Review of Forest Estate Scenarios

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1. Executive summary

Overall, the review of Forestry Tasmania's data management, inventory, growth and yield systems showed they were adequate for the task of assessing existing timber supply plans and a range of alternative future scenarios. The most important change from previously published assessments was the incorporation of a range of 'headroom' values to accommodate existing and future forest practices and operational constraints. This report uses headroom values from 10-40%, depending on the scenario, to encompass uncertainties about future forest management practices.

Broadly, the analyses show that if no new reserves are established, minimum Intergovernmental Agreement (IGA) commitments for high quality sawlog supply (155,000 m^3/yr) can be met from native forests until 2030 if headroom values are 30% or less (Figure 12). However, total demand including contracted sawmills (163,000 m^3/yr) and regional ('country') sawmills (up to 25,000 m^3/yr) cannot be met, even if headroom allowances are as low as 20%. Native forests alone cannot satisfy demand for peeler billets under any headroom assumptions. The results of this scenario illustrate that significant volumes will have to be sourced from plantations and / or private land if current demand is to be satisfied. Other examples in the body of the report reinforce this general conclusion.

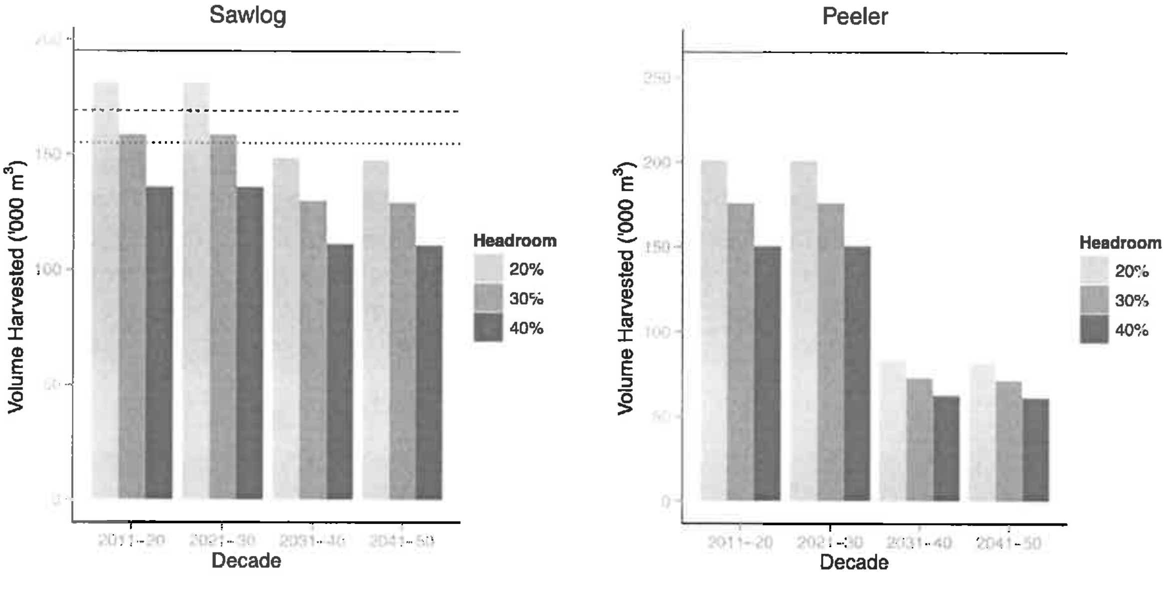

Figure 12 Maximum yield of High Quality Sawlog and Peeler Billets from public native forests if no new reserves are created. Dotted line: minimum sawlog commitment in the IGA. Dashed Line: Total Contracted Volumes. Solid Line: All Demand, including regional ('country') sawmills. These figures ignore potential supply of peeler billets from public plantations and private land.

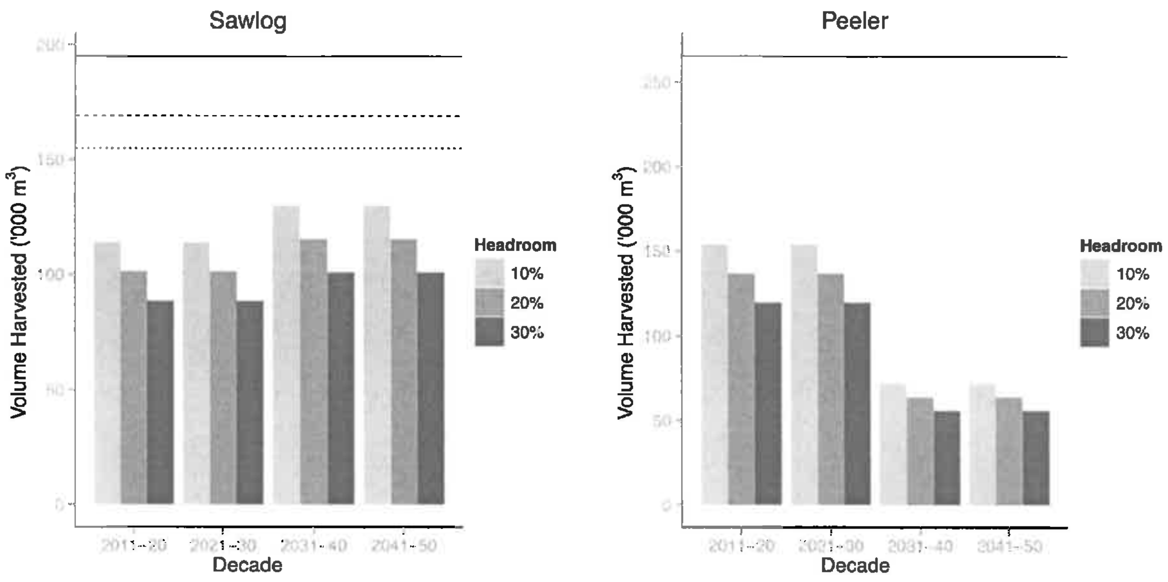

Figure 14 Maximum yield of High Quality Sawlog and Peeler Billets from public native forests if new reserves are created. Dotted line: minimum sawlog commitment in the IGA. Dashed Line: Total Contracted Volumes. Solid Line: All Demand, including regional ('country') sawmills.

In scenarios that include 572,000 ha of new, high conservation value forest reserves, shortfalls in the production of sawlogs and peeler billets from public native forests over the next 20 years are more substantial (Figure 14). If existing plantation resources contribute and new reserves are established, there is still a significant shortfall in sawlog and peeler supply over the next 20 years (Figure 18). Significant investments in new plantations and enabling technologies to process plantation sawlog and peeler material will be necessary to reconcile constraints after that period. Alternatively, supply will decline or the supply area will increase (i.e., reserve area will decrease). Transition plans should account for the time and budget necessary to develop appropriate plantation resources. A fuller analysis of risks and constraints of plantation grown material as a substitute for native forest material for sawlog and peeler billets is presented in Appendix 2.

The report presents estimates of the wood volumes that could be supplied from native forests, without any new reserves, over a 100 year period. Assuming 30% headroom, the sustainable sawlog yield is estimated to be approximately 137,000 m^3 per year. The sustainable peeler yield is estimated to be 88,000 m^3 per year. These sustainable yields are much less than the volumes agreed in the IGA. Contracted peeler and sawlog harvests cannot be sustained from native forest alone. The existing *Regional Forest Agreements* (RFAs) and *Tasmanian Community Forest Agreement* (TCFA) were designed to be sustained from both native forests and plantations.

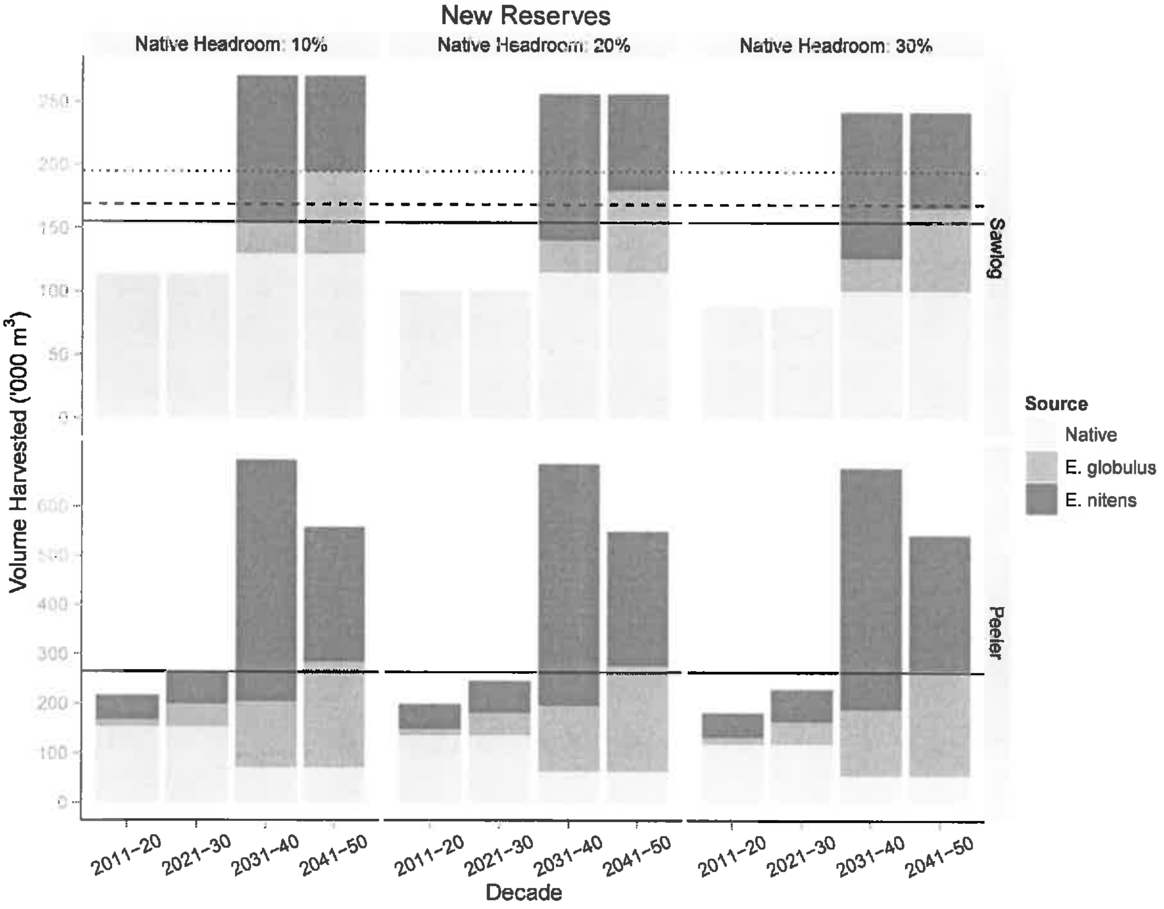

Figure 18 Potential supply of sawlogs and peeler billets from both native forests and public plantations, if they are appropriately managed with 572,000 of new reserves. Plantation supply of sawlogs and peeler billets from *E.globulus* plantations is generally seen to be less problematic than supply from *E. nitens* plantations.

