenile spacing to 1800 sph
SAU03	1400	Commercial thinning
	7500	Late spacing to 1800 sph
		Juvenile spacing to 1800 sph
SAU04	1400	Commercial thinning
	7500	Late spacing to 1400 sph
		Juvenile spacing to 1400 sph
SAU05	7500	Juvenile spacing to 1400 sph
SAU06	7500	Juvenile spacing to 1400 sph

Under all objectives, regimes that include commercial thinning help maintain harvest levels while allowing the residual stand to be held long enough to develop dimensional characteristics. This practice is most evident in SAU01 and SAU04 when the objective is product mix. Over 45% of the total area established at a density of 1400 sph is treated with regimes that include commercial thinning.

For SAU03 and S04, when the objective is product mix, the regime most often implemented on stands established at 7500 sph includes late spacing. This regime is the only regime that contributes to the high quality sawlog objective, which must make up 50% of the clearwood harvest.

The analysis unit having the most intense activity is SAU02, in which over 92% of the total area regenerated is scheduled for incremental silviculture activities regardless of establishment density.

Comparing the regimes chosen for each scenario is also instructive and emphasizes the importance of clarifying management objectives before trying to prescribe silvicultural regimes. For instance, comparing Table 4-3 and to Tables 4-4 and 4-5 shows the shift to regimes involving fertilizing and pruning when the management objective is changed from maximizing volume to product mix.

4.2 Short-term Strategy (Tactical Plan)

The strategic plan identifies the regimes that maximally contribute to achieving the management objectives specified for the TSA. However, in the first decade the opportunity to implement those regimes is constrained by the order in which stands are harvested (the harvesting queue), and the initial silvicultural state of the forest (i.e., the inventory of existing managed timber). The tactical plan identifies the activities that are operationally feasible in the first decade (Table 4-6).

Most of the activities listed in Table 4-6 are planting after harvesting undertaken in the first decade. Incremental activities scheduled for the first decade are spacing and fertilizing of existing managed stands in SAU02, indicated by shaded rows in Table 4-6. All spaced stands will be subsequently fertilized. When the objective is to maximize product mix the fertilized and spaced stands will be subsequently pruned or fertilized, and in the case of stands established at 7500 sph and spaced to 900 sph the stands will be subsequently fertilized and pruned.

There may be other silvicultural opportunities on the TSA in the first decade that are consistent with the silviculture strategy discussed in Section 4.1 but not revealed in this analysis. The modeling methods employed in this study are designed for the efficient determination and evaluation of strategic plans. Greater resolution in the first decade requires spatial methods operating at a finer time scale than was used in this study.

Table 4-6 Tactical plan, comprising decade 1 strategic-plan activities (ha) for scenarios S04, S05a, S05c. In the first decade most of the silvicultural activity is simply planting after harvesting. Only in the existing managed stands of SAU02 are incremental activities scheduled (shaded rows).

Silvicultural Activity	Regime #	S04	S05a	S05c
SAU01: ITG 1-7, 21-25, 28-30, Average SI=23.76				
Plant and ingress to 1400 sph, no further mgmt, clearcut	1001	242	303	320
Plant and ingress to 1400 sph, clearcut	1001	364	455	481
Plant and ingress to 3500 sph, clearcut	1007	7071	8 845	9 347
Plant and ingress to 7500 sph, no further mgmt, clearcut	1008	970	1 213	1 282
Plant and ingress to 7500 sph, clearcut	1008	1 455	1 820	1 923
Total area regenerated		10 101	12 636	13 353
SAU02: ITG 1-7, 21-25, 28-30, Average SI=19.32				
Plant and ingress to 1400 sph, no further mgmt, clearcut	1021	104	312	276
Plant and ingress to 1400 sph, clearcut	1021	26	78	69
Plant and ingress to 3500 sph, clearcut	1026	1511	4 555	4 027
Plant and ingress to 7500 sph, no further mgmt, clearcut	1027	207	625	552
Plant and ingress to 7500 sph, clearcut	1027	311	937	828
Total area regenerated		2 159	6 506	5 753
Plant and ingress to 1400 sph, fert, prune, clearcut	20221	-	5	5
Plant and ingress to 7500 sph, JS to 900 sph at ht < 10m, fert, prune, clearcut	20291	-	27	28
Plant and ingress to 7500 sph, JS to 1400 sph at ht < 10m, fert, clearcut	20301	424	319	77
SAU03: ITG 9-10, Average SI=20.5				
Plant and ingress to 1400 sph, no further mgmt, clearcut	1039	2	1	2
Plant and ingress to 1400 sph, clearcut	1039	1	0	1
Plant and ingress to 3500 sph, clearcut	1042	28	17	27
Plant and ingress to 7500 sph, no further mgmt, clearcut	1043	4	2	4
Plant and ingress to 7500 sph, clearcut	1043	6	3	5
Total area regenerated		40	24	38
SAU04: ITG 9-10, Average SI=15.7				
Plant and ingress to 1400 sph, no further mgmt, clearcut	1048	5	-	-
Plant and ingress to 1400 sph, clearcut	1048	1	-	-
Plant and ingress to 3500 sph, clearcut	1053	72	-	-
Plant and ingress to 7500 sph, no further mgmt, clearcut	1054	10	-	-
Plant and ingress to 7500 sph, clearcut	1054	15	-	-
Total area regenerated		103	-	-
SAU05: ITG 8,11,12-20,26-27,31-34, Average SI=17.4				
Plant and ingress to 1400 sph, clearcut	1061	478	191	50
Plant and ingress to 3500 sph, clearcut	1061	2 230	893	234
Plant and ingress to 7500 sph, no further mgmt, clearcut	1062	191	77	20
Plant and ingress to 7500 sph, clearcut	1063	287	115	30
Total area regenerated		3 185	1 276	334
SAU06: All ITGs, All SIs not captured in SAU01-SAU05				
Plant and ingress to 1400 sph, clearcut	1066	22	-	-
Plant and ingress to 3500 sph, clearcut	1067	253	-	-
Plant and ingress to 7500 sph, no further mgmt, clearcut	1068	35	-	-
Plant and ingress to 7500 sph, clearcut	1068	52	-	-
Total area regenerated		361	-	-
TOTALS		**16 375**	**20 794**	**19 589**

5.0 Limitations of this Study

This study is a descriptive analysis. It quantifies the changes in productive capacity of the Golden TSA that result from modifying:

- management objective
- level of expenditure
- intensity of management

This study is not prescriptive: it makes no recommendations concerning the appropriate management objectives and does not specify a desirable level of expenditure and intensity of management.

Prescriptive studies should follow confirmation of the descriptive model

The critical components of the physical production model (yield tables, silviculture history, and regime diagrams) should be confirmed before addressing the question of the appropriate level of silviculture investment.

1. Accuracy and yield components of the Yield Tables

All of the biology in the modeling process is contained in the yield curves. The remainder of the model is an accounting system that selects yield tables and moves hectares through feasible sequences (regimes) of activities. Therefore the accuracy of the forest-level yield forecasts of the model is largely associated with the accuracy of the yield tables, specifically the managed-stand yield tables developed with TASS.

TASS-TIPSY issues

In the execution of this project, it became apparent that a top-height adjustment was required in the development of the TASS tables to make them consistent with TIPSY managed stand yield tables. The inclusion of this adjustment necessitated the development of "work-around" procedures to simulate the application of juvenile spacing, pruning and commercial thinning to fertilized stands and stands grown from select stock (incorporating genetic gain). The yield tables developed for this study (Appendix E)—and in particular, the "work-around" methods devised to deal with the TIPSY–TASS differences—should be reviewed for plausibility, and, subsequently, the forest-level productivity forecasts reported in this document should be considered in light of this review.

TASS is central to silviculture strategies

The accuracy and scope of TASS is central to the development of meaningful silviculture strategies and forest-level plans. The strengthening of TASS should be encouraged and its proper application in studies such as this should be clarified and documented.

2. Representation of Silvicultural History

The accurate assignment of existing managed stands to silvicultural states is essential if the model is to develop a plausible schedule of management actions in the initial decades. The assignment of the existing managed stands to the inventory data set used in this study (Appendix A) was accomplished with an *ad hoc* procedure that is unlikely to be accurate. The representation of silviculture history in the model should be reviewed in conjunction with consideration of the short-term silviculture program (section 4.2).

Ultimately the silvicultural history records should be spatially integrated with the inventory database.

3. Modelling of Regimes

Just as the biology in the modeling process is contained in the yield curves, the alternative development pathways that a stand may take as the result of management actions are embodied in the regime diagrams. The diagrams must be accurate with respect to the transitions that occur when a stand is treated, and must be of appropriate scope—i.e., include sufficient management actions and development pathways to account for the current and future management of the stands.

Operability issues

Of special concern are limitations on management actions that are related to operability factors not included in the silvicultural state of the model. For example, according to a regime diagram, a stand may be operable for commercial thinning if certain target volume and residual tree requirements are met. However, the silviculturists may know that only 30% of the terrain is appropriate for commercial thinning, regardless of whether the stand meets the target volume and residual tree criteria. These operability constraints must be implemented in the model in order to obtain reasonable results. **We used estimates of operability supplied by District staff.**

Appendix A — Current Silvicultural State of the TSA

Assignment of existing managed stands

The accurate assignment of existing managed stands to silvicultural states is essential if the model is to develop a plausible schedule of management actions in the initial decades.

The silviculture state of a stand records the information that the manager needs in order to determine what silviculture activities are immediately feasible (not including operational considerations such as harvesting restrictions, accessibility, terrain, or markets). For example, the species mix, age, density, basal area, crown closure may be the variables that the silviculturist considers when deciding the treatment of a stand. These state variables change over time with the development of the stand (growth, competition, mortality) and with silviculture actions (e.g., juvenile spacing).

Describing the silviculture state at this level of detail is appropriate for tactical, program-level planning, but is too detailed for strategic, forest-level planning. For the purposes of this project, the silviculture state of forest stands will be described by the list of treatments already applied. The possible silviculture states for the Golden TSA are listed in Table B-1 (Appendix B).

Method

The assignment of the existing managed stands to the inventory data set used in this study was accomplished with an *ad hoc* procedure. From ISIS, a table was constructed that listed for each analysis unit and age class combination the total area recorded as planted, juvenile spaced, pruned and fertilized.

Each of these records (analysis unit x age class) was subdivided into additional records according to a set of rules based on logical silviculture practices:

1. The priority for areas to be fertilized will be, first, areas pruned, second, areas spaced but not pruned, and third, areas planted but not subsequently spaced or pruned.
2. The priority for areas to be pruned will be, first, areas spaced, and second, areas planted but not subsequently spaced.
3. The priority for areas to be spaced will be areas previously planted.
4. If the area fertilized or pruned or spaced exceeds the area planted, than it is assumed that the treatments were applied to natural stands, and the same hierarchy of treatment priorities applies.

While it is unlikely that applying these rules to the ISIS data has resulted in the exact silviculture state of the TSA, the procedure is unambiguous and results in a unique set of silviculture states for each age class of each analysis unit. Table A-1 summarizes the relevant silvicultural history for the Golden TSA as obtained from ISIS. Table A-2 shows how this history was allocated across the inventory as existing managed stands. Hectares for which no site index value was recorded were assigned to one of the medium-site analysis units (SAU 2 or SAU 4), depending on their species composition, and were assigned the weighted-average site index.

Table A-1 Silviculture history of the Golden TSA (source: ISIS).

Activity Year	JS	FE	PR	Total by Activity Year
1 978	98			98
1 979				-
1 980				-
1 981	23			23
1 982	51			51
1 984	113			113
1 985				-
1 986	30			30
1 987	122	269		391
1 988	336			336
1 989	305	439		744
1 990	296			296
1 991	572			572
1 992	450	387		837
1 993	314		47	361
1 994	39		16	55
1 995	195			195
1 996	507		193	700
1 997	224		15	240
1 998	126		24	150
2 000			22	22
	3 800	**1 095**	**318**	**5 212**

Criteria used to generate silviculture history summary

1 Silv. Base Code = JS or PR for FE
2 Actual Fund Source = RBM or VG or FR (VOI and RBI did not make any difference)
3 Silviculture Objective (for PR specified an objective of WQI or Null to weed out the Pw pruning which is not icremental silviculture)
4 Results Indicator =Y

Table A-2 Initial silvicultural state of the Golden TSA.

State Code	Silvicultural State	Inoperable	Operable Excluded	SAU1 Fd,Sx SI >22 11%	SAU2 Fd,Sx SI <22 25%	SAU3 Cw SI >19 0.4%	SAU4 CW 14>=SI<=18.9 0.3%	SAU5 H-B SI>14+ 15%	SAU6 others others 48%	Total
N	Natural	216 570	54 062	14 750	28 530	69	351	14 800	60 040	389 173
e14	Plt to 1200 sph, ing to 1400 sph	5 010	9 600	220	538	34	10	1 517	3 000	19 930
e14-P	Plt to 1200 sph, ing to 1400 sph, Pr				84					84
e35	Plt to 1200 sph, ing to 3500 sph			2 572	6 275	398	116	7 080	14 002	30 442
e75	Plt to 1200 sph, ing to 7500 sph			882	2 151	136	40	1 517	3 000	7 727
e7509EP	Plt to 1200 sph, ing to 7500 sph, Js to 900 sph, Pr				214					214
e7514E	Plt to 1200 sph, ing to 7500 sph, Js at age 20 to 1400 sph			356	2 322		29	417		3 124
e7514L	Plt to 1200 sph, ing to 7500 sph, Js at age > 20 to 1400 sph						28			28
e7518E	Plt to 1200 sph, ing to 7500 sph, Js at age 20 to 1800 sph					20				20
e7518E--F	Plt to 1200 sph, ing to 7500 sph, Js at age 20 to 1800 sph, Fe				1 094					1 094
e7518L	Plt to 1200 sph, ing to 7500 sph, Js at age > 20 to 1800 sph					21				21
	Total	221 580	63 662	18 780	41 208	678	574	25 332	80 042	451 856

Codes: Plt - Planted
Ing - Ingressed
Fe - Fertilized
Js - Juvenile spaced
Pr - Pruned

Appendix B — Regime Diagrams

Regime diagrams are the "blueprint" for the construction of the silviculture modules of the forest-level model. The silvicultural regime specifies a sequence of management actions that may be applied to the stands of the silvicultural analysis unit for which the regime was designed. Each of these actions causes the stand to change silvicultural state, and so alternative regimes result in alternative development pathways that a silvicultural analysis unit may follow.

A series of alternative regimes was specified for each of the 6 silvicultural analysis units defined for the Golden TSA by district staff, and the alternative development pathways were plotted (Figures B-1 to B-12). The arcs of these diagrams correspond to silvicultural actions and the nodes represent the silvicultural state of the stand. Tables B-1 and B-2 explain the codes used in these diagrams and Tables B-3 and B-4 list the treatment specification for each feasible regime. Table B-5 is the spreadsheet of specifications for the TASS managed stand yield tables. Note that clearcut harvesting (clc_m) may occur from any treatment state (including planting and ingress only), but the activity arcs that would lead back to regenerating (R) are not shown in the regime diagrams in order to maintain legibility. Also, forest stands are not required to progress along a pathway— a stand may remain in any state indefinitely.

Table B-1 Activity codes, Golden TSA.

Code	Activity Description
clc_managed	Clearcut managed stands
cThin	Commercial thinning of operable stands
plntCycleFert	Plant to 1400 then cyclic fertilization
plntFert	Plant to 1400 then fertilization
plntFertPrune	Plant to 1400, fert, prune
plntFertPruneLateFert	plntFertPruneLateFert N
plntLateFert	Plant to 1400 then late fertilization
plntPrune	Plant to 1400 prune
plntSAU	Plant to various densities
plntThinLateFert	Plant to 1400, CT, late fert
space1400Early	JS to 1400 at height < 10m
space1400Fert	JS to 1400 then fert
space1400Late	JS to 1400 at height = 10m
space1400Prune	JS to 1400 sph then prune
space1800Early	JS to 1800 at height < 10m
space1800EarlyFert	JS to 1800 early < 10m then fert
space1800Late	JS to 1800 at height = 10m
space1800ThinLateFert	JS to 1800 Early, CT, late fert
space900	JS to 900 sph
space900Fert	JS to 900 then fert
space900FertPrune	JS to 900, fert, prune
space900Prune	JS to 900 sph then prune
space900PruneCyclicFert	JS to 900, prune, cyclic fert

Table B-2 State codes, Golden TSA.

Code	Treatment state
N	Natural stands
12	Planted to 1200 sph, ingress to 1200 sph
14	Planted to 1200 sph, ingress to 1400 sph
14---F	Planted to 1200 sph, ingress to 1400 sph, fertilized
14---FC	Planted to 1200 sph, ingress to 1400 sph, multiple fertilizations
14---FL	Planted to 1200 sph, ingress to 1400 sph, late fertilization
14-P	Planted to 1200 sph, ingress to 1400 sph, pruned
14-P-F	Planted to 1200 sph, ingress to 1400 sph, fertilized, pruned
14-P-FL	Planted to 1200 sph, ingress to 1400 sph, fertilized, pruned, late fertilization
14-PT	Planted to 1200 sph, ingress to 1400 sph, pruned, commercial-thinned
14--T	Planted to 1200 sph, ingress to 1400 sph, commercial-thinned
14--TFL	Planted to 1200 sph, ingress to 1400 sph, commercial-thinned, late fertilization
35	Planted to 1200 sph, ingress to 3500 sph
75	Planted to 1200 sph, ingress to 7500 sph
7509E	Planted to 1200 sph, ingress to 7500 sph, spaced to 900 sph
7509E--F	Planted to 1200 sph, ingress to 7500 sph, spaced to 900 sph, fertilized
7509EP	Planted to 1200 sph, ingress to 7500 sph, spaced to 900 sph, pruned
7509EP-F	Planted to 1200 sph, ingress to 7500 sph, spaced to 900 sph, pruned, fertilized
7509EP-FC	Planted to 1200 sph, ingress to 7500 sph, spaced to 900 sph, pruned, multiple fertilizations
7514E	Planted to 1200 sph, ingress to 7500 sph, spaced at age 20 to 1400 sph
7514E--FC	Planted to 1200 sph, ingress to 7500 sph, spaced to 1400 sph, multiple fertilizations
7514EP	Planted to 1200 sph, ingress to 7500 sph, spaced to 1400 sph, pruned
7514EPT	Planted to 1200 sph, ingress to 7500 sph, spaced to 1400 sph, pruned, commercial-thinned
7514E-T	Planted to 1200 sph, ingress to 7500 sph, spaced to 1400 sph, commercial-thinned
7514L	Planted to 1200 sph, ingress to 7500 sph, spaced at age > 20 to 1400 sph
7518E	Planted to 1200 sph, ingress to 7500 sph, spaced at age 20 to 1800 sph
7518E--F	Planted to 1200 sph, ingress to 7500 sph, spaced at age 20 to 1800 sph, fertilized
7518E-T	Planted to 1200 sph, ingress to 7500 sph, spaced at age 20 to 1800 sph, commercial-thinned
7518E-TF	Planted to 1200 sph, ingress to 7500 sph, spaced at age 20 to 1800 sph, commercial-thinned, fertilized
7518E-TFL	Planted to 1200 sph, ingress to 7500 sph, spaced at age 20 to 1800 sph, commercial-thinned, late fertilization
7514EPT	Planted to 1200 sph, ingress to 7500 sph, spaced to 1400 sph, pruned, commercial-thinned
7514E-T	Planted to 1200 sph, ingress to 7500 sph, spaced to 1400 sph, commercial-thinned
7514L	Planted to 1200 sph, ingress to 7500 sph, spaced at age > 20 to 1400 sph
7518E	Planted to 1200 sph, ingress to 7500 sph, spaced at age 20 to 1800 sph
7518E--F	Planted to 1200 sph, ingress to 7500 sph, spaced at age 20 to 1800 sph, fertilized
7518E-T	Planted to 1200 sph, ingress to 7500 sph, spaced at age 20 to 1800 sph, commercial-thinned
7518E-TF	Planted to 1200 sph, ingress to 7500 sph, spaced at age 20 to 1800 sph, commercial-thinned, fertilized
7518E-TFL	Planted to 1200 sph, ingress to 7500 sph, spaced at age 20 to 1800 sph, commercial-thinned, late fertilization

Table B-3 Fertilization schedule, Golden TSA

Managed Regime #	State Label	SAU	Sp	SI	Fertilize at age:
40211	14---F	2	FdSxPl	19.32	20
40212	14--FC	2	FdSxPl	19.32	20,35,50
40213	14--FL	2	FdSxPl	19.32	70
4023	14--TFL	2	FdSxPl	19.32	70
4024	14--TFL	2	FdSxPl	19.32	70
4025	14--TFL	2	FdSxPl	19.32	70
4028	7509E--F	2	FdSxPl	19.32	20
4030	7514E--FC	2	FdSxPl	19.32	20,35,50
4034	7518E--F	2	FdSxPl	19.32	20,35
40351	7518E-TF	2	FdSxPl	19.32	20,35
40361	7518E-TF	2	FdSxPl	19.32	20,35
40371	7518E-TF	2	FdSxPl	19.32	20,35
40352	7518E-TFL	2	FdSxPl	19.32	20,35,70
40362	7518E-TFL	2	FdSxPl	19.32	20,35,80
40372	7518E-TFL	2	FdSxPl	19.32	20,35,90

Table B-4 Management assumptions for TASS yield curves, Golden TSA.

1 Utilization levels

min dbh	max stump	min top dib
17.5 cm	30 cm	10 cm

2 Operational adjustment factors

OAF 1	15
OAF 2	5

3 Juvenile spacing

- leave well-spaced trees, favouring tallest

4 Commercial thinning

- thin from below: removing shortest, and leaving well-spaced trees, favouring fattest
- CT stems leave takes precedence over volume remove

5 Pruning

- retain 30% live crown on first lift, 40% on second lift (minimum live crown retained on shortest trees), with majority of trees having 40% to 50% live crown.
- prune all trees that meet the crown ratio condition, OR the largest trees (ordered by diameter) that meet the CR condition up to the max number specified in the spreadsheet, e.g., the "best 300".