2. Introduction

2.1 Purpose

This report documents the verification of wood supply estimates undertaken at the request of the *Tasmanian Forests Intergovernmental Agreement*, Independent Verification Group (IVG).

2.2 Overview of Terms of Reference

This draft of this report focuses on two of the terms of reference of the IVG:

2. In consultation with the Signatories, design and implement an independent and transparent verification process to assess and verify stakeholder claims relating to sustainable timber supply requirements (including at the regional level), available native forest and plantation volumes in both the short and longer term, and areas, conservation values and boundaries of reserves from within the ENGO-nominated 572,000 hectares (Clauses 20 and 28). In making its assessments, the group will have access to and use the best available data (including data on demand and usage), including that held by Forestry Tasmania and others.
6. Assess and provide advice on whether at least 155,000 cubic metres per year of high- quality sawlogs, 265,000 cubic metres of peeler billets, and an appropriate supply of specialty timber noting that the industry claim is 12,500 cubic metres, (Clause 17) can be sustainably supplied from outside the areas identified in paragraph 5 above over both the short and longer terms, taking into account existing wood supply requirements, contracts and usage, potential voluntary exits and availability of suitable plantation wood supply as noted in Clauses 23 and 24 of the IGA, respectively.

To address these terms of reference, this report provides the following analyses:

1. A summary of work conducted previously on these issues
2. An outline of the processes followed by us in verifying wood supply
3. A description of the existing wood supply system, outlining what is done, providing a description prior to the critical assessment of tools and procedures
4. A comparison of the wood supply system used in Tasmania with systems deployed in a number of other jurisdictions
5. An evaluation of the assumptions, strengths and weaknesses of growth and yield models, inventory and monitoring that underpin the wood supply system
6. Results of scenarios that scope possible resource management options, from a range of stakeholder perspectives, including summary tables and maps
7. Static maps of wood supply values for peeler billets and sawlogs that may be used to assist discussions about resource implications arising from alternative scenarios.

It does not address the issues of the configuration of economically sustainable or viable sawlog or peeler billet industries. That is, it does not evaluate the implications of reducing demand below 155,000 m^3 of sawlog or 265,000 m^3 of peeler billets or what is an appropriate size or scale for the industry in Tasmania. Nor does it consider the role of the softwood sector.

Documentation of the existing stock, supply, demand and contractual commitments for different wood types, in public and private forests and plantations, appear in another report to the IVG.

2.3 Summary of previous work

2.3.1 Existing public hardwood plantation assessments

Forestry Tasmania (2011) reported the result of projections for native Eucalypt forest for three scenarios that were run to support the deliberations of the Reference Group, including a baseline scenario, and two scenarios that were proposed by environmental non-governmental organisations (ENGOs) and forest industries. The average yields for the three products of particular interest for the scenarios, namely, peeler billets, high-quality sawlog, and arisings, were reported in two 20-year blocks (10 year blocks are reported in the appendixes).

The baseline scenario represents the amount of timber that may be available if no new reserves are proclaimed. The ENGO scenario was computed by identifying 572,000 ha of forest interpreted to be of high conservation value (HCV) and removing the volume contributed by them from the baseline. The Industry scenario was computed by identifying 140,000 ha of forest interpreted to be HCV and removing the volume contributed by them from the baseline. The results of the scenarios reported in Forestry Tasmania (2011) are summarized in Table 1.

Table 1 **Summary of evaluation of wood resource scenarios (modified from Forestry Tasmania, 2011). All units are in 1000 m^3/yr and reflect a 10% discount for headroom. All rows show figures for public native forest except for the row for supply of peeler billets. Peeler billet scenarios include 39,000 m^3 sourced from areas outside the public native forest (NF) estate.**

Product	Time period	Base	ENGO	Industry
Sawlog	2011 – 2030	204	117	199
	2031 – 2050	166	130	164
Peeler billet	2011 – 2030	265*	191	265
	(public NF)	(226)	(152)	(226)
	2031 – 2050	93	71	92
Specialty timber	2011 – 2050	12.5	6.7	11.5

* Page 21 of Forestry Tasmania (2011) notes that 39,000 m^3 of this supply was sourced from plantation and private land, so only 226,000 m^3 of this supply is sourced from native forests on public land. The analyses for public native forest developed in this report do not include this plantation and private land source.

An appendix was supplied after the IGA was signed that gave an additional scenario for wood supply given protection of 430,000 ha of proposed HCV forests in new reserves.

Forecasts of timber available from existing plantations on State Forests for which Forestry Tasmania (FT) has or shares ownership of the crop were made by Forestry Tasmania (2011). These tree growth and yield forecasts were made using the models documented in Candy (1997). Volume returns were projected using equations provided in Goodwin (2009). Estate modelling was conducted using Woodstock, a software program from Remsoft[1], coupled with the Mosek linear programming optimiser.

FT conducted two major reviews of plantation productivity in the last five years (2006, published in Forestry Tasmania 2007; 2010 published in Forestry Tasmania 2011) with the latter showing a dramatic decline in the estimates of productivity (Table 2). The difference between the projected volumes flows is considerable. For example, on the later review, the effect of start dates on the supply of High Quality Sawlog (HQSL) is such that non-declining yield of 124,000 m^3/yr of HQSL can be achieved with a start date of 2026. However, the original review (Forestry Tasmania, 2007), using a slightly smaller land base (1,000 ha less), suggested that plantation-derived HQSL will equal 155,000 m^3/yr, with a start date in about 2023. This is a difference of about 30,000 m^3/yr, which is about 20% of the amount expected to be sourced from FT whole-or-part owned plantations in achieving the minimum HQSL requirement of 300,000 m^3/yr set by the RFA and the *Forestry Act 1920.*

Three reasons have been advanced to explain the decline in expected productivity (Forestry Tasmania 2011). First, only about a tenth of the plantation resource had been inventoried at the time that the 2007 sustainability report was being compiled, whereas about 70% of the plantation resource has been inventoried by 2011. This greater inventory detail has increased the estimate of the amount of defect, which reduces the volume of product. Second, the plantations are four years older, which improves the predictions of yield at harvest. Third, an updated pruning algorithm is being used for the current report, which no longer simply assumes that the largest trees will be pruned and will survive thinning.

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[1] http://www.remsoft.com/products.php?id=1, last accessed 1/12/2011.

Table 2 **Assessments of plantation production of High Quality Sawlogs (HQSL) in Forestry Tasmania 2007 and 2011. Units are '000 m^3 per year.**

	August 2007	June 2011			
Average for five years ending	Forestry Tasmania (2007)	20 / 25 yr harvest; p. 27	Commence 2021; p. 30	Commence 2026; p. 30	Commence 2031; p. 30
2020	30	28			
2025	145	82	89		
2030	155	82	89	124	
2035	155	98	89	124	157
2040	155	-	89	124	157
2045	155	-	89	124	157
2050	155	-	89	124	157

2.3.1.1 New plantation scenario (June 6 Report)

This scenario was created by Forestry Tasmania (2011), as requested by the Signatories, assuming that the plantations required for sawlog production have to be created from either existing plantations or new land, under new silvicultural practices. The New Plantation scenarios were projected using the Candy (1997) plantation growth model in the Farm Forestry Toolbox[2]. The scenarios were optimised using Goalseek tools in Microsoft Excel.

Scenario 4 in the June 6 Report explored the additional area of plantation forest required to facilitate any total transition from native forests to plantation resources whilst maintaining the minimum industry wood supply requirements of 155,000 m^3/yr of high quality eucalypt sawlogs and a minimum of 265,000 m^3/yr of appropriate peeler quality billets. This scenario relies on multiple thinning ('Lonely Tree') regimes to produce large, pruned, high quality eucalypt sawlogs, greater than 40 cm small end diameter. Total transition relying on this method of silviculture will require new areas of plantation. A portion of the existing *Eucalyptus nitens* plantation estate on state forest (between approximately 9,000 ha and 18,000 ha depending on the level of risk accepted with planting frost-sensitive *Eucalyptus globulus*) could be converted to *E. globulus* plantations, reducing the total required new area; nevertheless, substantial new plantation areas will be required.

Delivering the required logs where each hectare holds 100 trees will require a total of 112,162 planted hectares. Assuming that 18,000 ha of the existing *E. nitens* plantations on state forest can be converted at maturity to *E. globulus*, the requirement is 94,162 of additional net planted hectares. The requirement to convert at maturity will constrain transition schedules. The optimal

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[2] http://www.privateforests.tas.gov.au/products/farm_forestry_toolbox, last accessed 6/12/2011.

average harvest age to deliver the indicated outcomes is about 25–30 years and will additionally result in annual arisings of 427,000 m^3/yr of sawlog from unpruned trees, 202,000 m^3/yr of pulpwood and 41,000 m^3/yr of unallocated residues. About 4,400 to 4,800 gross hectares of new plantation will need to be established on average every year for 25–30 years, plus conversion of about 700 to 1100 gross hectares of existing *E. nitens* plantation to *E. globulus* each year. The new resource would theoretically come on line from 2037–2042 and would require a total estate of 130,000 ha. Given the environmental and social constraints, an implementation program would need to assess whether land required for these developments would be available in suitable locations to provide sawlog and peeler billets for existing mills. That is, designs would need to account for constraints on conversion of farmland to plantations, the suitability and productivity of potential sites, the economics and logistics of transportation, and so on.

2.3.2 Greaves: Plantation analysis

Greaves (2010a) analysis estimated the estate would produce 150,000 m^3 of peeler logs sustainably. The log-grade-outturn of eucalyptus plantations grown for production of pruned peeler-logs was predicted using the Farm Forestry Toolbox (V. 4.9) for six silvicultural management options (with final stockings ranging from 100 sph to 300 sph), including early pruning and early non-commercial thinning. The mean annual increment (MAI) of peeler log production was around 9 m^3/ha/yr for stands thinned to 200 sph and pruned to 11 m (pruning to 6.4 m. was also simulated).

For peelers, Greaves' analysis estimated an estate of 32,000 hectares of appropriately managed plantation (with around 25,000 ha of trees) growing in suitable environments on 25-year rotation and pruned to 6.4 m would be expected to produce around 150,000 m^3 of pruned peelers per year. Pruning to 11 m reduces the required estate size to 19,200 ha (15,400 ha of trees). A new plantation estate of 32,000 ha growing on a 25-year rotation requires the establishment of 1,280 ha per year, with first crop available in 25 years. A new 25-year plantation estate of 19,200 ha requires establishment of about 770 ha per year.

For sawlogs, Greaves' (2010b) analysis estimates 150,000 m^3 of sawlog to be produced sustainably. The MAI of sawlog production was around 9 m^3/ha/yr for stands thinned to 100 sph and pruned to 11 m. An estate of 32,700 ha of appropriately managed plantation (with around 26,100 ha of trees) growing in suitable environments on 25-year rotation and pruned to 6.4 m would be expected to produce around 150,000 m^3 of sawlog per year. Pruning to 11 m reduces the required estate size to 20,200 ha (16,700 ha of trees). A new plantation estate of 32,700 ha growing on a 25-year rotation requires the establishment of 1,308 ha per year, with first crop in 25 years. A new 25-year plantation estate of 20,200 ha requires establishment of about 810 ha per year.