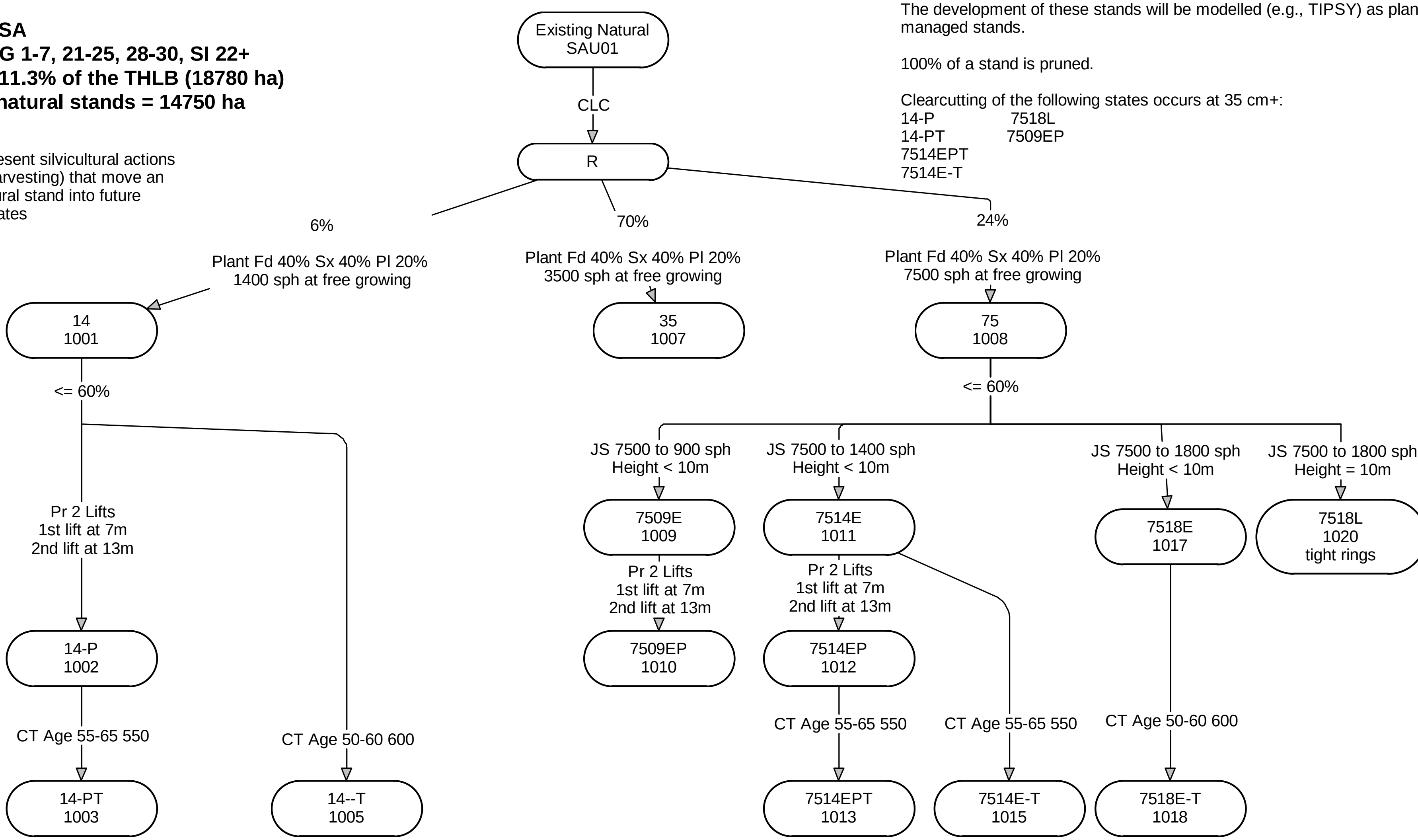
SAU	Managed Regime #	Height Adjustment	State Label	Plant species	site index range	Weighted average site index	Regen Lag	Plant tph	natural ingress species	natural ingress tph	Density after ingrowth	Pct Age	PCT leave tph	1st prune dominant ht (m)	1st prune age (yrs)	1st prune lift (m)	2nd prune dominant ht (m)	2nd prune age (yrs)	2nd prune lift (m)	CT Utilization Height > m	CT age	CT leave >tph	CT remove > m3/ha	1st Fertilization	2nd Fertilization	3rd Fertilization
1	1001	yes	14	Fd40Sx40Pl20	SI>=22	23.76	2	1200	FdSxPl	200	1400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1002	yes	14-P	Fd40Sx40Pl20	SI>=22	23.76	2	1200	FdSxPl	200	1400	0	0	7	19	2.8	13	31	5.6	0	0	0	0	0	0	0
1	1003	yes	14-PT	Fd40Sx40Pl20	SI>=22	23.76	2	1200	FdSxPl	200	1400	0	0	7	19	2.8	13	31	5.6	22	55	550	100	0	0	0
1	1004	yes	14-PT	Fd40Sx40Pl20	SI>=22	23.76	2	1200	FdSxPl	200	1400	0	0	7	19	2.8	13	31	5.6	22	65	550	100	0	0	0
1	1005	yes	14--T	Fd40Sx40Pl20	SI>=22	23.76	2	1200	FdSxPl	200	1400	0	0	0	0	0	0	0	0	22	50	600	100	0	0	0
1	1006	yes	14--T	Fd40Sx40Pl20	SI>=22	23.76	2	1200	FdSxPl	200	1400	0	0	0	0	0	0	0	0	22	60	600	100	0	0	0
1	1008	yes	75	Fd40Sx40Pl20	SI>=22	23.76	2	1200	FdSxPl	6300	7500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1009	yes	7509E	Fd40Sx40Pl20	SI>=22	23.76	2	1200	FdSxPl	6300	7500	17	900	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1010	yes	7509EP	Fd40Sx40Pl20	SI>=22	23.76	2	1200	FdSxPl	6300	7500	17	900	7	19	2.8	13	31	5.6	0	0	0	0	0	0	0
1	1011	yes	7514E	Fd40Sx40Pl20	SI>=22	23.76	2	1200	FdSxPl	6300	7500	17	1400	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1012	yes	7514EP	Fd40Sx40Pl20	SI>=22	23.76	2	1200	FdSxPl	6300	7500	17	1400	7	19	2.8	13	31	5.6	0	0	0	0	0	0	0
1	1013	yes	7514EPT	Fd40Sx40Pl20	SI>=22	23.76	2	1200	FdSxPl	6300	7500	17	1400	7	19	2.8	13	31	5.6	22	55	550	100	0	0	0
1	1014	yes	7514EPT	Fd40Sx40Pl20	SI>=22	23.76	2	1200	FdSxPl	6300	7500	17	1400	7	19	2.8	13	31	5.6	22	65	550	100	0	0	0
1	1015	yes	7514E-T	Fd40Sx40Pl20	SI>=22	23.76	2	1200	FdSxPl	6300	7500	17	1400	0	0	0	0	0	0	22	55	550	100	0	0	0
1	1016	yes	7514E-T	Fd40Sx40Pl20	SI>=22	23.76	2	1200	FdSxPl	6300	7500	17	1400	0	0	0	0	0	0	22	65	550	100	0	0	0
1	1017	yes	7518E	Fd40Sx40Pl20	SI>=22	23.76	2	1200	FdSxPl	6300	7500	17	1800	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1018	yes	7518E-T	Fd40Sx40Pl20	SI>=22	23.76	2	1200	FdSxPl	6300	7500	17	1800	0	0	0	0	0	0	22	50	600	100	0	0	0
1	1019	yes	7518E-T	Fd40Sx40Pl20	SI>=22	23.76	2	1200	FdSxPl	6300	7500	17	1800	0	0	0	0	0	0	22	60	600	100	0	0	0
1	1020	yes	7518L	Fd40Sx40Pl20	SI>=22	23.76	2	1200	FdSxPl	6300	7500	24	1800	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1021	yes	14	Fd40Sx30Pl30	17<=SI<22	19.32	2	1200	FdSxPl	200	1400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1022	yes	14-P	Fd40Sx30Pl30	17<=SI<22	19.32	2	1200	FdSxPl	200	1400	0	0	7	23	2.8	13	38	5.6	0	0	0	0	0	0	0
2	1023	yes	14--T	Fd40Sx30Pl30	17<=SI<22	19.32	2	1200	FdSxPl	200	1400	0	0	0	0	0	0	0	0	22	65	600	100	0	0	0
2	1024	yes	14--T	Fd40Sx30Pl30	17<=SI<22	19.32	2	1200	FdSxPl	200	1400	0	0	0	0	0	0	0	0	22	75	600	100	0	0	0
2	1025	yes	14--T	Fd40Sx30Pl30	17<=SI<22	19.32	2	1200	FdSxPl	200	1400	0	0	0	0	0	0	0	0	22	85	600	100	0	0	0
2	1026	yes	35	Fd40Sx40Pl20	17<=SI<22	19.32	2	1200	FdSxPl	2300	3500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1027	yes	75	Fd40Sx40Pl20	17<=SI<22	19.32	2	1200	FdSxPl	6300	7500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1028	yes	7509E	Fd40Sx40Pl20	17<=SI<22	19.32	2	1200	FdSxPl	6300	7500	20	900	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1029	yes	7509E-P	Fd40Sx40Pl20	17<=SI<22	19.32	2	1200	FdSxPl	6300	7500	20	900	7	23	2.8	13	38	5.6	0	0	0	0	0	0	0
2	1030	yes	7514E	Fd40Sx40Pl20	17<=SI<22	19.32	2	1200	FdSxPl	6300	7500	20	1400	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1031	yes	7514E-T	Fd40Sx40Pl20	17<=SI<22	19.32	2	1200	FdSxPl	6300	7500	20	1400	0	0	0	0	0	0	22	70	550	100	0	0	0
2	1032	yes	7514E-T	Fd40Sx40Pl20	17<=SI<22	19.32	2	1200	FdSxPl	6300	7500	20	1400	0	0	0	0	0	0	22	80	550	100	0	0	0
2	1033	yes	7514E-T	Fd40Sx40Pl20	17<=SI<22	19.32	2	1200	FdSxPl	6300	7500	20	1400	0	0	0	0	0	0	22	90	550	100	0	0	0
2	1034	yes	7518E	Fd40Sx40Pl20	17<=SI<22	19.32	2	1200	FdSxPl	6300	7500	20	1800	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1035	yes	7518E-T	Fd40Sx40Pl20	17<=SI<22	19.32	2	1200	FdSxPl	6300	7500	20	1800	0	0	0	0	0	0	22	60	550	100	0	0	0
2	1036	yes	7518E-T	Fd40Sx40Pl20	17<=SI<22	19.32	2	1200	FdSxPl	6300	7500	20	1800	0	0	0	0	0	0	22	70	550	100	0	0	0
2	1037	yes	7518E-T	Fd40Sx40Pl20	17<=SI<22	19.32	2	1200	FdSxPl	6300	7500	20	1800	0	0	0	0	0	0	22	80	550	100	0	0	0
2	1038	yes	7518L	Fd40Sx40Pl20	17<=SI<22	19.32	2	1200	FdSxPl	6300	7500	30	1800	0	0	0	0	0	0	0	0	0	0	0	0	0
3	1039	yes	14	Cw20Sx60Hw20	SI>=19	20.5	2	1200	CwSxHw	200	1400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	1040	yes	14--T	Cw20Sx60Hw20	SI>=19	20.5	2	1200	CwSxHw	200	1400	0	0	0	0	0	0	0	0	22	55	550	100	0	0	0
3	1041	yes	14--T	Cw20Sx60Hw20	SI>=19	20.5	2	1200	CwSxHw	200	1400	0	0	0	0	0	0	0	0	22	65	550	100	0	0	0
3	1042	yes	35	Cw20Sx60Hw20	SI>=19	20.5	2	1200	CwSxHw	2300	3500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	1043	yes	75	Cw20Sx60Hw20	SI>=19	20.5	2	1200	CwSxHw	6300	7500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	1044	yes	7518E	Cw20Sx60Hw20	SI>=19	20.5	2	1200	CwSxHw	6300	7500	27	1800	0	0	0	0	0	0	0	0	0	0	0	0	0
3	1045	yes	7518E-T	Cw20Sx60Hw20	SI>=19	20.5	2	1200	CwSxHw	6300	7500	27	1800	0	0	0	0	0	0	22	55	550	100	0	0	0
3	1046	yes	7518E-T	Cw20Sx60Hw20	SI>=19	20.5	2	1200	CwSxHw	6300	7500	27	1800	0	0	0	0	0	0	22	65	550	100	0	0	0
3	1047	yes	7518L	Cw20Sx60Hw20	SI>=19	20.5	2	1200	CwSxHw	6300	7500	36	1800	0	0	0	0	0	0	0	0	0	0	0	0	0
4	1048	yes	14	Cw20Sx60Hw20	14<=SI<19	15.7	2	1200	CwSxHw	200	1400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	1049	yes	14--T	Cw20Sx60Hw20	14<=SI<19	15.7	2	1200	CwSxHw	200	1400	0	0	0	0	0	0	0	0	22	70	600	100	0	0	0
4	1050	yes	14--T	Cw20Sx60Hw20	14<=SI<19	15.7	2	1200	CwSxHw	200	1400	0	0	0	0	0	0	0	0	22	80	600	100	0	0	0
4	1051	yes	14--T	Cw20Sx60Hw20	14<=SI<19	15.7	2	1200	CwSxHw	200	1400	0	0	0	0	0	0	0	0	22	90	600	100	0	0	0
4	1052	yes	14--T	Cw20Sx60Hw20	14<=SI<19	15.7	2	1200	CwSxHw	200	1400	0	0	0	0	0	0	0	0	22	100	600	100	0	0	0
4	1053	yes	35	Cw20Sx60Hw20	14<=SI<19	15.7	2	1200	CwSxHw	2300	3500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	1054	yes	75	Cw20Sx60Hw20	14<=SI<19	15.7	2	1200	CwSxHw	6300	7500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	1055	yes	7514E	Cw20Sx60Hw20	14<=SI<19	15.7	2	1200	CwSxHw	6300	7500	34	1400	0	0	0	0	0	0	0	0	0	0	0	0	0
4	1056	yes	7514E-T	Cw20Sx60Hw20	14<=SI<19	15.7	2	1200	CwSxHw	6300	7500	34	1400	0	0	0	0	0	0	22	80	550	100	0	0	0
4	1057	yes	7514E-T	Cw20Sx60Hw20	14<=SI<19	15.7	2	1200	CwSxHw	6300	7500	34	1400	0	0	0	0	0	0	22	90	550	100	0	0	0
4	1058	yes	7514E-T	Cw20Sx60Hw20	14<=SI<19	15.7	2	1200	CwSxHw	6300	7500	34	1400	0	0	0	0	0	0	22	100	550	100	0	0	0
4	1059	yes	7514L	Cw20Sx60Hw20	14<=SI<19	15.7	2	1200	CwSxHw	6300	7500	46	1400	0	0	0	0	0	0	0	0	0	0	0	0	0
5	1061	yes	14	Sx50Bl20Hw20Pl10	SI>=14	17.4	2	1200	SxBlHwPl	200	1400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	1062	yes	35	Sx50Bl20Hw20Pl10	SI>=14	17.4	2	1200	SxBlHwPl	2300	3500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	1063	yes	75	Sx50Bl20Hw20Pl10	SI>=14	17.4	2	1200	SxBlHwPl	6300	7500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	1064	yes	7514E	Sx50Bl20Hw20Pl10	SI>=14	17.4	2	1200	SxBlHwPl	6300	7500	31	1400	0	0	0	0	0	0	0	0	0	0	0	0	0

SAU	Managed Regime #	Height Adjustment	State Label	Plant species	site index range	Weighted average site index	Regen Lag	Plant tph	natural ingress species	natural ingress tph	Density after ingrowth	Pct Age	PCT leave tph	1st prune dominant ht (m)	1st prune age (yrs)	1st prune lift (m)	2nd prune dominant ht (m)	2nd prune age (yrs)	2nd prune lift (m)	CT Utilization Height > m	CT age	CT leave >tph	CT remove > m3/ha	1st Fertilization	2nd Fertilization	3rd Fertilization
6	1066	yes	14	Sx40Bl40Pl20	All low	12.1	2	1200	SxBlHwPl	200	1400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	1067	yes	35	Sx40Bl40Pl20	All low	12.1	2	1200	SxBlHwPl	2300	3500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	1068	yes	75	Sx40Bl40Pl20	All low	12.1	2	1200	SxBlHwPl	6300	7500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	1069	yes	7514E	Sx40Bl40Pl20	All low	12.1	2	1200	SxBlHwPl	6300	7500	42	1400	0	0	0	0	0	0	0	0	0	0	0	0	0
No height adjustment, not fertilized																										
2	5021	no	14	Fd40Sx30Pl30	17<=SI<22	19.32	2	1200	FdSxPl	200	1400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	5022	no	14-P	Fd40Sx30Pl30	17<=SI<22	19.32	2	1200	FdSxPl	200	1400	0	0	7	23	2.8	13	38	5.6	0	0	0	0	0	0	0
2	5023	no	14--T	Fd40Sx30Pl30	17<=SI<22	19.32	2	1200	FdSxPl	200	1400	0	0	0	0	0	0	0	0	22	65	600	100	0	0	0
2	5024	no	14--T	Fd40Sx30Pl30	17<=SI<22	19.32	2	1200	FdSxPl	200	1400	0	0	0	0	0	0	0	0	22	75	600	100	0	0	0
2	5025	no	14--T	Fd40Sx30Pl30	17<=SI<22	19.32	2	1200	FdSxPl	200	1400	0	0	0	0	0	0	0	0	22	85	600	100	0	0	0
2	5028	no	7509E	Fd40Sx40Pl20	17<=SI<22	19.32	2	1200	FdSxPl	6300	7500	20	900	0	0	0	0	0	0	0	0	0	0	0	0	0
2	5029	no	7509E-P	Fd40Sx40Pl20	17<=SI<22	19.32	2	1200	FdSxPl	6300	7500	20	900	7	23	2.8	13	38	5.6	0	0	0	0	0	0	0
2	5030	no	7514E	Fd40Sx40Pl20	17<=SI<22	19.32	2	1200	FdSxPl	6300	7500	20	1400	0	0	0	0	0	0	0	0	0	0	0	0	0
2	5034	no	7518E	Fd40Sx40Pl20	17<=SI<22	19.32	2	1200	FdSxPl	6300	7500	20	1800	0	0	0	0	0	0	0	0	0	0	0	0	0
2	5035	no	7518E-T	Fd40Sx40Pl20	17<=SI<22	19.32	2	1200	FdSxPl	6300	7500	20	1800	0	0	0	0	0	0	22	60	550	100	0	0	0
2	5036	no	7518E-T	Fd40Sx40Pl20	17<=SI<22	19.32	2	1200	FdSxPl	6300	7500	20	1800	0	0	0	0	0	0	22	70	550	100	0	0	0
2	5037	no	7518E-T	Fd40Sx40Pl20	17<=SI<22	19.32	2	1200	FdSxPl	6300	7500	20	1800	0	0	0	0	0	0	22	80	550	100	0	0	0
No height adjustment, fertilized																										
2	30211	no	14---F	Fd40Sx30Pl30	17<=SI<22	19.32	2	1200	FdSxPl	200	1400	20	1400	0	0	0	0	0	0	0	0	0	0	20	0	0
2	30212	no	14---FC	Fd40Sx30Pl30	17<=SI<22	19.32	2	1200	FdSxPl	200	1400	20	1400	0	0	0	0	0	0	0	0	0	0	20	35	50
2	30213	no	14---FL	Fd40Sx30Pl30	17<=SI<22	19.32	2	1200	FdSxPl	200	1400	20	1400	0	0	0	0	0	0	0	0	0	0	70	0	0
2	30221	no	14-P-F	Fd40Sx30Pl30	17<=SI<22	19.32	2	1200	FdSxPl	200	1400	20	1400	7	23	2.8	13	38	5.6	0	0	0	0	20	0	0
2	30222	no	14-P-FL	Fd40Sx30Pl30	17<=SI<22	19.32	2	1200	FdSxPl	200	1400	20	1400	7	23	2.8	13	38	5.6	0	0	0	0	20	70	0
2	3023	no	14--TFL	Fd40Sx30Pl30	17<=SI<22	19.32	2	1200	FdSxPl	200	1400	0	0	0	0	0	0	0	0	22	65	600	100	70	0	0
2	3024	no	14--TFL	Fd40Sx30Pl30	17<=SI<22	19.32	2	1200	FdSxPl	200	1400	0	0	0	0	0	0	0	0	22	75	600	100	70	0	0
2	3025	no	14--TFL	Fd40Sx30Pl30	17<=SI<22	19.32	2	1200	FdSxPl	200	1400	0	0	0	0	0	0	0	0	22	85	600	100	70	0	0
2	3028	no	7509E--F	Fd40Sx40Pl20	17<=SI<22	19.32	2	1200	FdSxPl	6300	7500	20	900	0	0	0	0	0	0	0	0	0	0	20	0	0
2	30291	no	7509E-PF	Fd40Sx40Pl20	17<=SI<22	19.32	2	1200	FdSxPl	6300	7500	20	900	7	23	2.8	13	38	5.6	0	0	0	0	20	0	0
2	30292	no	7509E-PFC	Fd40Sx40Pl20	17<=SI<22	19.32	2	1200	FdSxPl	6300	7500	20	900	7	23	2.8	13	38	5.6	0	0	0	0	20	35	50
2	3030	no	7514E--FC	Fd40Sx40Pl20	17<=SI<22	19.32	2	1200	FdSxPl	6300	7500	20	1400	0	0	0	0	0	0	0	0	0	0	20	35	50
2	3034	no	7518E--F	Fd40Sx40Pl20	17<=SI<22	19.3	2	1200	FdSxPl	6300	7500	20	1800	0	0	0	0	0	0	0	0	0	0	20	35	0
2	30351	no	7518E-TF	Fd40Sx40Pl20	17<=SI<22	19.3	2	1200	FdSxPl	6300	7500	20	1800	0	0	0	0	0	0	22	60	550	100	20	35	0
2	30361	no	7518E-TF	Fd40Sx40Pl20	17<=SI<22	19.3	2	1200	FdSxPl	6300	7500	20	1800	0	0	0	0	0	0	22	70	550	100	20	35	0
2	30371	no	7518E-TF	Fd40Sx40Pl20	17<=SI<22	19.3	2	1200	FdSxPl	6300	7500	20	1800	0	0	0	0	0	0	22	80	550	100	20	35	0
2	30352	no	7518E-TFL	Fd40Sx40Pl20	17<=SI<22	19.3	2	1200	FdSxPl	6300	7500	20	1800	0	0	0	0	0	0	22	60	550	100	20	35	70
2	30362	no	7518E-TFL	Fd40Sx40Pl20	17<=SI<22	19.3	2	1200	FdSxPl	6300	7500	20	1800	0	0	0	0	0	0	22	70	550	100	20	35	80
2	30372	no	7518E-TFL	Fd40Sx40Pl20	17<=SI<22	19.3	2	1200	FdSxPl	6300	7500	20	1800	0	0	0	0	0	0	22	80	550	100	20	35	90

Figure B-1. Alternate Development Pathways for Managed Stands

Golden TSA
SAU01 ITG 1-7, 21-25, 28-30, SI 22+
SAU01 = 11.3% of the THLB (18780 ha)
Existing natural stands = 14750 ha

Arrows represent silvicultural actions (including harvesting) that move an existing natural stand into future managed states



Existing Natural and Future Managed Stands

The development of these stands will be modelled (e.g., TIPSY) as planted managed stands.

100% of a stand is pruned.

Clearcutting of the following states occurs at 35 cm+:
14-P 7518L
14-PT 7509EP
7514EPT
7514E-T

Managed State Codes

75 - plant to 7500 sph
14E - early (< 10m) juvenile spaced to 1400 sph
14L - late (= 10m) juvenile spaced to 1400 sph
P - pruned - 100% of stand is pruned
F - fertilized
FL - fertilized late (10 years prior to harvest)
FC - cyclic fertilization
T - commercially thinned

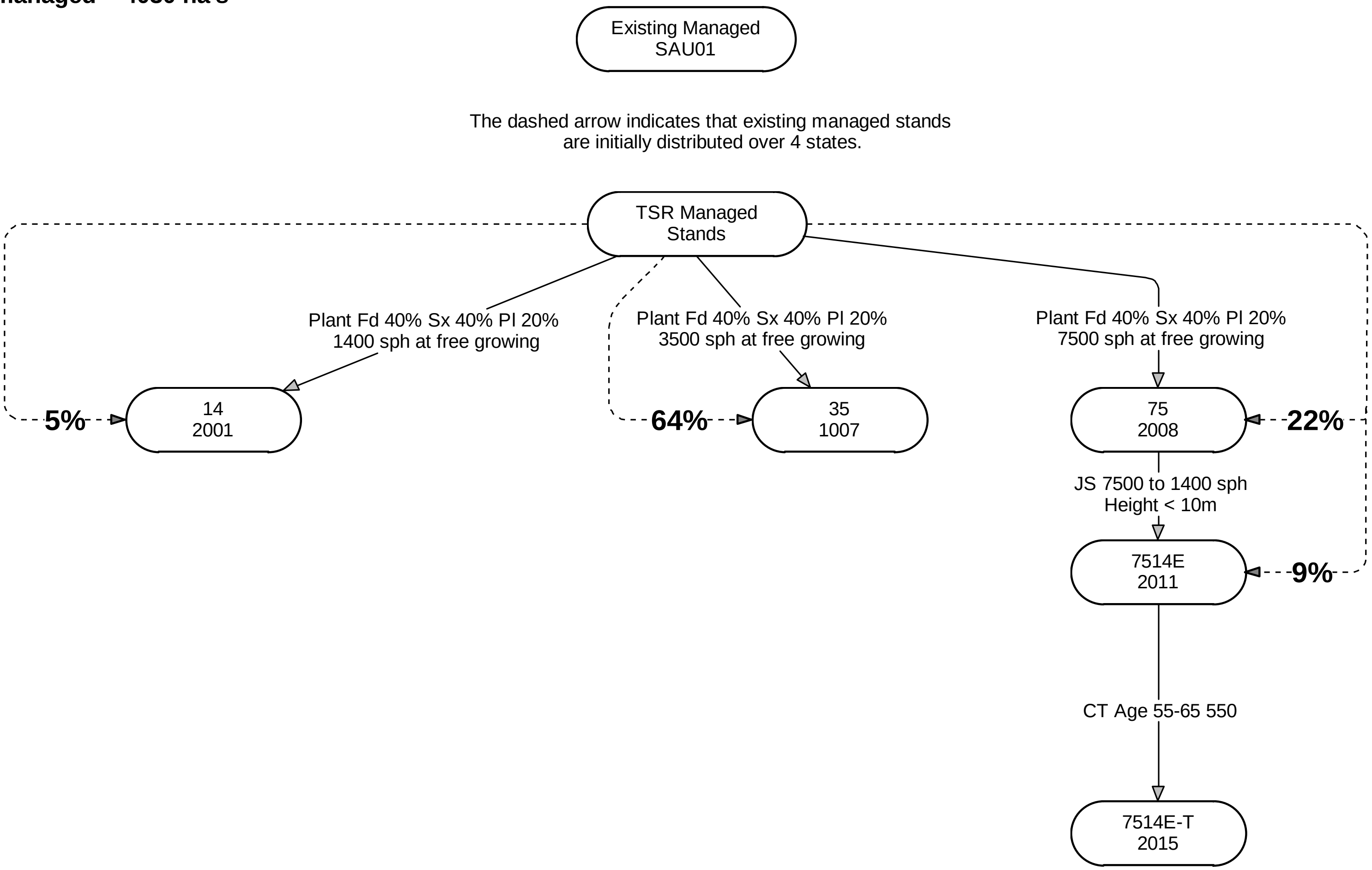
Action Codes

CLC - clearcut
Plant sp1 % sp2 % sp3 % - species mix
JS - juvenile spaced planting density to n sph
Pr - pruning
CT - commerial thinning
Fert - fertilize

CT Opportunity	**CT States**
14	14--T
7514E	7514E-T
7514EP	7514EPT
7518E	7518E-T

Figure B-2. Alternate Development Pathways for Existing Managed Stands

Golden TSA
SAU01 ITG 1-7, 21-25, 28-30, SI 22+
Existing managed = 4030 ha's



Existing Managed Stands

The development of these stands will be modelled (e.g., TIPSY) as planted managed stands.