Taking the estimates for sawlogs and peelers together, Greaves' analysis indicates that (approximately) 90,000 ha of plantation estate would be required to satisfy the agreed volumes. The analysis did not consider the wood quality associated with the logs as the simulation software does not have models for predicting wood quality properties such as drying distortion, checking defects, and hardness. Both this analysis and the FT analysis of this silvicultural approach did not consider headroom for issues such as disease, beyond-Code aspirations for coupe dispersal, visual management or hydrology issues.

2.3.2.1 Specialty Timber

Specialty timbers arise in several different forest types and encompass a range of species (Figure 1 and Figure 2). The June 2011 report adopted the supply targets outlined in the *Special Timbers Strategy* (Forestry Tasmania 2010) of 10,000 m^3/yr for Blackwood sawlogs, and 2,500 m^3/yr of special timbers other than Blackwood for the ten-year period to 2019. This supply will be sourced from the Special Timbers Zone defined in the *Special Timbers Strategy*. The non-blackwood special timbers will be sourced, at very low rates, primarily from non-swamp areas in the Special Timbers Zone. The IGA notes that the guaranteed supply of specialty timbers of 12,500 m^3 should be verified. The assessment of demand for these timbers will appear in a separate report.

It is less clear what the source of specialty timbers will be for the period after 2019. For instance, it is suggested that the Blackwood volume will be supplied primarily from Blackwood swamps (6,000 m^3/yr) and from mature wet eucalypt and rainforest areas in the Special Timbers Zone (4,000 m^3/yr; Forestry Tasmania 2010). From 2050 a component will be supplied from FT's developing fenced intensive Blackwood program. To date, much of the specialty timbers have arisen from logging mature forest. Forestry Tasmania (2007) indicated that harvesting of mature Eucalypt forest would cease in 2030. Selective logging of small quantities of special timber from rainforests is planned to continue indefinitely. This implies that sustainable supply of specialty timbers (other than Blackwood), which typically require much longer rotations than do eucalypt forests, will require silvicultural practices and appropriate business models to support them.

The development of the scenarios for specialty timbers is beyond the scope of this report as there is insufficient date on growth and yields and we therefore cannot verify claims regarding this resource. The *Special Timbers Strategy* identifies an area of 20,000 ha of mature wet eucalypt forest that would be managed on a long rotation (200 years) for Special Timbers production. A proportion of this area falls within the 572,000 ha of proposed new reserves. Of the total of approximately 98,000 ha that contain Specialty Timbers, approximately 64,000 ha falls within the proposed new reserves (Figure 2). We could not assess the relative quality of the available resource in different areas, or the potential for areas outside FT's Special Timber Zones to supply specialty timbers (see below).

The effects of the alternative scenarios on special timbers supply were calculated purely on an area basis of management zones. The assessment here did not reconcile supply estimates with an analysis of the verified presence of special timbers. For example, the Map of potential HCV reserves would exclude 10% of the Blackwood swamp resource by area (Figures 1 and 2). This area estimate was used to calculate the reduction in sustainable yield from about 6000 to 5400 m^3/yr. Supply levels for the two 20-year periods 2011–2030 and 2031–2050 have not been separately identified, and the 10% notional discount for forest practices constraints (i.e., headroom) has not been applied. These assumptions were made to simplify calculations. If any assumptions appear to have important consequences for planning scenarios, they should be revisited.

The impacts of the HCV reserve proposals on special timber supply from native forests are uncertain but may be significant. Blackwood and Silver Wattle grow relatively quickly and are adapted to large-scale disturbances such as wildfire. These species commonly occur in the understoreys of eucalypt regrowth forests (Forestry Tasmania 2010). A significant proportion of Silver Wattle forest is in State Forest outside the proposed area of new reserves. As noted above, about 10% of the Blackwood production area intersects proposed reserves. Forestry Tasmania (2010) indicated that of the 10,000 m^3/yr of Blackwood supply, 4,000 m^3/yr is gathered from a range of public native forest harvesting including mature eucalypt forests and regrowth eucalypt forests. The implications of the proposed HCV reserves should account for species-specific existing and future supply plans. The critical species include Celery Top, Myrtle and Huon Pine and, though to a lesser degree, Blackwood and Silver Wattle.

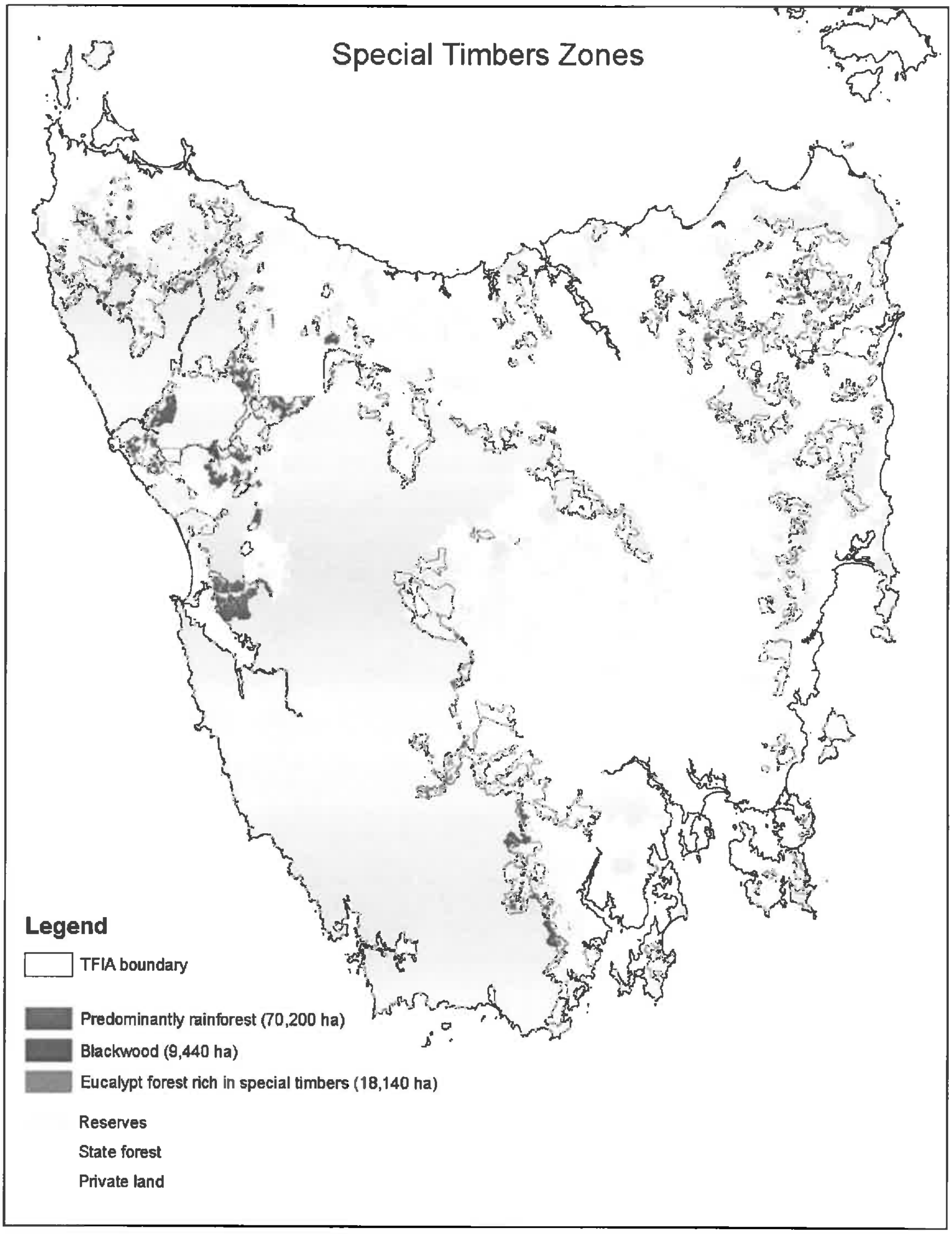

Figure 1 **Breakdown of three forest types within the Special Timbers Zones**

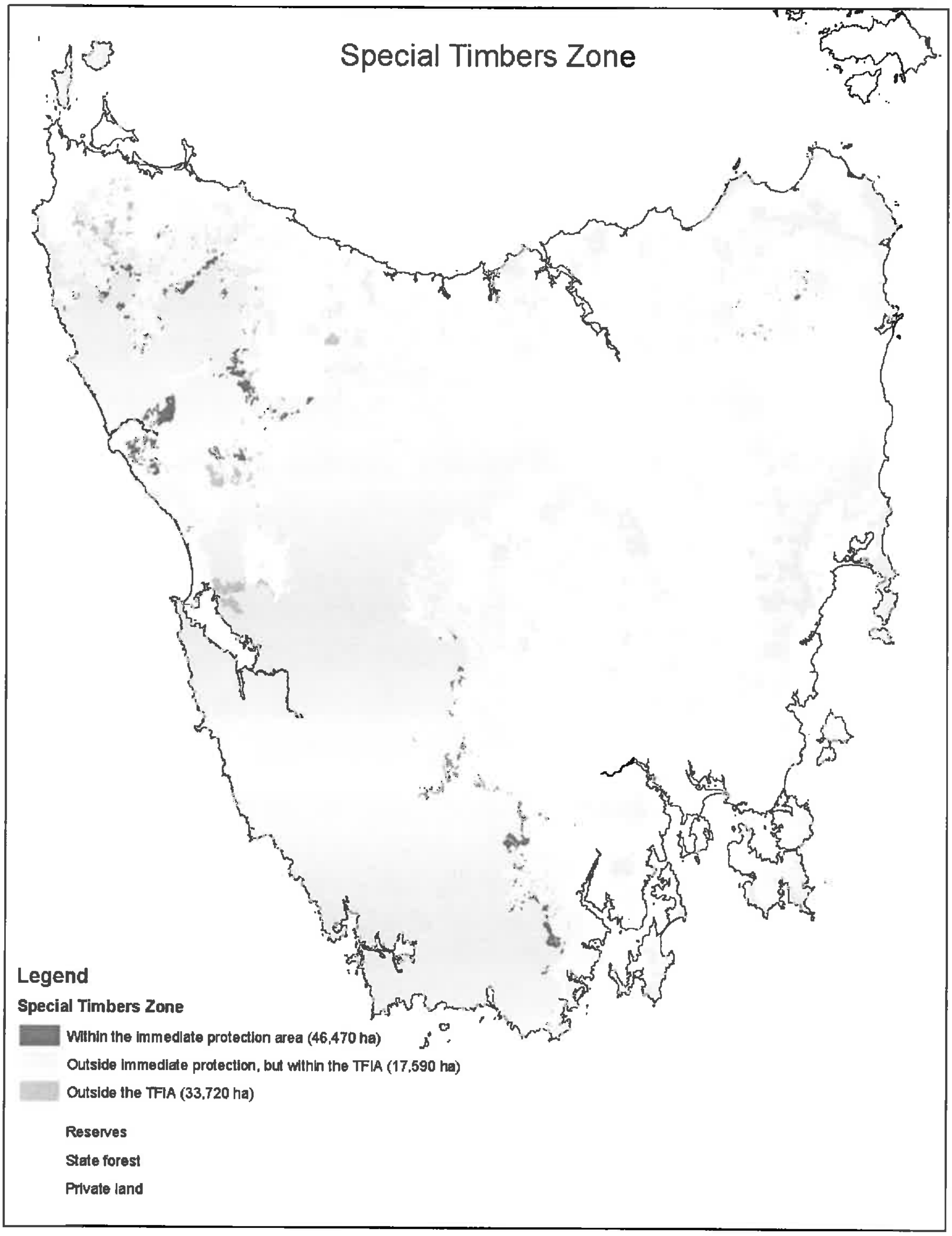

Figure 2 Intersection of Special Timbers Zones with the proposed new reserve areas

2.3.3 *Brack and Vanclay assessment*

Brack and Vanclay (2011) provided an independent assessment of the scenarios. Briefly, Brack and Vanclay (2011) were asked to examine 1) the basis of various aspects of the 2007 RFA Wood Review, and 2) the use of datasets, models, systems and methodology covered in task 1 for modelling the three wood supply scenarios reported in Forestry Tasmania (2011). The report was generally positive in its assessment of FT methods and models, but the authors noted that the Yield Regulation System has the potential to be re-run with poor or worst-case estimates of growth and yield to determine if the long-term security of production is constrained by underpinning assumptions.

Headroom refers to the reduction that wood supply planners apply to account for unanticipated constraints and constraints that go beyond the existing Forest Practices Code. That is, headroom accounts primarily for future, unanticipated changes, and also for tactical and operational constraints that are known at present but are not captured by area discounts. During our initial assessment of the work reported by Forestry Tasmania (2011) and Brack and Vanclay (2011), two concerns emerged. First, the scenarios used only 10% headroom. From discussions with the Reference Group, IVG members and other experts, it was clear that the 10% contingency may not have been sufficient to account for current and anticipated new forest practices constraints, other constraints and uncertainties that arise in operations. The review by Brack and Vanclay (2011) indicated that it would be prudent to assume a headroom greater than 10%. Accordingly we asked FT to provide data on area adjustments for two detailed planning scenarios (detailed later in this report) and to repeat the baseline and other scenarios using headrooms of 20% and 30% (correspondence from the Forest Practices Authority suggests headroom as high as 40% may be necessary, if no new reserves are proclaimed).

The methods for evaluating wood supply allow an analyst to focus on (constrain) the scenario to generate a given volume of wood, or it can guarantee some other property (reserve area, for instance), and maximize wood supply, in which wood supply is simpl an output. In cases where the volume was purely an output, the additional headroom assessments require simple linear corrections; for example, if the original forecast were 100,000 m^3, and then reduced to 90,000 m^3 by the application of 10% headroom, then 20% and 30% headrooms would correspond to 80,000 m^3 and 70,000 m^3 respectively. In cases in which the volume is a constraint, the scenarios have to be run again, because a simple linear correction is inadequate, although it may suffice for back-of-the-envelope approximations.

Second, the two non-baseline scenarios involved the removal of portions of the forest from active management. Specifically, the ENGO scenario was the base case without 572,000 ha of forest that had been identified as potential HCV forest reserves (Table 1, Forestry Tasmania 2011), and the industry scenario was the base case without 140,350 ha of potential HCV forest reserves (Table 2, Forestry Tasmania 2011). In the analyses reported by Forestry Tasmania (2011), these scenarios were performed simply by masking the potential HCV reserve areas and re-calculating volume accordingly. Although Brack and Vanclay (2011) comment that a straightforward subtraction strategy such as this is sufficient for direct comparison, we are not comfortable with this approach because it does not take account of possible inherent nonlinearities in the constraints. Therefore, we have asked that these scenarios be re-run with the excluded forest removed from the operational forest, before optimisation.

2.4 Current stocks and flows

Assessments of contracts for the supply of specialty timbers, sawlog and peeler billets will be presented in a separate (companion) report to the IVG. This report was informed by developments in the wood demand verification process but did not have access to final estimates at the time these analyses were undertaken. This report assumes values that will be close to the final assessments to be presented in the companion report. Any differences will not make a substantial difference to the conclusions presented here.

2.4.1 Private forests (including plantations)

In 2010–11, private land holdings in Tasmania comprised approximately 860,000 ha of native forests and 180,000 ha of plantations. In 2009–10 the private estate contributed 36.6% to State timber production, and in 2010–11, 34.0%. Private native forests produced about 54,000 tonnes of sawlog, veneer and ply per year in 2010 and 2011 although the quality of logs from private property is generally lower than the category 1 and 3 HQSL standard used in State Forests. Private hardwood plantations produced about 4,000 tonnes of these products (Table 3). An unknown but significant proportion of private native forests are subject to conservation covenants, non-timber harvest owner intent, and other agreements that limit wood supply. Future supply options are clouded by lack of knowledge regarding owner intent, and by formal and informal commitments by individual landowners to supply different segments of the timber processing industry. However, a total of 471,255 ha of private forests have been approved as private timber reserves, indicating the land is dedicated to long-term forest management and wood supply (PFT 2011). No data are available on the proportion of these forests that have been operationalised or converted to plantations. In the last ten years, total wood production from private native forests declined from over 2,000,000 tonnes in 2001 to less than 500,000 tonnes in 2011 (PFT 2011).

Table 3 Private forest harvest volumes (tonnes) (PFT 2011) [3]

	2009-10	**2010-11**
Native hardwood forest		
Sawlog, Veneer & Ply	54,067	54,133
Pulpwood	537,740	426,650
Plantation hardwood		
Sawlog, Veneer & Ply	3,712	4,514
Pulpwood	807,411	741,124
Plantation softwood		
Sawlog, Veneer & Ply	64,991	125,495
Pulpwood	230,646	268,655

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[3] Additional data going back further in time will be added to future versions of this report.

Virtually all private plantations are currently being managed on a 10 to 12 year rotation for pulp wood and could not be used for sawlog or peeler production, because pruning after age 4 years will not result in certain development of clear wood below five metres (Nolan et al. 2005). Pitt and Sherry (2012) provided an analysis of product returns from the private plantation estate under three scenarios: i) current management, ii) thinning and pruning where possible and clearfall at 30 years, and iii) thinning and pruning where possible and clearfall at 40 years. Table 4, Figure 3 and Figure 4 are excerpts from their report. It assumes the caveats about the utility of plantation timbers for sawlog production have been accounted for through plantation acquisition, planting, management practices and investment in technology and market development. Industry interests are skeptical of the potential for these problems to be resolved in the short to medium term (see below). Our assessment of these issues is developed fully in Appendix 2.

Table 4 Potential Plantation Hardwood Sawlogs m^3 per year from private plantations under three different scenarios (without headroom allowances)

	Current Management	Maximize Thinning and Pruning, Harvest at 30	Maximize Thinning and Pruning, Harvest at 40
2012–2016	60	72	24
2017–2021	222	224	21
2022–2026	676	2,202	107
2027–2031		7,921	528
2032–2036		19,345	5,226
2037–2041		61,487	18,251
2042–2046			42,098
2047–2051			151,778

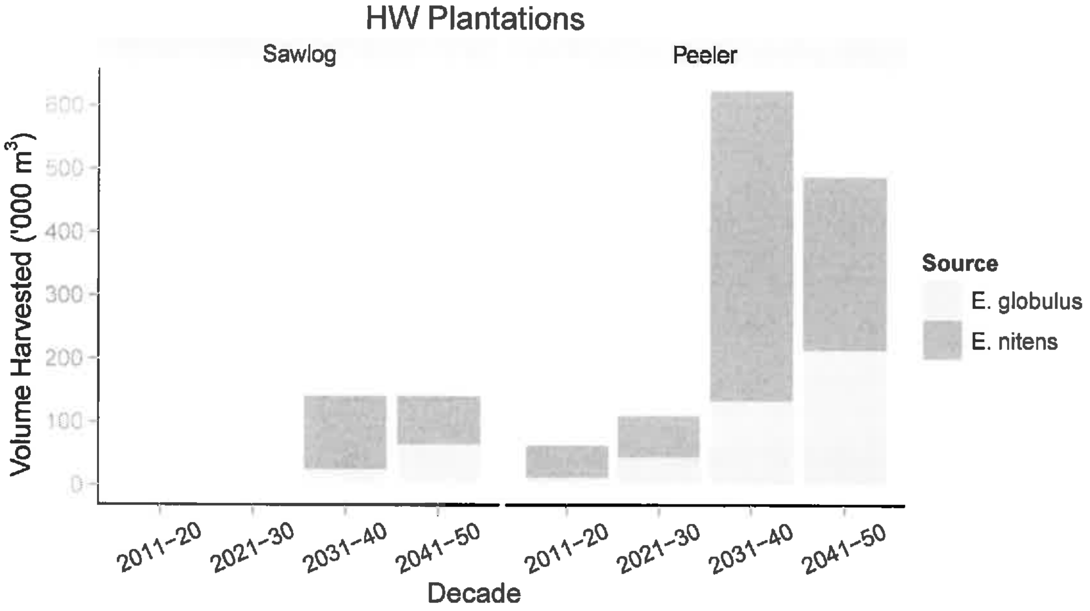

Figure 3 Public hardwood plantations: Potential production of sawlog and peeler billets from public hardwood plantations, assuming 2030 start date.

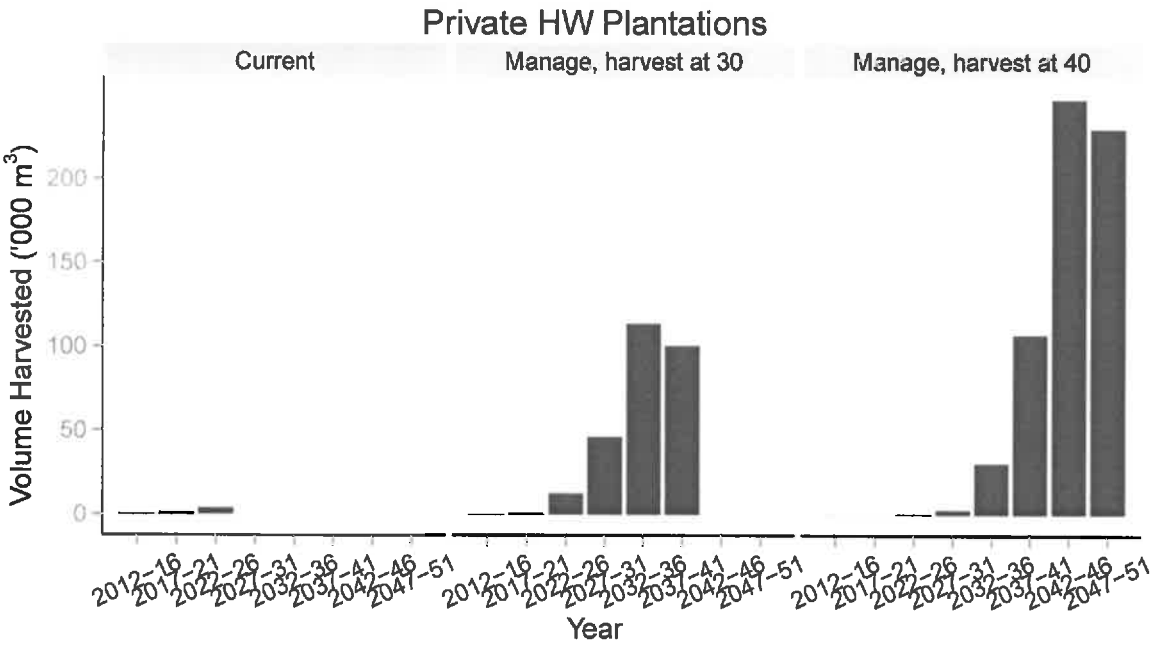

Figure 4 Potential production of sawlog and peeler billets from private hardwood plantations

Interpretation of these results rests on some important practical caveats and operational constraints about the volumes of sawlog and peeler billets that can be expected from private land. The analysis is likely to overstate the potential availability of high quality sawlog as it assumes that thinning and pruning can be commenced now. It also ignores information about landowner intent. For example, Gunns own well over 50% of the private hardwood plantations. Under current practices and arrangements, these will not be converted to sawlog regimes and will be managed for short-rotation pulpwood production.