CT Opportunity	**CT States**
7514E	7514E-T

Figure B-3. Alternate Development Pathways for Managed Stands

Golden TSA
SAU02 ITG 1-7, 21-25, 28-30, 17<=SI<22
SAU02 = 24.7% of the THLB (41208 ha)
Existing natural stands = 28350 ha

Arrows represent silvicultural actions (including harvesting) that move an existing natural stand into future managed states

Existing Natural and Future Managed Stands

The development of these stands will be modelled (e.g., TIPSY) as planted managed stands.

100% of a stand is pruned.

Clearcutting of the following states occurs at 35 cm+:
14-P-FL
7518L
7514E-T

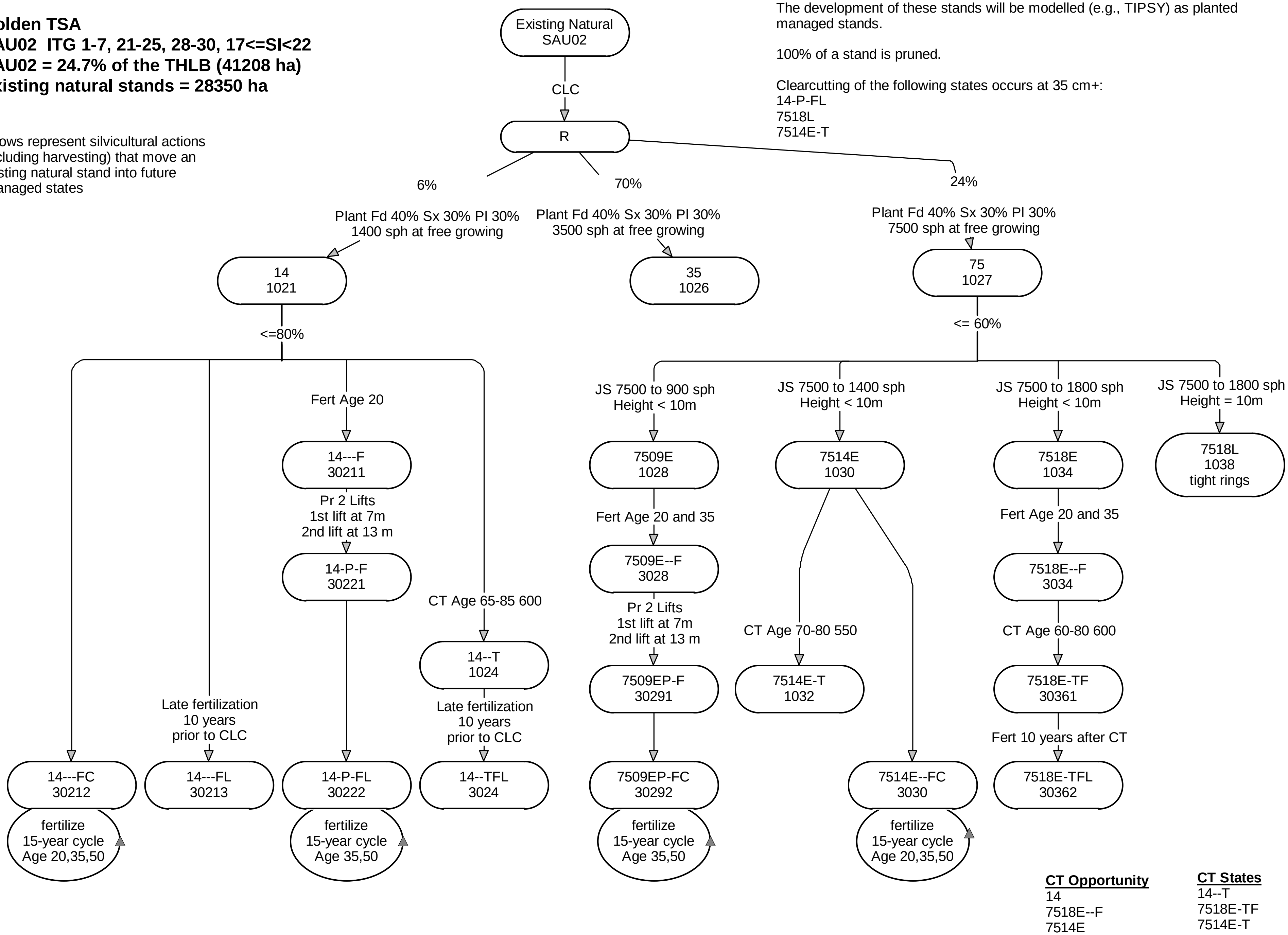
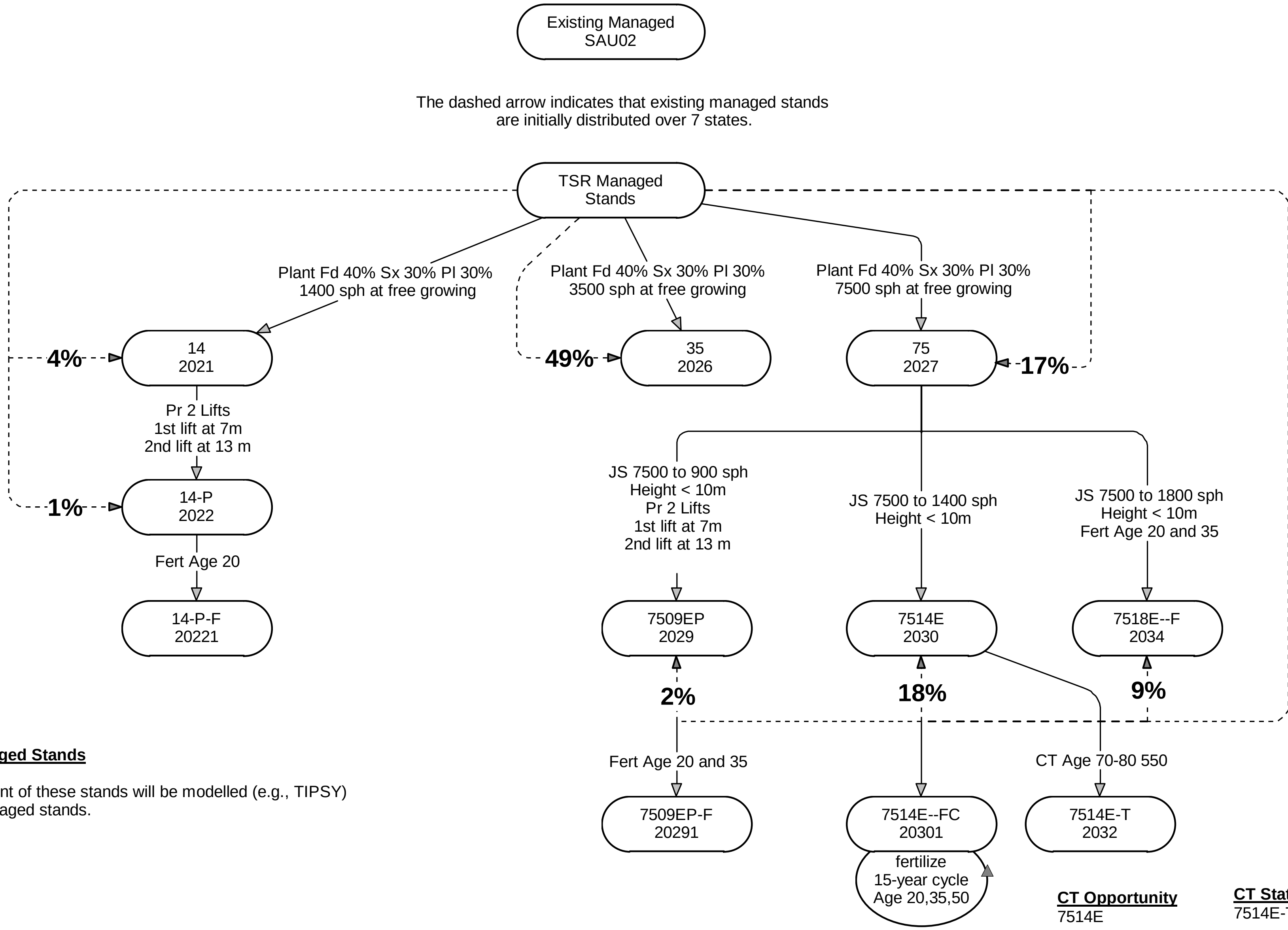


Figure B-4. Alternate Development Pathways for Existing Managed Stands

Golden TSA
SAU02 ITG 1-7, 21-25, 28-30, 17<=SI<22
Existing managed stands = 12677 ha



Existing Managed Stands

The development of these stands will be modelled (e.g., TIPSY)
as planted managed stands.

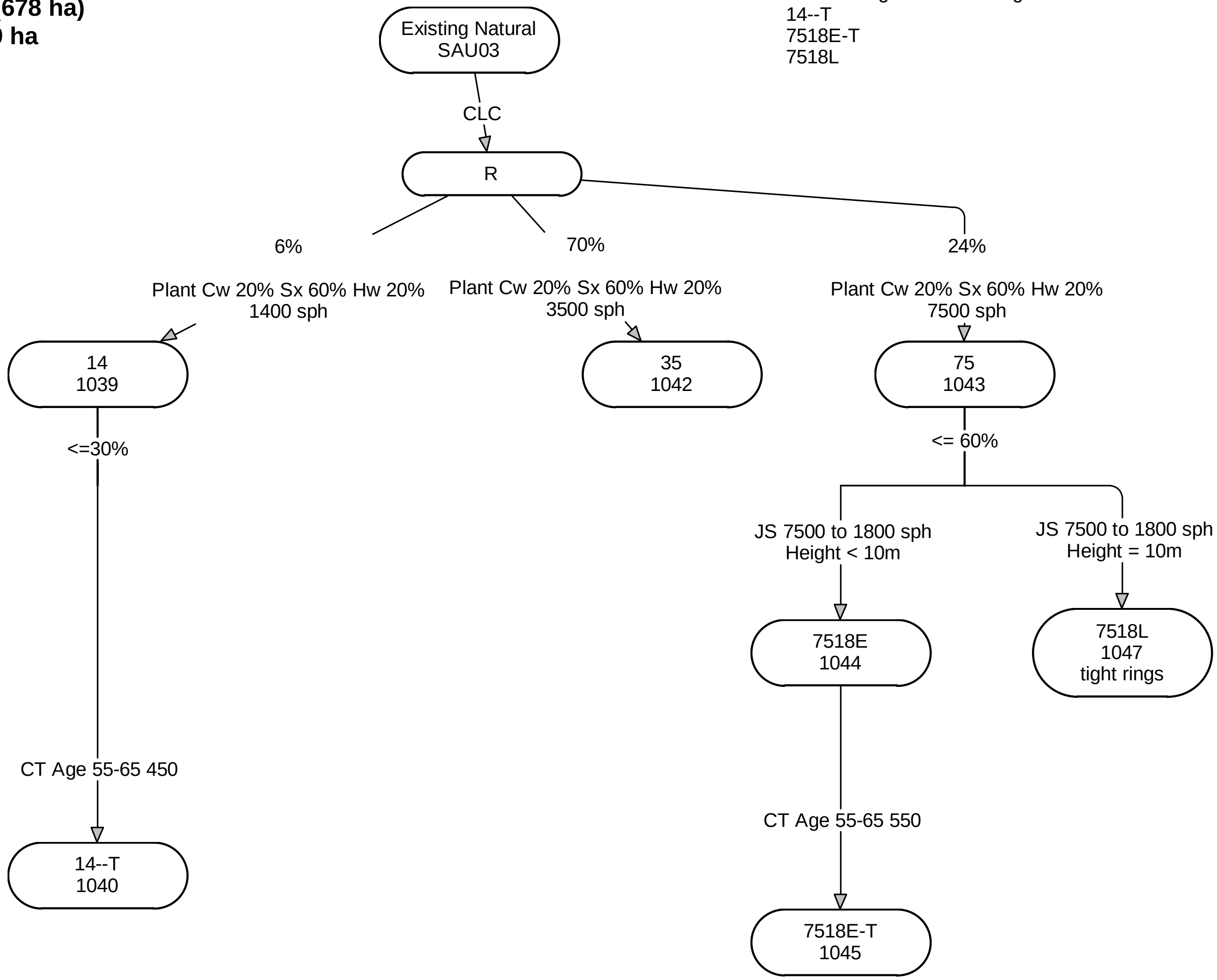
CT Opportunity
7514E

CT States
7514E-T

Figure B-5. Alternate Development Pathways for Managed Stands

Golden TSA
SAU03 ITG 9-10, SI 19+
SAU03 = 0.4% of the THLB (678 ha)
Existing natural stands = 69 ha