2.5 Process

The verification commenced with a review of documents relevant to the issues raised in the Intergovernmental Agreement and the Terms of Reference of the IVG. This was followed by rounds of interviews with FT staff, panel discussions with the Reference Group, face to face discussions with Reference Group members and other stakeholders, and email exchanges between many parties to clarify objectives and the details of assessments.

The review of FT systems was based on in-person and telephone interviews with various FT personnel, including Martin Stone, Tom Kelley, John Hickey, Steve Whiteley, David Mannes, Rob Musk, Mike McLarin, Tim Osborn, Lee Stamm, and Michael Wood. The materials and evaluations provided in interviews were supported by internal and external literature, and numerous follow-up questions by email. Questions regarding the wood supply models, assumptions, and processes were addressed in detail during these discussions and are summarized below.

We also reviewed the processes involved in creating yield tables for use in sustainable yield analyses, examined samples of source code for the forest growth simulator, and observed growth simulations (input/output). Information regarding timber supply was included to illustrate how it affects and is affected by yield analyses. All materials pertaining to the process were provided for the purposes of review only.

3. Description

Figure 5 provides a schematic overview of the processes that contribute to the calculation of sustainable yield by FT.

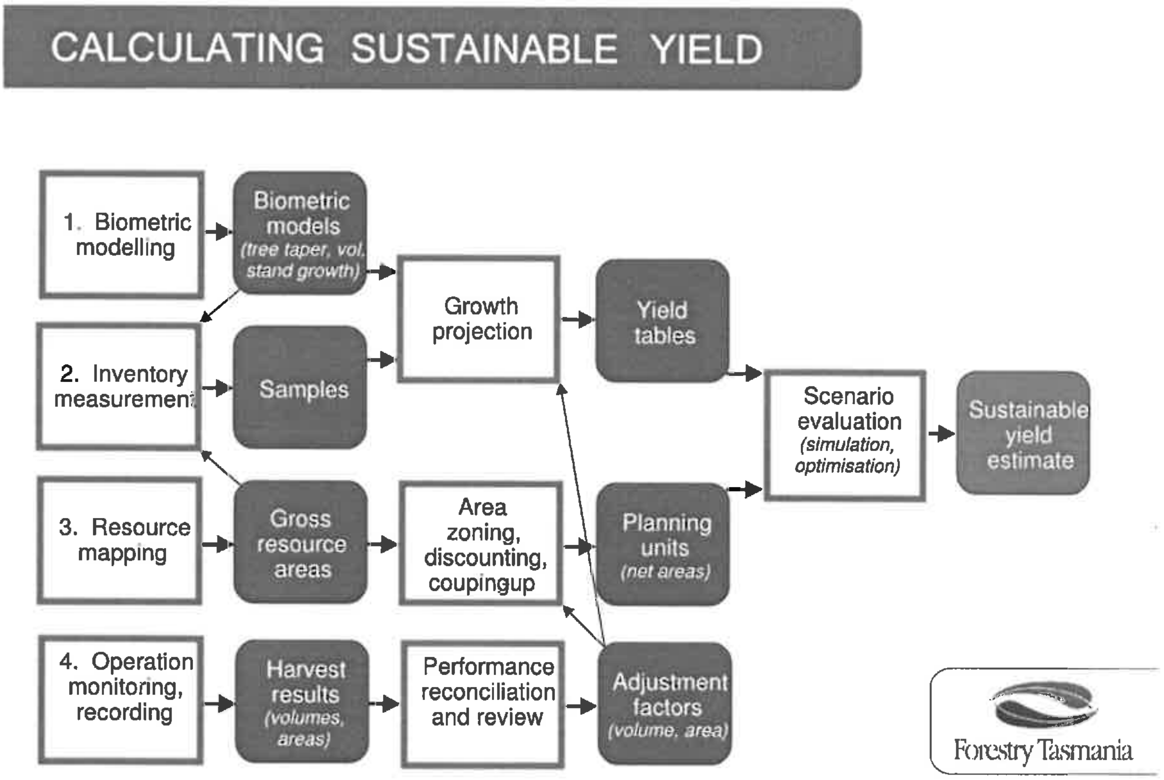

Figure 5 Schematic diagram of Forestry Tasmania forest projection system (Stone, M. pers. comm. 2011)

3.1 Synopsis

This section contains a brief overview of the system that is used to calculate sustainable yield by FT. Whiteley (1999) is also a useful resource.

Tasmania's production native forests cover two main types: tall wet eucalypt forests (historically regenerated by clearfall, burn, and sow silviculture; more recently, often by aggregated retention) and dry eucalypt forests (usually managed by selective harvesting and natural regeneration). The tall wet eucalypt forests produce greater wood volumes per ha/yr. The operational forested area of all forest types including native eucalypt forest, plantation and special timber areas, is currently divided into approximately 14,500 provisional coupes (hereafter, coupes) covering about 682,000 ha (Figure 6). The division of the forest into coupes is based on forest types and operational factors (such as slopes, rockiness, accessibility, and proximity to reserves). Each coupe is located within an inventory area (IA), of which there are 21. Each IA is within one of four forest districts (FD), although some IAs cross district borders. The coupes are the operational planning (harvesting) units. Each coupe is identified as comprising one or more forest classes (FC), of which there are 91. FCs are a stratification of forest type, mapped across State forest by aerial photo interpretation (API), and classifying forest structure according to its height, potential height, density and growth stage.

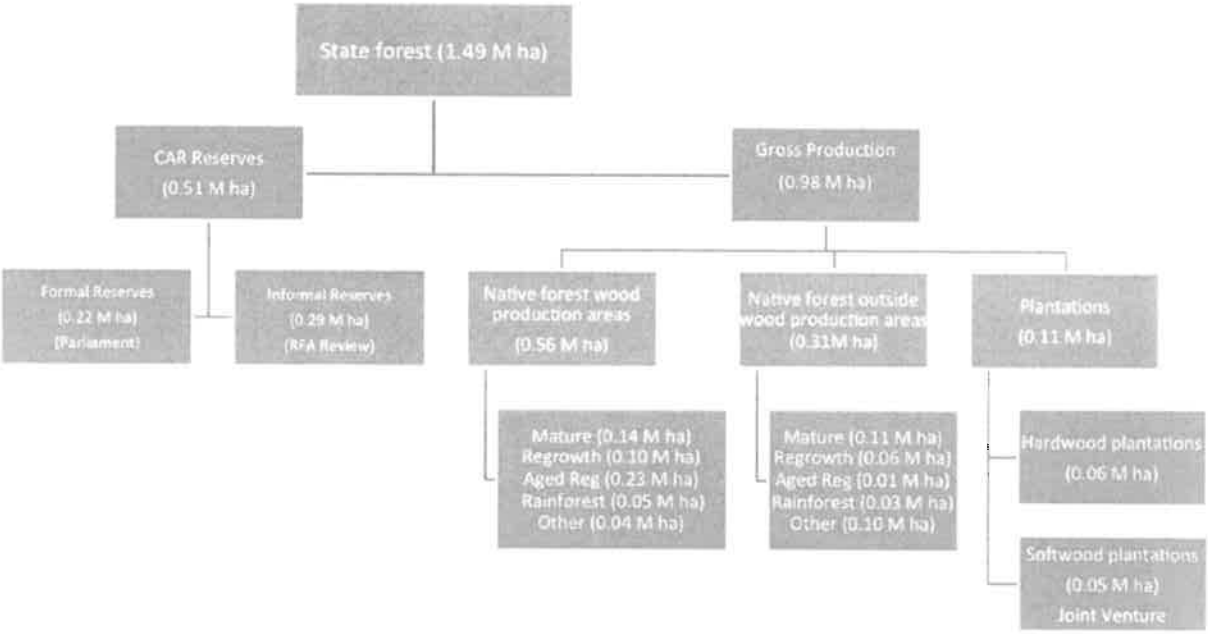

Figure 6 Breakdown of Tasmanian State Forest designation in reserves and production areas (FT, pers. comm.)

For the documented scenarios, FT used a collection of 2,976 unique sample plots allocated amongst the FC across the IAs, at an average rate of about one plot per 200 ha. Most of these sample plots are temporary plots. These sample plots are used as the starting points of growth prediction: the volume is projected forward in time for each available sample plot, and these volumes are averaged for each planning period to represent all the forest within each FC/IA combination. An assessment of the distribution and analysis of inventory plots is provided below.

Each coupe is then provided a volume per hectare yield table that reflects the proportion of its area that is covered by each FC, determined from API. This yield table is created from the growth models developed from the sample plot data. The table is discounted by volume corrections from a volume reconciliation exercise (VRE) and by the volume-equivalent of area corrections from an area reconciliation exercise (ARE). These quality-control processes are outlined and assessed below.

A considerable portion of the forested area is unavailable for operations because of exclusions of various kinds, including slope, rockiness, streams, etc. These considerations motivate the ARE calculations mentioned above. Additionally, each coupe is assigned a Coupe Confidence Classification (CCC) by regional foresters, which represents their confidence that FT will be able to harvest the coupe and meet forest practices, operational and economic constraints.

The coupe-level yield table projections, discounted by the three factors (VRE, ARE, CCC) are then provided to the forest estate modelling software Woodstock (coupled to the Mosek linear programming optimiser), along with any constraints, such as even flow requirements, and an objective function, for example, to maximize net revenue. These inputs and constraints form the basis of a forest projection scenario. A final discount, termed 'headroom', is levied on the outcome to reflect uncertainty that is due to factors difficult to predict and to potential future changes in forest practices.

The entire process is driven by four basic processes: *forest inventory* to provide the starting conditions for the model projections (and also the raw information needed to maintain the growth models, when they are updated), *regional mapping* to determine the boundaries and composition of the forest coupes, and the FC and IA of each temporary plot, *growth and yield modelling* to project the forest forwards in time, and *operational monitoring* to determine the area- and volume-based corrections that are applied before the yield table is provided to the optimiser.

3.2 Growth and yield modelling

Forest growth models are used to project available volume forward in time. FT uses separate forest growth projection systems for projecting plantations and native forest systems. The native forest projection model is documented internally (West 2008c). The plantation forest projection model is documented in Candy (1997), and details of its implementation are recorded in McLarin et al. (2006). As with the native growth model, the plantation model (Candy 2007) comprises statistical sub-models of growth and yield processes. The source data used to fit the models includes experimental plots for thinning and pruning, enabling these management operations to be represented in the model. FT is moving towards integration of modelling systems for plantations and native forests into a common software framework. This integration will eliminate inefficiencies such as dual software maintenance. The projections will not change.

The native forest estate is projected using a suite of forest growth and yield models that are documented in internal reports (West 2007, 2008a–c) and some published literature (the taper model, Goodwin 2009). The models are cohort based, which means that trees are aggregated into cohorts by age class and species group, and the growth and yield of the cohorts are projected as a unit. Cohort-based forest growth simulation is an efficient and reasonably accurate strategy for forest estate models (see e.g., Weiskittel et al. 2011), although most modern forest growth systems are based on simulating the individual tree.

The native forest coupes comprise mixtures of species and, often, mixtures of ages, depending on the treatment and disturbance history of the coupe. Each species-group/age-class combination present in a stand is represented and modeled as a separate cohort. Forest composition is highly variable in some locations. The model handles variable composition of the forest coupes by assigning a unique site index to each cohort based on its height and estimated age. Cohort growth is then projected conditional on the assigned site index, and competition from other cohorts. Species growth patterns are assumed to be sufficiently distinct that the cohort-specific site index information captures important inter-species variation.

Taper and bark thickness models are used to convert projected standing volume into products. Both models are species specific. The taper model is documented in Goodwin (2009); the bark thickness model is documented in West (2008c), and uses an empirical Bayes strategy following Gertner (1984). Such a strategy has been used to obtain good predictions of tree dimensions such as height and volume in other situations; see e.g. Lappi (1991) and Robinson and Wykoff (2004).

Growth and yield models, the basis of the production management system, are empirical models constructed from permanent plot (mostly ex-CFI) data. The system comprises cohort-level growth models, species-specific taper models, species-specific bark thickness models, and general mortality models and ingrowth models. The models are all empirical, which is to say that they are statistical models of the various cohort-level forest processes. The permanent plots used for the mortality model are the same as those used for the basal area increment model.

The mortality model works by reducing the sample weight of the cohort proportionately to the expected probability of mortality, which smooths out variability. Mortality encompasses both endemic and self-thinning components. The endemic mortality probability is computed for each tree using a statistical function of the cohort's predicted basal area growth, the diameter of the tree, and the species group site index of the cohort (West 2008c). The self-thinning mortality probability is a function of the tree's position in the cohort, the crown widths, and the amount of growing space (West 2008c).

The models aim to account for endemic (non-catastrophic) disturbance implicitly. The data that contribute to growth models and inventory are assumed to reflect typical levels of endemic disturbance, including drought, insects, and fire. Our review of the inventory plot location specifications did not identify any obvious sources of bias with respect to the location of sample sites in relation to disturbance or growth (see Section 3.3 below). If sample locations are unbiased, the models should provide unbiased estimates in the presence of endemic damage, and are likely to underestimate growth in undisturbed stands. If fires are low intensity and relatively small (less than 2000ha), then salvage logging is considered to be an option, such that wood supply would not be unduly compromised. High-intensity fires are generally larger in scale and would compromise predictions as to both the quantities of wood and the qualities of certain classes of wood products supplied.

We now distinguish between the projections made by the whole model and its components, the sub-models. Despite the lack of obvious sources of bias in the inventory and growth model parameter estimates, sub-model projections are positively biased (that is, they over-estimate the available resource, West 2008b). For example, West (2008b) found over a reasonably random sample of permanent plots, the predicted growth was 0.15 m^2/ha/yr higher than the observed growth, and cohort stocking density for young single-cohort eucalypt stands was about 90 stems/ha too high. The source of this bias is unclear, and West's (2008b) efforts to improve the sub-models individually were unsuccessful. Consequently, the model projections are corrected for bias in the sub-model projections, as reported in West (2008b). Out-of-sample estimates of the bias improvement were not made.

Growth projections generate expected volumes of different products by FC and, using those expected FC volumes, by coupe. The coupe volumes are then summed to regional levels. The projections are handled on an annual basis. Volumes of products per hectare are calculated at given time points, and averaged for the forest class. The volume per hectare is discounted by the VRE and ARE that are appropriate to the class. For each coupe, the weighted average of its constituent FCs is computed. The product of the weighted average volumes and the coupe area is provided to Woodstock, along with a CCC flag. VRE, ARE, and CCC are explained in greater detail in a following section.

Regeneration is handled by plot-level imputation of the temporary or permanent sample plots that were installed in coupes that were harvested and treated in the 1980s. These plots are considered representative of the regrowth to be expected from current silvicultural practice.

3.3 Inventory

The forest inventory plays two roles; firstly as a source of plots that are used to represent the initial conditions for the FC and IA that the plots inhabit, and secondly as a source of forest growth and dynamics information for evaluating and refining the forest growth model. For the documented scenarios, FT used a collection of 2,976 unique sample plots, applied to sample FC at an average rate of about one plot per 200 ha. Of these sample plots, 2,468 (83%) are temporary plots. FT's quality assurance policy (Hodge 2010) ensures that a minimum of 5% of all strategic inventory plots completed by FT staff undergo a Quality Assurance Check (QAC). This is process-based, rather than outcome-based and it evaluates infractions including the mis-measurement of trees. It does not assess bias. In the last five years, of the 89 plots audited, one has failed.

3.3.1 Permanent plots

The permanent plots are a source of growth and yield information that has been used to test and update the forest growth models. A number of the randomly-located plots are also used (with temporary plots) as representative samples of initial conditions for forest growth projection for certain FC/IA combinations. Standard procedures describe installation and measurement instructions for field crews (Mannes & Bennett 2002).

Many of the older permanent inventory plots were once CFI plots; sample allocation was based on stratified random sampling. The sampling rate was proportional to stratum area. The CFI plots were augmented by plots for trials and other special purposes for the purpose of model construction. The spatial pattern of permanent plots reflects historical treatments (see Appendix 2 for maps of plot locations). Previously, growth plots had not been installed in mature forest or in areas not managed by FT / Forest Commission. Therefore, large areas of forest were not sampled for a long time, particularly the dry east coast forests, and the Australian Newsprint Mills (ANM) concession areas in central Tasmania. This imbalance has since been remedied with the establishment of new plots (see Appendix 2).

3.3.2 Temporary plots

Along with some of the permanent plots, the temporary sample plots are used as representative samples of the starting points of growth prediction: the volume is projected forward in time for each available sample plot, and these volumes are averaged to represent all the forest within FC/IA combination. The plots are allocated within the forest as a random cluster sample, which means that clusters of three or six fixed-area or (preferably) variable-radius plots are located at random.

Guidelines for the installation and measurement instructions are provided to field crews (Mannes 2003). Plots are not relocated if they cover roads, harvested areas, or damaged area. Plots are relocated for representativeness if they cover streams (which are removed from the coupe areas by the area reconciliation exercise) or approach a boundary. The positions of the plots remain fixed, whereas the stratum boundaries often move when the forest is re-stratified by API, leaving plots arguably randomly located with respect to edges. Therefore it is possible for plots to change classes upon retyping, and indeed this happened to about 10% of the plots in the last five years.

Temporary plots are usually retired from the projections if they are older than 15 years, but may be retained if there is insufficient recent inventory in an area. Plots are also retired if they are harvested, suffer significant disturbance, or end up outside the production zone.

3.4 Resource mapping

The landscape is mapped into Forest Classes (FCs) using API and field updates, using a procedure that is explained in detail by Stone (1998). FCs are used to stratify forest into structural stands based on species (more specifically, eucalyptus/not eucalyptus), height, crown density, and growth stage.

API is repeated on a 20-year cycle through the state, using colour 1:20,000 photography and stereoscopes. As well as this periodic re-mapping, the FC stratification is updated at least annually to reflect forest harvesting and significant wildfires. API has been ground-truthed internally on two occasions in the 2000s. We comment on this below.

Within the forest, areas are delineated as operational planning units, or coupes, to divide the forest into stands that are as homogenous as possible in terms of structure and productivity, The division of the forest into coupes is undertaken by field planners, based on forest types and operational factors (such as slopes, rockiness, accessibility, and proximity to reserves). Each coupe notionally represents a forest stand that will be managed and harvested as a unit. Coupes are reviewed and updated constantly by field staff to reflect recent operational experience, re-mapping, field surveys, and changes to forest practices guidelines.

3.5 Operation monitoring

Operational monitoring by FT provides two important corrections that are used to improve the accuracy of the predicted extractions: a volume correction and a coupe area correction.

3.5.1 Volume reconciliation

Inventory and yield predictions are verified in an approximately five-yearly exercise in which extracted volumes are compared with projected volumes (Anonymous 2011). Extracted and predicted volumes per hectare are recorded on a coupe-by-coupe basis. The predicted and observed volumes are used to calculate a ratio of means correction for aggregated classes of FC and IA. This exercise provides class-specific volume reconciliation ratios. (The classes are hierarchically clustered into larger cohesive categories because the harvested coupes are sparse within combinations of IA and FC).

Extracted volume information is regularly updated using a geospatial database (Spatial Oracle Database) of harvest information provided in the Supply Chain Management System (SCMS; formerly, SALES) and the Forest Operations Database (FOD). Adjustments are calculated using assessed and recovered volumes by Forest Quality Class (FQC), which are mapped onto the FC's by IA.

The VRE proceeds as follows. The 91 forest classes are aggregated into about 10 broad quality classes. Coupes that are in a single quality class are selected. The coupe extractions and the coupe predictions are summed by quality class, and thus a ratio-of-means style correction is developed for each aggregated class. Therefore, past correction factors are assumed to adequately anticipate future biases, and the extent to which they do not is assumed to be covered by the *headroom* (q.v.). Examples of sources of such biases are the presence of internal rot, biases in growth projection, and variation in product realisation from standing volume.

A graphical summary of the VRE can be found in Figure 7 and Figure 8. The data have been derived as follows. Each point on the graph represents a coupe. The coupes are coloured by forest district. The coupes for each of six important forest quality classes are presented, and each panel within a figure represents a different class (forest classes presented in figures include Mature Eucalypt Forest, Mixed Mature / Regrowth Eucalypt Forest and Regrowth Eucalypt Forest). The x-axis of each graph reports the sawlog or pulpwood that was estimated by FT, scaled by the VRE ratio computed as an outcome of the 2011 reconciliation. The y-axis of each graph reports the sawlog or pulpwood actually harvested, scaled as follows.