Arrows represent silvicultural actions (including harvesting) that move an existing natural stand into future managed states



Existing Natural and Future Managed Stands

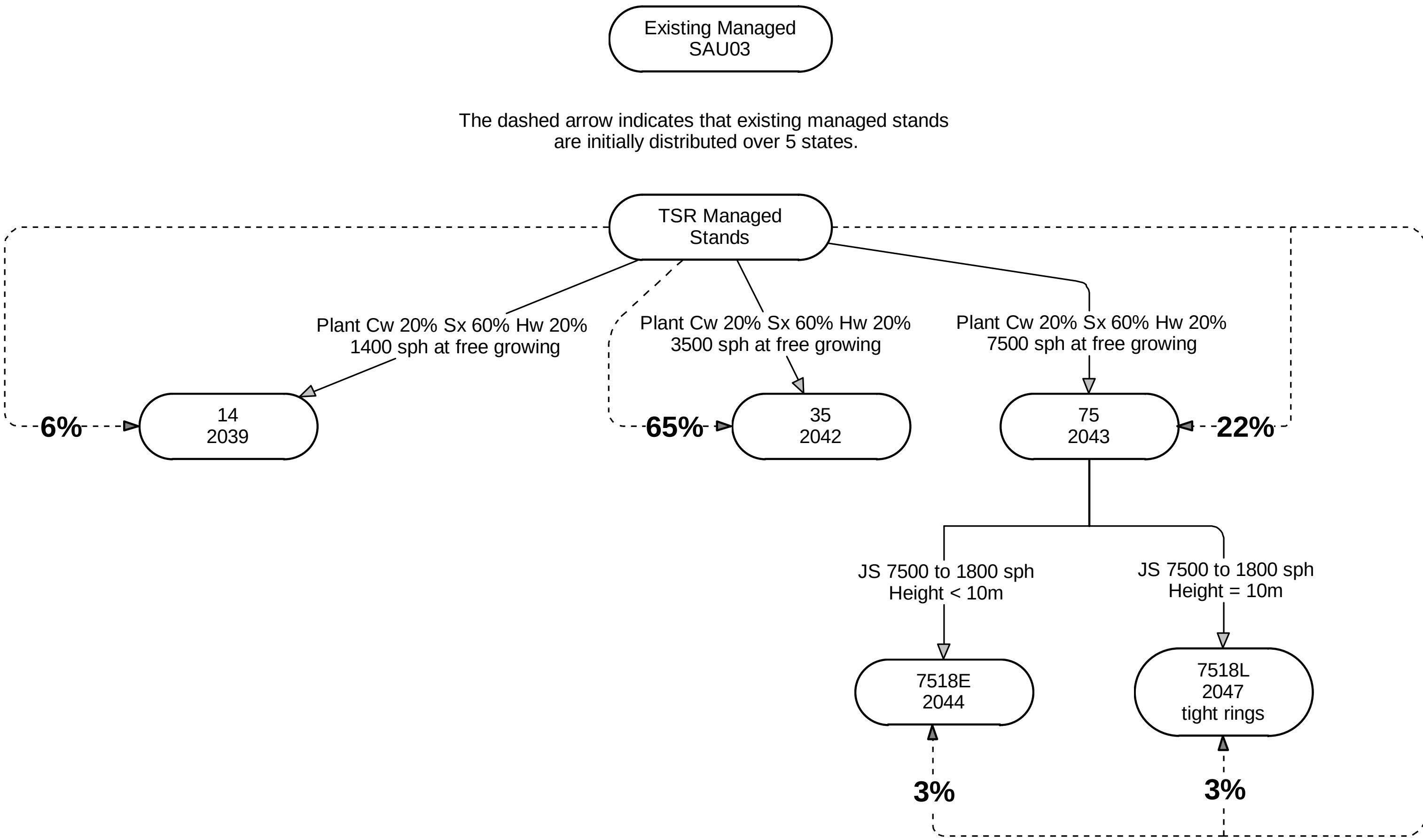
The development of these stands will be modelled (e.g., TIPSY) as planted managed stands.

Clearcutting of the following states occurs at 35 cm+:
14--T
7518E-T
7518L

CT Opportunity	CT States
14	14--T
7518E	7518E-T

Figure B-6. Alternate Development Pathways for Existing Managed Stands

Golden TSA
SAU03 ITG 9-10, SI 19+
Existing managed stands = 609 ha



<u>Existing Managed Stands</u>

The development of these stands will be modelled (e.g., TIPSY) as planted managed stands.

Figure B-7. Alternate Development Pathways for Managed Stands

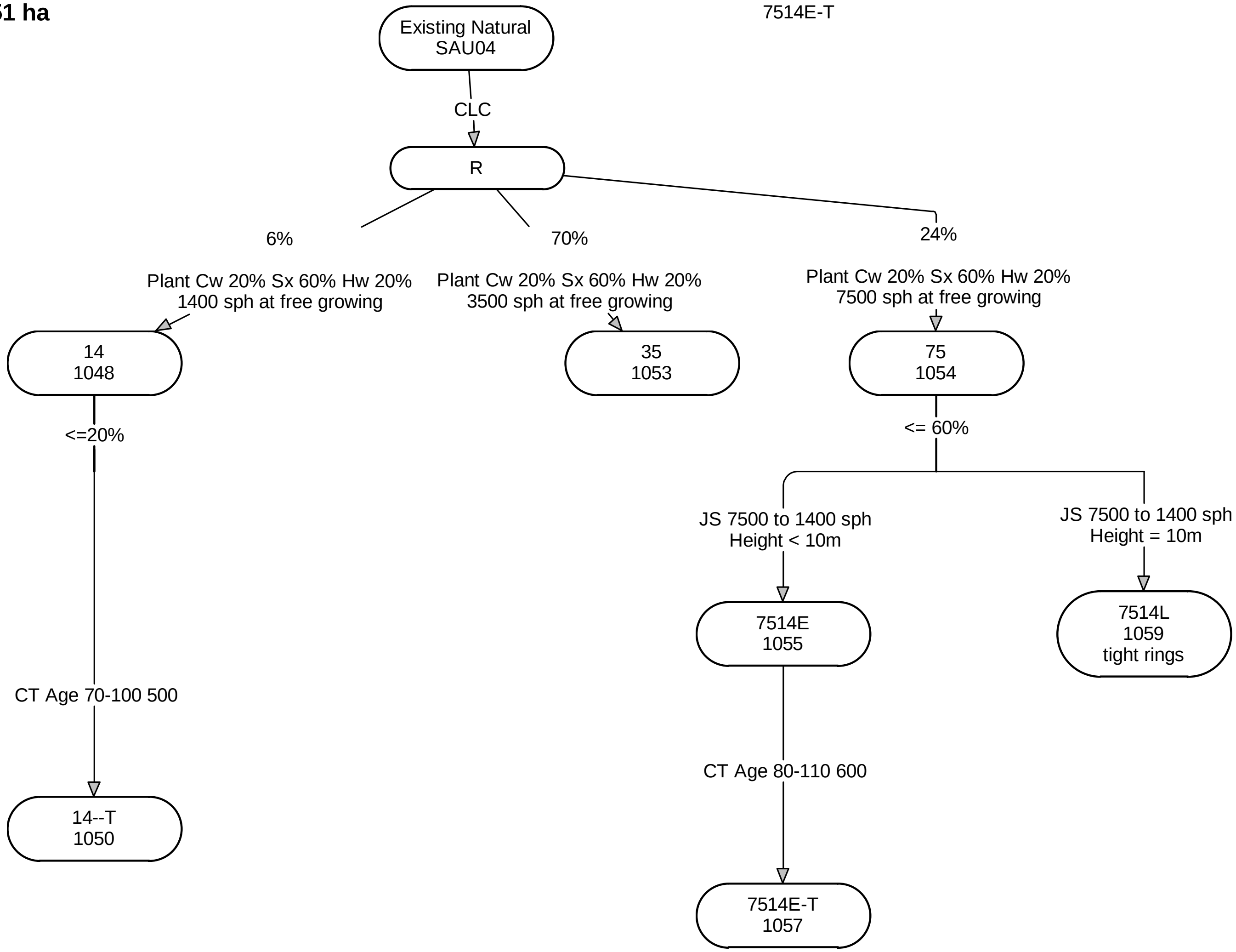
Golden TSA
SAU04 ITG 9-10, 14<=SI<=18.9
SAU04 = 0.3% of the THLB (574 ha)
Existing natural stands = 351 ha

Arrows represent silvicultural actions (including harvesting) that move an existing natural stand into future managed states

Existing Natural and Future Managed Stands

The development of these stands will be modelled (e.g., TIPSY) as planted managed stands.

Clearcutting of the following states occurs at 35 cm+:
7514L
7514E-T

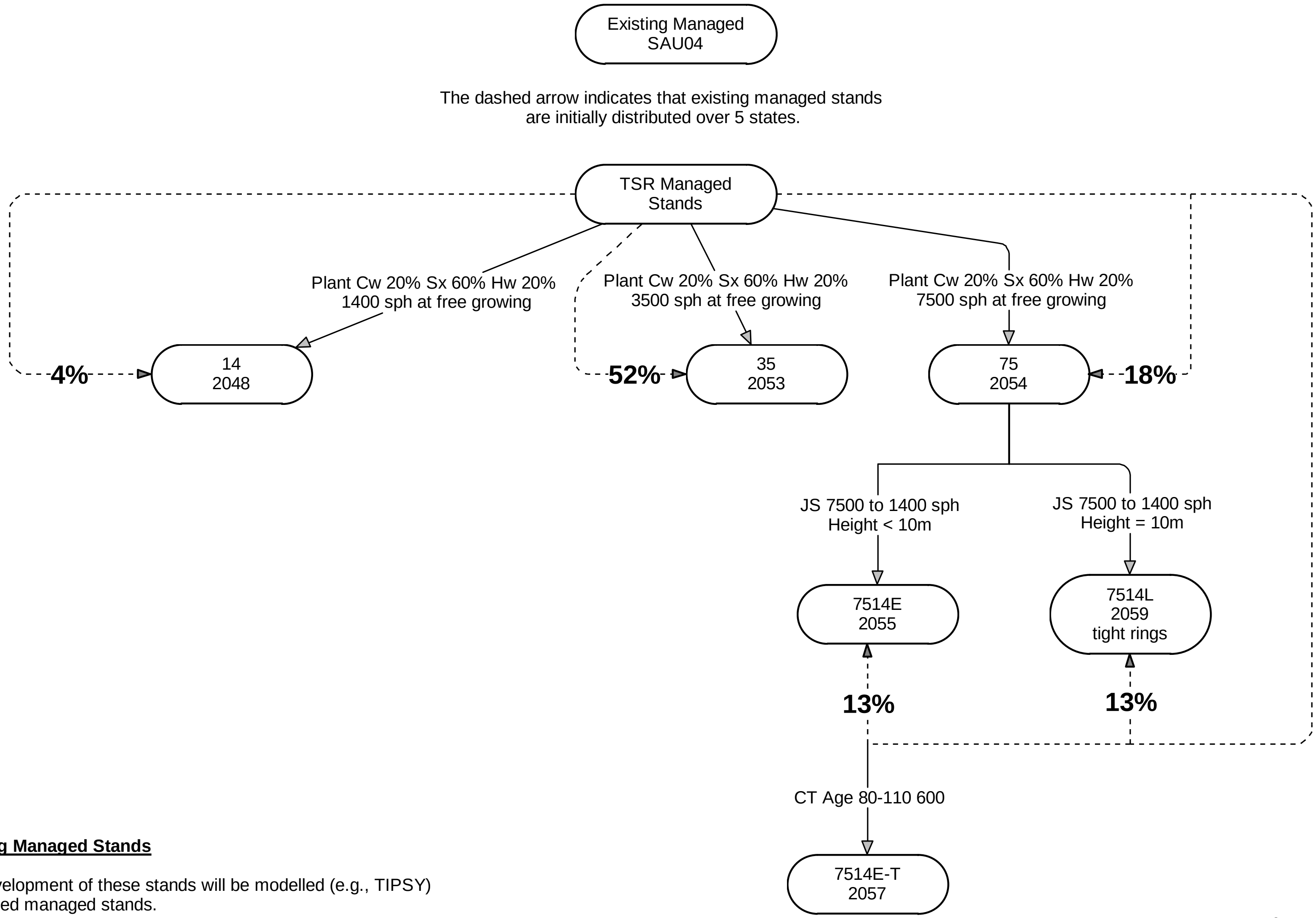


CT Opportunity
14
7514E

CT States
14--T
7514E-T

Figure B-8. Alternate Development Pathways for Existing Managed Stands

Golden TSA
SAU04 ITG 9-10, 14<=SI<=18.9
Existing managed stands = 223 ha



Existing Managed Stands

The development of these stands will be modelled (e.g., TIPSY) as planted managed stands.

CT Opportunity
7514E

CT States
7514E-T

Figure B-9. Alternate Development Pathways for Managed Stands

Golden TSA
SAU05 ITG 8,11,12-20,26-27,31-34, SI 14+
SAU05 = 15.2% of the THLB (25332 ha)
Existing natural stands = 14800 ha

Arrows represent silvicultural actions (including harvesting) that move an existing natural stand into future managed states

<u>Existing Natural and Future Managed Stands</u>

The development of these stands will be modelled (e.g., TIPSY) as planted managed stands.

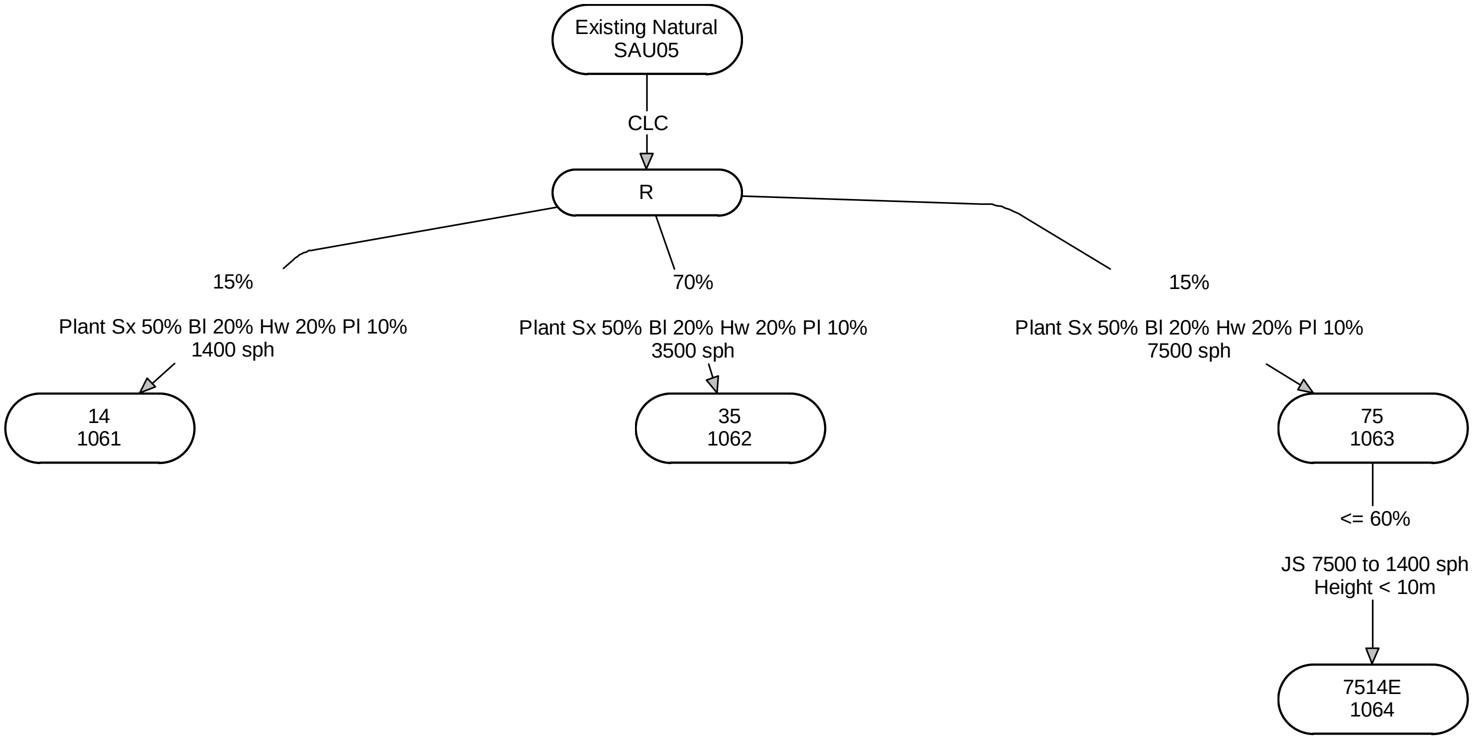
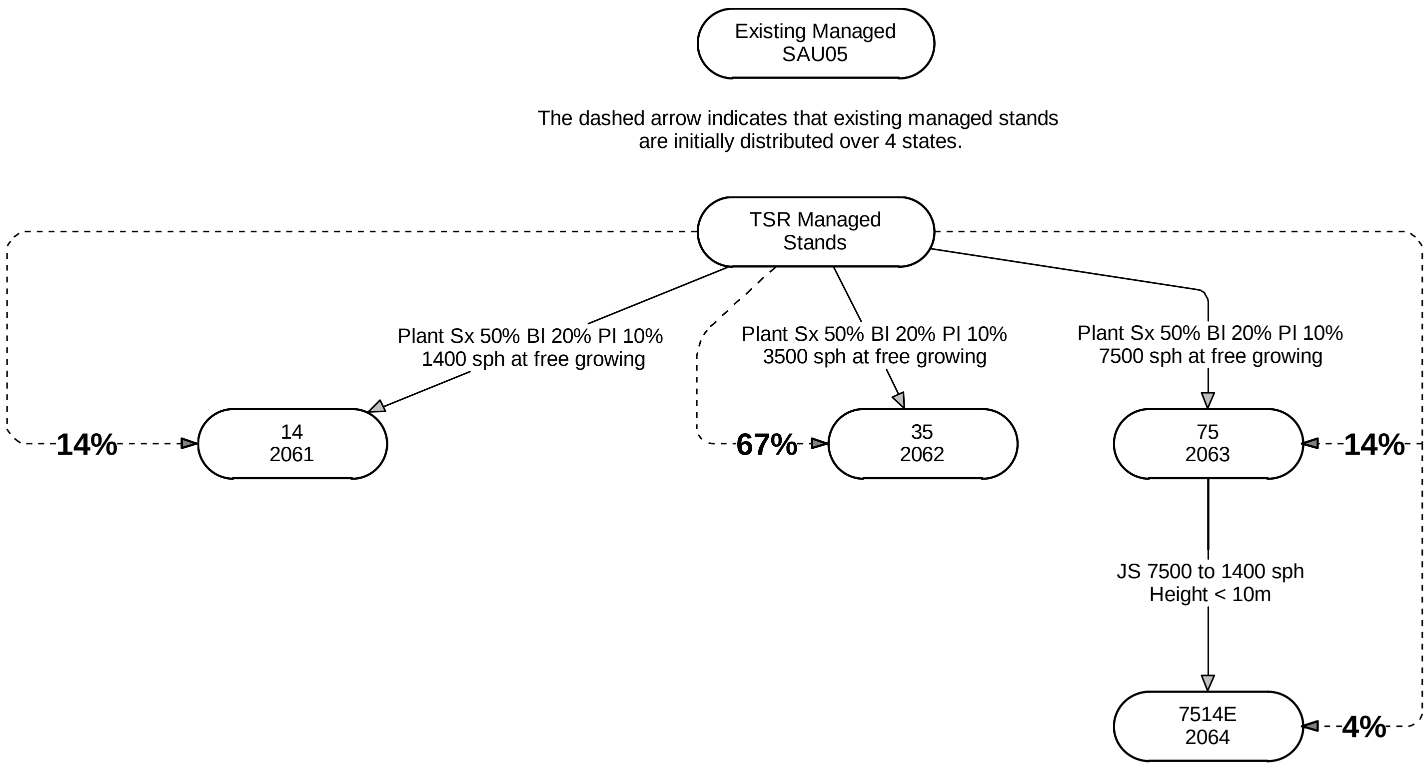


Figure B-10. Alternate Development Pathways for Existing Managed Stands

Golden TSA
SAU05 ITG 8,11,12-20,26-27,31-34, SI 14+
Existing managed stands = 10531 ha



Existing Managed Stands

The development of these stands will be modelled (e.g., TIPSY) as planted managed stands.

Figure B-11. Alternate Development Pathways for Managed Stands

Golden TSA
SAU06 All ITG's, all SI's not captured in SAU01-SAU05
SAU06 = 48% of the THLB (80042 ha)
Existing natural stands = 60040 ha

Existing Natural and Future Managed Stands

The development of these stands will be modelled (e.g., TIPSY) as planted managed stands.

Arrows represent silvicultural actions (including harvesting) that move an existing natural stand into future managed states