To permit comparison with actual sawlog and pulpwood yields arising from various harvest operations ranging from clearfell (where all standing volume log product is harvested) to partial logging (where a proportion of the standing volume is removed), actual yields are adjusted to standing volume of log product based on an estimate from the field of the percentage of standing volume of log product harvested (i.e., what proportion of the standing volume of log product has been harvested in the operation). Finally, a least-squares regression line is for each district is superimposed on each panel, along with a 1:1 line to facilitate comparison. The proximity of the least-squares line to the 1:1 line is a measure of the quality of the VRE ratios at the district level within each quality class.

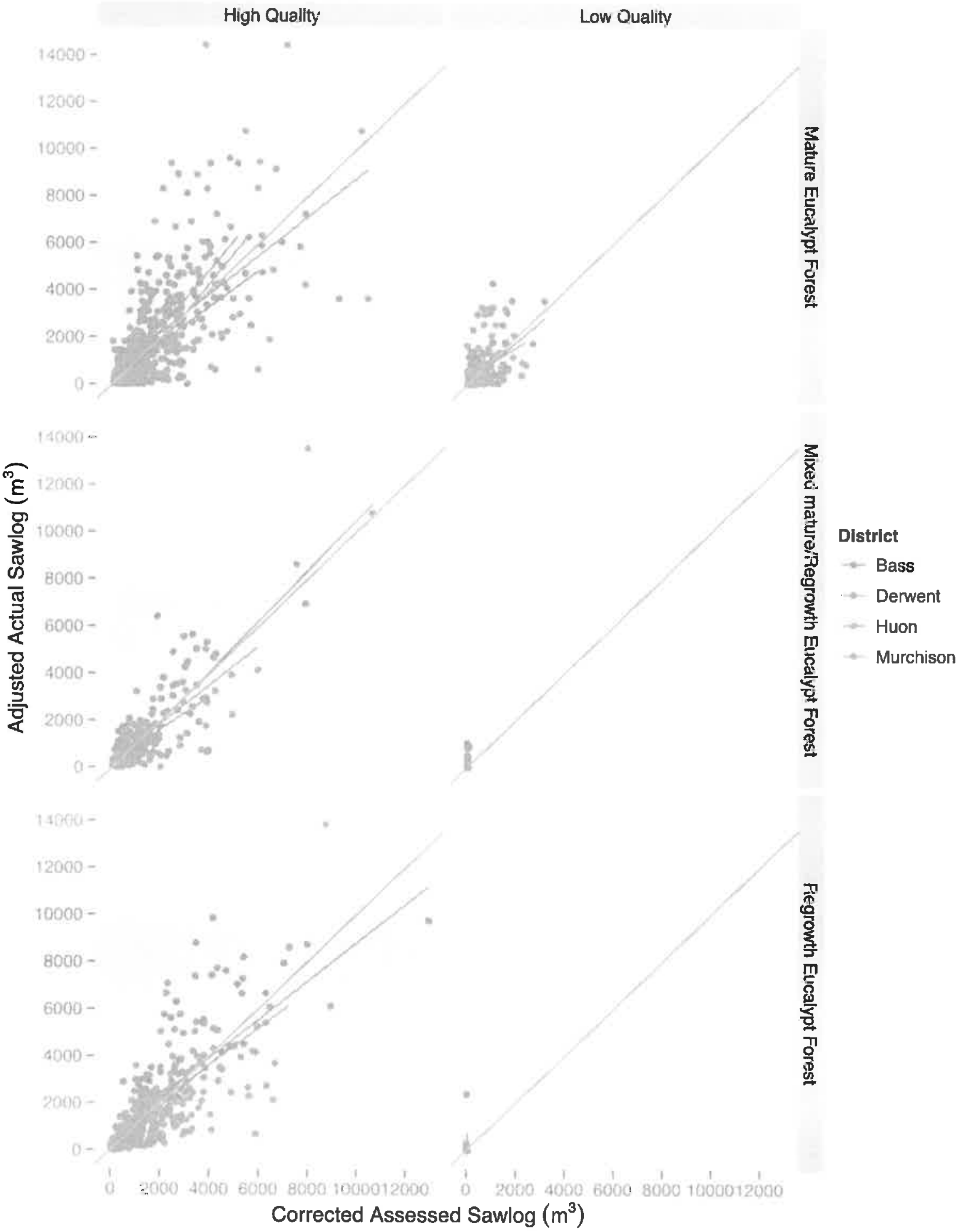

Figure 7 Outcome of VRE analysis for sawlogs, reported for six important forest quality classes

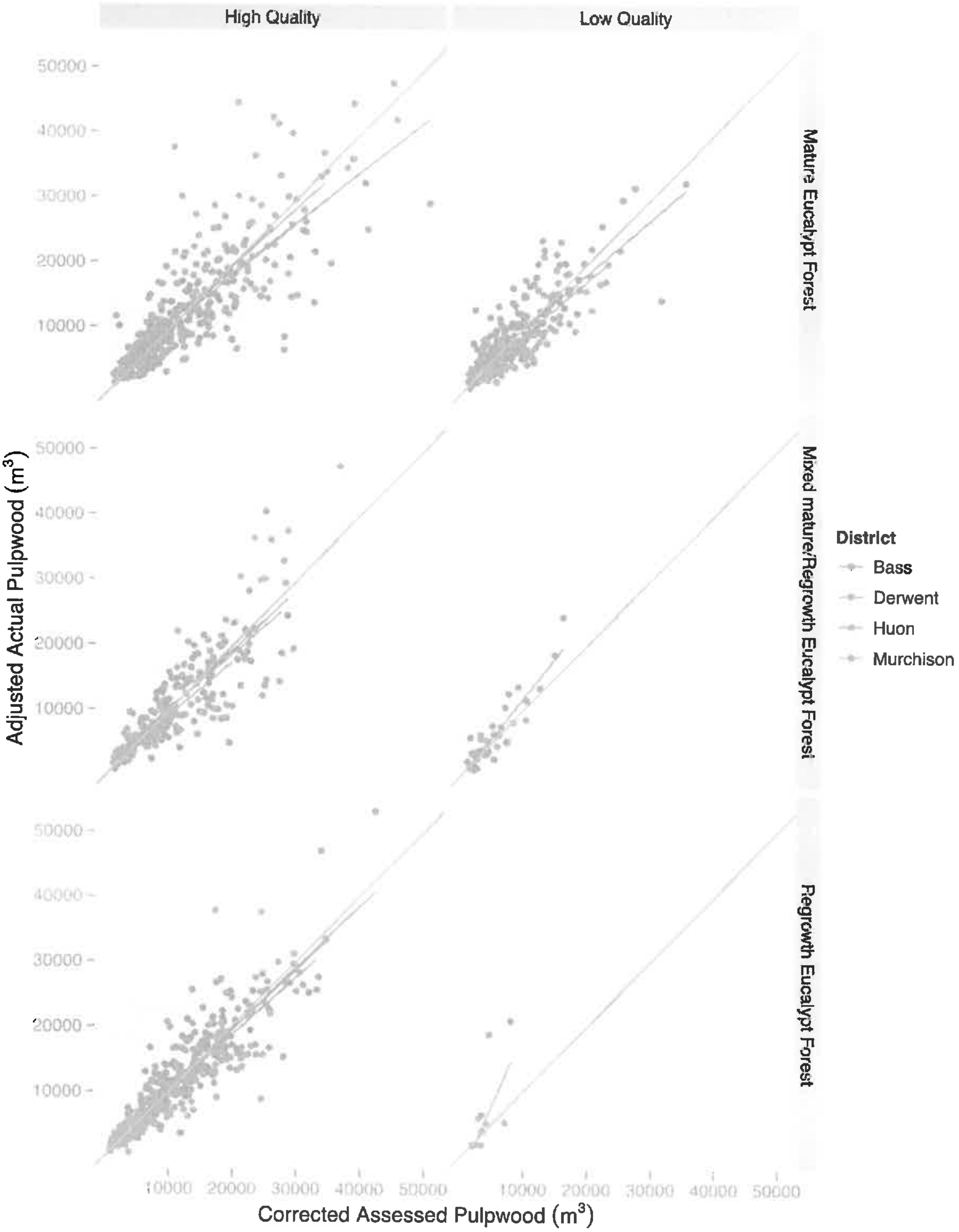

Figure 8 **Outcome of VRE exercise for pulpwood, reported for six important forest quality classes**

3.5.2 Coupe area reconciliation

The class-specific area factors are based on comparison of area harvested in each coupe (GPS perimeter for clearfall and API for shelterwood operations) and the projected area harvested. The Area Reconciliation Exercise follows a similar process to the Volume Reconciliation Exercise outlined above (Stamm 2011a), although the details are considerably more complicated because provisional coupes may be intersected by more than one forest class and inventory area, and more than one operational coupe. Therefore verifying the ARE does not lend itself to as straightforward a comparison as does the VRE. We examined the available documentation and undertook several interviews of key personnel to grasp the process, and compared the outcome with the results of previous exercises conducted in 2003 and 2006. The computed AREs have changed only marginally from those used previously. The discount between projected and achieved harvested area is due to a range of factors including forest practices prescriptions, steepness, drainage and commerciality.

3.6 Scenario evaluation

The forest scenario evaluation and optimisation are carried out by Woodstock, a software program from Remsoft[4], coupled with the Mosek linear programming optimiser.

Forest simulation scenarios typically assume native forests are managed for a 90-year rotation for extensive management, 65 years for thinned regrowth, 70 years for Blackwood and 200 years for Myrtle (Whiteley 1999). A 50-year lower age limit was applied for the documented scenarios, meaning that no regrowth stand could be entered until at least 50 years after previous harvest. However, the time of harvesting of each coupe is chosen by the optimiser, and is not set as an externally controlled parameter.

The 14,500 coupes are also distinguished by operational likelihood (Stamm 2011b). This provides a coupe weighting (CCC), described above that reflects the probability that the coupe will be able to be harvested within forest practices, operational and economic constraints. The Eucalypt Estate Model excludes coupes with a CCC of 0%, and by default counts all coupes with CCC > 0%. From there, the coupes can be included or excluded and / or woodflow reported by CCC (see Section 5.6).

The within-coupe class area is discounted by class-specific area factors (ARE) and the projected timber is discounted by IA/FC-specific reconciliation ratios (VRE) as noted above. Hence, projected timber yields are discounted to reflect otherwise unforeseen harvesting constraints such as the presence of class-4 streams and slope, as well as otherwise unforeseen volume reductions such as internal rot, fire, and insect damage.

Headroom refers to a percentage of the predicted harvestable resource that is excluded in the scenario as a buffer against unexpected changes in future conditions, spatial constraints, and the like. The 6/6 scenarios used 10% headroom. The scenarios documented in this report use varying amounts. Area reconciliation (ARE) discounts are usually about 20%, based on historical application of the Code. This area is taken into account in modelling before headroom factors are applied. Thus, if a 30% headroom is applied, then the output indicates that approximately half

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[4] http://www.remsoft.com/products.php?id=1, last accessed 1/12/2011.

(56%) of the areas potentially available for harvesting can actually be harvested. Below, we evaluate headroom levels and their applicability to different scenarios.