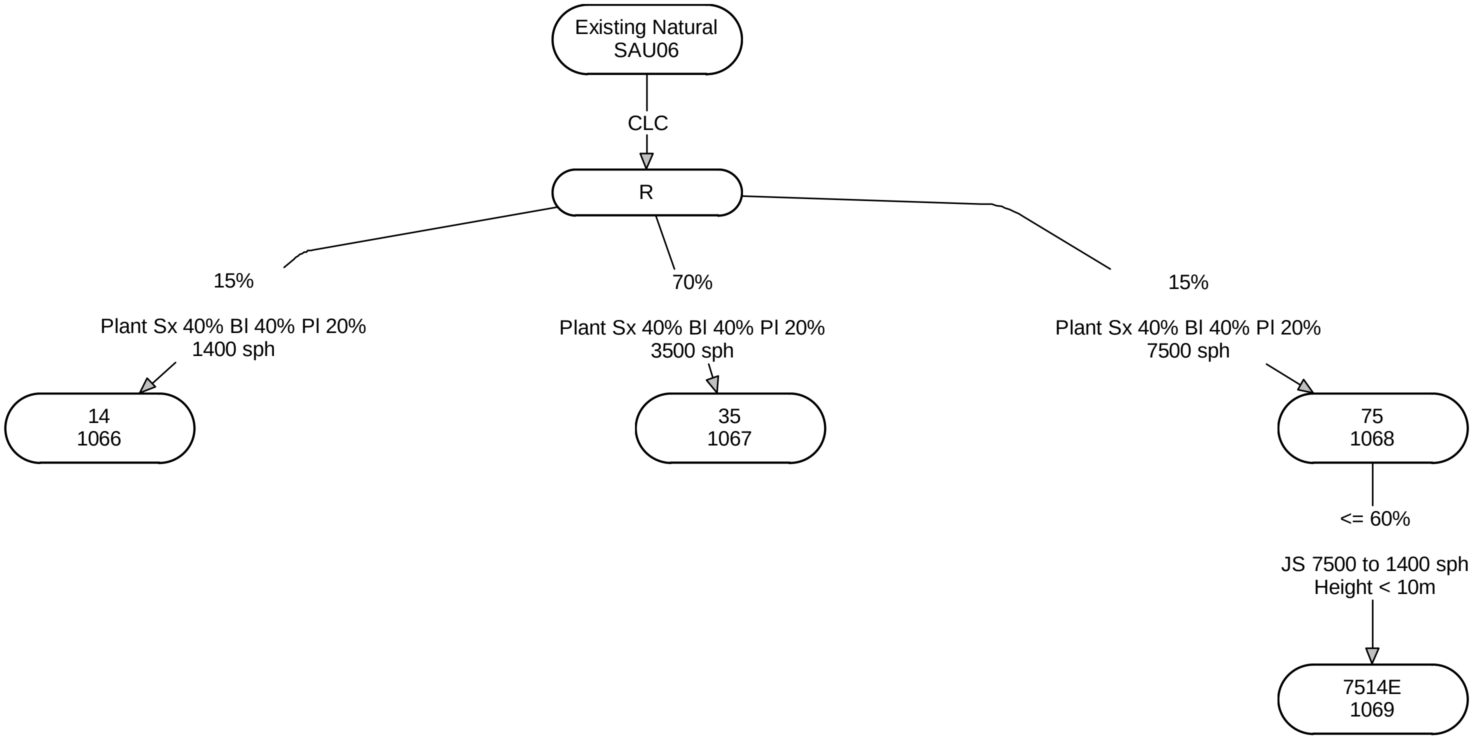
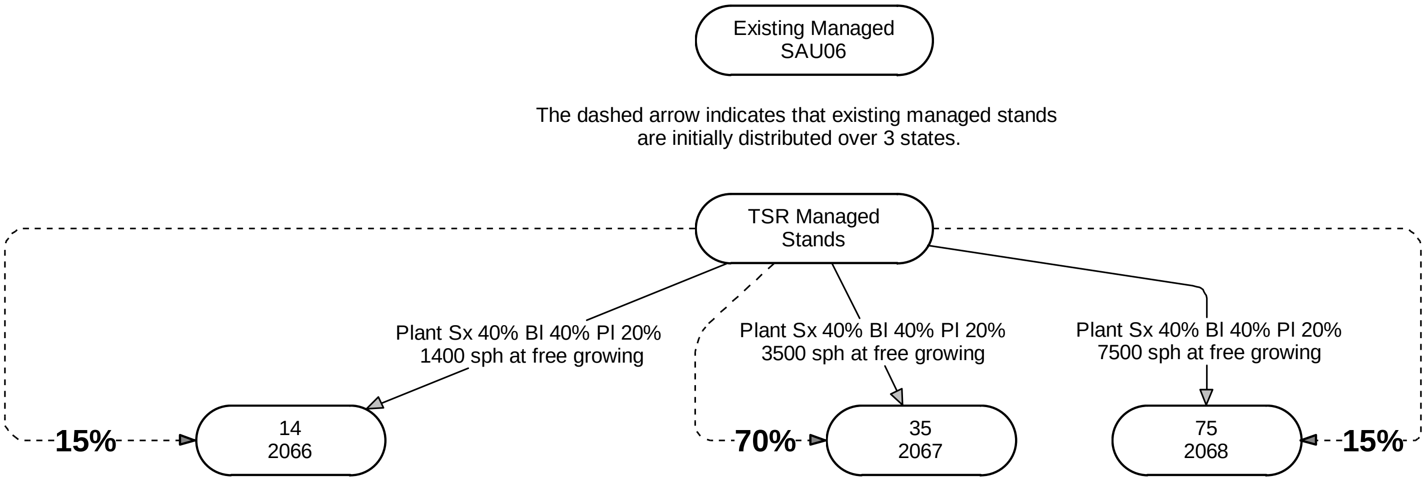


Figure B-12. Alternate Development Pathways for Existing Managed Stands

Golden TSA
SAU06 All ITG's, all SI's not captured in SAU01-SAU05
Existing managed stands = 20002 ha



Existing Managed Stands

The development of these stands will be modelled (e.g., TIPSY) as planted managed stands.

Appendix C — Genetic Gain

The forecast gain in volume from improved seed (Table C-1) for the Golden TSA was obtained from the Forest Genetics Council. The gain forecast for 2010 was assumed to be applicable out to the planning horizon of this study (25 decades) and was prorated over the planting mixes identified by the district and the proportion of the TSA in each elevation zone.

Table C-1 Forecast genetic gain by silvicultural analysis unit.

SAU	Species	Species %	% Gain	Species % Gain	SAU % Gain
SAU1	Fdi	40	8.9	3.6	
	Sx	40	21.1	8.4	
	Pli	20	0.4	0.1	
					12.1
SAU2	Fdi	40	8.9	3.6	
	Sx	30	21.1	6.3	
	Pli	30	0.4	0.1	
					10.0
SAU3	Cw	20	0.0	0.0	
	Sx	60	21.1	12.7	
	Hw	20	0.0	0.0	
					12.7
SAU4	Cw	20	0.0	0.0	
	Sx	60	21.1	12.7	
	Hw	20	0.0	0.0	
					12.7
SAU5	Sx	50	21.1	10.6	
	Bl	20	0.0	0.0	
	Hw	20	0.0	0.0	
	Pli	10	0.4	0.0	
					10.6
SAU6	Sx	40	21.1	8.4	
	Bl	40	0.0	0.0	
	Pli	20	0.4	0.1	
					8.5

Appendix D — Analysis Method

The key component of the analysis method is the development of a silvicultural planning model that is consistent with the TSR model and base case for the Golden TSA, and also fully represents the additional forest-level objectives and silvicultural activities required for silvicultural planning in a multiple-resource planning context. The model emulates the TSR base case if incremental silvicultural activities are turned off (i.e., the silviculture budget is constrained to $0). As the budget is increased, the model selects silvicultural activities that maximize its objectives. In essence, the model devises a silvicultural strategy from the silvicultural treatments specified for each SAU that is consistent with the analyst's objectives for the TSA.

3.1 Develop a LP Model of the TSR Base Case

The silviculture model is constructed with Woodstock/LP

One of the major differences between this analysis and the TSR is the choice of the forest estate model. While the TSR uses FSSIM, a forest-level simulator, this analysis casts the silvicultural planning problem as a linear model, solvable by linear programming (LP). Woodstock™ (Remsoft, 1997) was used to create the LP model and two optimization codes (C-Whiz™ and XA™) were used to solve it.[7]

The first step in the analysis is to develop an LP model formulation of the TSR base case. An LP model represents the forest and its management as a series of linear equations arranged in a matrix. One equation, the objective function, expresses the forest-level objective (e.g., maximize volume production). Other equations represent the forest management rules such as limits on harvest fluctuation and forest cover constraints. The LP solution software finds the set of management activities (e.g., harvesting) that best meet the objective.

3.2 Implement Silvicultural Activities

Regime diagrams are the "blueprint" for the model

The regime diagrams (Appendix B) are implemented in the silvicultural planning model as activities, transitions, inputs and outputs.

Actions are defined in the model to represent each silvicultural activity listed or implied in the regime diagram for each SAU. Transitions map the flow of land between states. For example, a spacing action moves land from a regenerated state to a spaced state and a pruning action moves spaced land to a post-first-lift state.

Costs are incurred and outputs generated with each transition initiated by an action. Costs are summed by regime, by strategy, and in total, and are constrained by budget. Other outputs, such as employment, volume harvested,

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[7] *C-WHIZ Linear Programming Optimizer*, Ketron Management Science, July 1994
XA/LP, Sunset Software Technology, San Marino, CA

quality and value measures, are a summed to the appropriate objective functions in the model.

3.3 Implement Forest Level Objectives

Multiple objectives guide the analysis

Each forest-level objective must be implemented in the silvicultural planning. The current version of the Golden model has six objectives implemented:

- maximize short-term timber harvest (decades 1-2)
- maximize mid-term timber harvest (decades 3-14)
- maximize long term timber supply (decades 15-20)
- maximize a priority-structured timber supply
- minimize the deviation from a specified product mix

The priority-structured objective maximizes the harvest over the entire 25-decade planning horizon but puts the highest priority on maximizing harvest levels in decade 2, the second priority in the mid term (decades 3-14), and the lowest priority in the long term (decades 15-25).

Only one of the forest-level objectives can be active at a time and the other rows are described as non-constraining. These non-constraining rows calculate the contribution of harvesting and silvicultural activities to each forest level objective and are referred to as objective tracking rows.

3.4 Implement Management Rules as LP Constraints

Forest cover constraints

Forest cover constraints, as specified in the TSR, are represented explicitly in the LP model of the base case.

Harvest-flow guidelines

TSR harvest forecasts are shaped in part by harvest-flow guidelines. When using a simulation model such as FSSIM, the modeler implements harvest-flow guidelines during the search for the best harvest schedule. However, with an LP model, the harvest flow guidelines must be implemented explicitly in the model as constraints.

To model the TSR base case, the following constraints were added to the model.

decade 1:	annual harvest = the current AAC
decade 2:	annual harvest ≤ annual harvest decade 1
decade 3-5:	annual harvest ≥ 88% of annual harvest previous decade
decade 6 –25:	annual harvest ≥ annual harvest of previous decade

Disturbance constraints

Constraints on the area disturbed (not "greened up") are specified for each of the eight management zones recognized in the TSR.

Sustainable target forest

Other forest management rules may be added as constraints. To ensure that the long-term harvest is sustainable in decades 26 and beyond, the growing stock (total inventory volume) in decade 25 is constrained to equal or exceed 17 288 000 m^3. This growing stock level was identified through experimentation with the base case model.

Harvest profile

The first-decade harvest profile (Section 2.4) for clear cutting and commercial thinning is implemented in the LP model as constraints.

3.5 Analyze Scenarios

The silvicultural planning problem expands the timber supply problem by adding silvicultural activities, constraints on silvicultural expenditures, and the objective function rows required to calculate contributions to forest-level objectives.

Silvicultural scenarios are constructed in such a manner that the benefits from specific silvicultural practices can be identified in terms of the model objectives, e.g., the impact (benefit) of fertilization on mid-term timber supply.

The LP solver finds both the harvest area and the level of silvicultural activity for each of the time periods represented in the model. Silvicultural expenditures are constrained and shadow prices (sensitivity coefficients) associated with each constraint are calculated as part of the solution process.

The scenarios developed for this analysis are:

S01 TSR2 Base Case—This scenario reproduces the TSR2 base case in order to validate the data and model. The management objective is to maximize priority-structured timber supply.

S01b Silviculture Base Case—TSR 2 base case assumptions with silvicultural history land base and new analysis units and yield tables.

S02 TSR2 Base Case plus Planting Select Stock—This scenario assumes that select stock will be planted for species for which it is available, with genetic gains as described in Appendix C. The management objective is to maximize priority-structured timber supply.

S02a TSR2 Base Case plus Planting Select Stock—This scenario assumes that select stock will be planted for species for which it is available, with genetic gains as described in Appendix C. The management objective is to maximize the product mix (see S05 for specifications) while maintaining the S02 harvest level

S02b TSR2 Base Case plus Planting Select Stock—This scenario assumes that select stock will be planted for species for which it is available, with genetic gains as described in Appendix C. The management objective is to maximize the product mix (see S05 for specifications) while allowing the harvest to decrease by as much as 60% from the S02 harvest level.

S03 TSR2 Base Case plus Commercial Thinning and Select Stock – This scenario demonstrates the changes in the harvest forecast attributable to commercial thinning. The management objective is to maximize priority-structured timber supply.

S04 Optimal Management Scenario– This scenario demonstrates the combined effects of all of the silvicultural activities implied by the regimes defined for the TSA. It assumes an unlimited silviculture budget. The management objective is to maximize priority-structured timber supply.

S05 Product Mix Scenario– This scenario demonstrates the combined effects of all of the silvicultural activities implied by the regimes defined for the TSA. It assumes an unlimited silviculture budget. This scenario attempts to meet a product mix specified by the District:

Product	Target
Sawlogs, 27.5+ cm (total)	60% of harvest
High quality sawlogs, 27.5 cm, tight rings	50% of clear wood harvest
Clear wood, > 32.5 cm	30% of harvest
Fibre, 17.5-27.4 cm	residual

S05a Product Mix Scenario– This scenario demonstrates the combined effects of all of the silvicultural activities implied by the regimes defined for the TSA. It assumes an unlimited silviculture budget. This scenario attempts to meet the product mix specified by the District while maintaining the S04 harvest level.

S05c. Product Mix Scenario– This scenario demonstrates the combined effects of all of the silvicultural activities implied by the regimes defined for the TSA. It assumes an unlimited silviculture budget. This scenario attempts to meet the product mix specified by the District while allowing the harvest to decrease by as much as 60% from the S04 harvest level.

Appendix E —Yield Tables

Pages