The wood supply verification report team assessed the amount of field work that would be necessary to validate the FT inventory of both native forest and plantations, by forest type, region and product type. We used standard formulas for determining sample sizes (see e.g. Avery and Burkhart 2002, Chapter 3) and plot-level estimates of volumes per hectare, by product, provided by FT. Assuming that the intention is to estimate the state-level average standing volume per hectare with a 95% confidence interval of ± 5%, a simple random sample of 1243 field plots would be needed for total volume, 3,968 plots for sawlog, and 1,192 plots for pulpwood (sawlog is relatively more variable than the pulpwood or the total).

As a rule of thumb, doubling the allowable interval width will reduce the needed plots by a factor of four. So, to obtain a 95% confidence interval of ± 10%, a simple random sample of 311 field plots would be needed for total volume across the entire state.

If stratification by district and forest quality class were used then the plot counts to achieve the same interval width would be about half: 580 for the total of all products, 2,131 for sawlogs, and 690 for pulp. The numbers of plots required to obtain similarly-sized interval estimates at the regional level using stratified random sampling, where stratification is performed by forest quality class, are presented in Table 5 (see section 3.3).

Table 5 **Plot counts needed to obtain 95% confidence interval estimates of ± 5% using stratified random sampling by forest quality class within regions. Counts are not laterally cumulative.**

	Total volume	Sawlogs	Pulp
Bass	606	1849	749
Derwent	745	2599	954
Huon	468	1864	527
Murchison	665	2731	691
Total	2484	9043	2921

4. Comparison

4.1 Growth and yield modelling

In this section we provide a brief comparative review of forest growth models that are used in other jurisdictions. We focus on those models that are currently or that have been in use for forest estate or regional forest planning. This omits a number of potential models that, while perhaps theoretically worthy, have not yet been demonstrated as being suitable for large-scale forest estate modelling.

The earliest operational, growth and yield model reported is Prognosis (Stage 1973), which is an individual tree mixed-species, mixed-age forest growth and yield simulator developed for northern and central Idaho, USA. Prognosis was the basis for the Forest Vegetation Simulator (FVS; Crookston & Dixon 2005), and more than 20 variants of the Prognosis model are now operating as FVS in different areas of the United States. The Prognosis model has also been ported to Austria (PrognAUS; Monserud & Sterba 1996) and British Columbia, Canada (Prognosis-BC; Anonymous 2006) and variants are also in use in Italy and Russia (Crookston & Dixon 2005). FVS/Prognosis also inspired the development of Organon for forest management in Oregon, and is used as the engine for NED-2, the successor to NED-SIPS (Twery et al 2005).

Other models were developed in other areas of the USA following the success of Prognosis, including CACTOS/Calpro in California (Liang et al 2004), Organon in Oregon (Hann 2011), FIBER in the north-east (Solomon et al. 1995), along with NED-SIPS and then NED-2 (Simpson et al. 1995; Twery et al. 2005), and STEMS in the mid-West (Belcher et al. 1981). Similar developments have occurred in Europe, with the BWIN-Pro and now the open-source TreeGrOSS (Hasenauer 2006), and similar models such as SILVA, MOSES, and STAND (see Hasenauer 2006 and the citations therein).

A summary of characteristics of a sample of reasonably comparable forest growth models is presented in Table 7. In terms of model infrastructure, the FT model is similar to StandSim, Tipsy/TASS, and FPS in that the source code and model documentation are not freely available. All the other models either make the source code or suitable model documentation available, and many of them have been extensively published in peer-reviewed literature. The FT model has been tested (West 2008a) and improved (West 2008b) using independent growth data. The results of these tests are not publicly available.

Table 6 **Attributes of a set sample of forest estate models**

Name	Region	Source Code	Docu-ment	Peer Review	Smallest Unit	Uses Age	Site Quality	Detailed Testing	Useful Citation
BWIN-Pro	Germany	Yes	Yes	Yes	Tree			Yes	Hasenauer (2006)
Calpro	CA, USA	Eq	Yes		D. class	No	Trees		Liang et al (2004)
FIBER	NE USA	Eq	Yes	Yes	D. class	No	Site		Solomon et al (1995)
FT (Native)	**Tasmania**	**No**	**No**	**No**	**Cohort**	**No**	**Trees**	**Yes**	**West (2008c)**
FT (Plant.)	**Tasmania**	**No**	**Yes**	**Yes**	**Tree**	**Yes**	**Trees**	**Yes**	**Candy (1997)**
Various	NSW Aus.	?	Internal	No	Tree	No	Trees	Unsure	Unknown
Various	Qld Aus.	Yes	Archived	Some	Cohort	No	Site	Yes	Vanclay (1989)
Various	WA Aus.	No	Internal	Yes	Tree	Yes	Trees	Yes	Rayner (1992)
FPS	USA	No	No	No	Tree	Can	Either		Arney and Milner (2007)
FVS	USA	Yes	Yes	Yes	Tree	Can	Site	Yes	Crookston and Dixon (2005)
NED-SIPS	USA	Yes	Yes		Stand	No	Trees		Simpson et al. (1995)
Organon	PNW USA	Yes	Yes	Yes	Tree	No	Trees	Yes	Hann (2011)
Prognosis	Idaho	Yes	Yes	Yes	Tree	No	Site	Yes	Stage (1973)
PrognAUS	Austria	Yes	Yes	Yes	Tree	No	Site	Yes	Monserud and Sterba (1996)
PrognosisBC	BC/Can	Yes	Yes	Yes	Tree	No	Site	Yes	Anonymous (2006)
StandSim	Vic, Aus.	FIA	Some	Some	Tree	Yes	Trees	Yes	Wang and Hamilton (2003)
STEMS	MW USA	?	Yes	Yes	Tree	No	Trees	Yes	Belcher et al (1981)
Tipsy/TASS	BC/Can	No	Some	Yes	Tree	Yes		Yes	Di Lucca (2002)

Table notes: the models selected on the basis that the models are currently or have been in use for large-scale mixed-species, mixed-age forest estate planning. The *Region* column refers to the original location of the model. The *Source Code* column has two values: Yes, meaning that the source code is freely available (most open), and No, meaning that the source and equations are unavailable. *Document* refers to whether sufficient documentation is publicly available to assess the model. *Peer Review* refers to whether the motivating documents have been published in peer-reviewed literature. The *Smallest Unit* refers to the lowest-scale modelling unit in the model. *Uses Age* refers to whether or not the ages of the trees are used as a variable in the growth models. *Site Quality* indicates whether the growing conditions are measured from *Site* variables such as habitat type and soil class, or inferred from the height/age growth pattern of dominant *trees*. *Detailed Testing* refers to whether or not there is evidence (public or otherwise) of rigorous statistical, mensurational, or ecological testing of the model. Source code for STEMS is probably available but could not be located by the authors. Blanks are left where suitable evidence could not be found in the time available. The FT models are in bold font to ease comparison.

In terms of model structure, the FT native model is the only one reported that uses a cohort of trees as the smallest unit; other models use individual trees or stands of trees. The model could be used as an individual tree model, just as Stage's Prognosis and its successors could be used as cohort models, because each of these models uses sample-based expansion factors to represent the sampling weight of the tree. Cohort models were more common prior to 2000, when computing resources for simulations at forest estate levels were more limited. The FT plantation model simulates individual tree growth.

Most of the models do not use tree age as a predictor variable for growth and dynamics. The models showed a reasonably even split between those that use site characteristics such as dominant vegetation as a proxy for the quality of growing conditions, and those that use some assumed relation between height and age. Each of the strategies has its strengths.

A few characteristics were common to all of the models, and thus were not useful for tabling. All the models divide the projection of forest growth and dynamics into logical sub-processes, such as growth, mortality, and ingrowth. All of the models that are sufficiently documented use empirical statistical models for each of these components; TASS is a probable exception, but documentation is not available. Of all the models, only Prognosis and, by extension, some versions of FVS, directly facilitate the propagation of uncertainty, although of course it is possible to use any model to assess uncertainty with randomly perturbed starting conditions. All of the models are available as computer-executable files. It is usual for modern forest models to produce estimates of product instead of cubic wood volume, for those models in areas where product specifications are suitably static.

Only TASS provides strict spatial competition, that is, competition in which the exact spatial location and height of competitors is accounted for, but for forest estate modelling, TASS is used to create yield tables that are presented in TIPSY, and these yield tables are not spatial. All the other models use measures of competition appropriate to the forests that they represent. For example, Prognosis uses the basal area of larger trees in the sample plot, as growth in the target populations is mainly limited by light availability.

One area in which the FT approach differs from the norm is in handling ingrowth. Modeling ingrowth is almost invariably intractable because of the very wide range of conditions and processes that are required. The FT solution is to impute values from plots with known age and treatment. This is a sound strategy (see e.g., Ek et al. 1996) and, so long as the range of conditions required is covered in the imputation database, it provides a robust solution to a messy problem.

Other criteria are possible for the comparison of forest estate models; we selected those that reflected the broad model-construction and model-handling choices. See Peng (2000), Porté and Bartelink (2002), Robinson and Monserud (2003) and, more recently, Taylor et al. (2009) and Weiskittel et al (2011) for alternative although related points of view.

4.2 Inventory

Tomppo et al (2010) provide a useful overview of the designs of numerous national forest inventories. Some key statistics are shown in Table 7. In general, the forest area represented by NFI field sample plots varies enormously, from 50 ha per plot in Luxembourg to 269,700 ha per plot in Canada (c.f. 140 ha per plot for FT). For a national comparison, the FT rate is substantially higher (i.e. more plots per unit area) than advocated for Queensland by Beetson et al. (1992), which amounted to one permanent plot for each 3,844 ha of forest.

Table 7 **Summary of national and state-level forest inventory design parameters, constructed from Tables 2.3 and 2.4 of Tomppo et al. (2010) and other sources. Plantations are excluded.**

Country / Region	Number of interpreted "photo-plots"	# of field sample plots on land	# of field sample plots on forest land	Forest area represented by each field plot (ha)	Plots/ Cluster	PP (Prop. of plots that are permanent)
Australia (NSW)			3,481	265	1	0
Australia (QLD)	100% cover		7,836	4,600	1–10	~0.08
Aust (WA Jarrah)	29,324		2,918	500	1	0.67
Aust (WA Karri)			~ 600	80–250	1	0.5
Australia (TAS)	100% cover		2,976	200	3–6	0.17
Australia (VIC)			4,350	~ 425	1	~0.25
Austria		22,236		178	4	1
Belgium (WR)					1	1
Brazil					4	-
Canada	18,850	1,885	1,150	269,700	1	1
China	2,844,4000	415,000		407	1	1
Croatia	30,000		~ 6,000			
Cyprus			1,970	88	1	1
Czech Republic	~39,000		~ 14,000	197	1	1
Denmark	42,793		7,610	87	4	~0.33
Estonia		4,500	2,300	1,040	16	0.25–0.5
Finland		69,388	51,845	129–1997	9–14	~ 0.25
France	275,000	50,000	35,000	449	2	0
Germany			54,009	205	4	1
Great Britain	100% cover		~ 15,000	170	1	-
Greece	95,220	2,744		916		
Iceland (Birch)			203	450	1	1
Ireland	17,423	17,423	1,742	400	1	1
Italy	301,000 (p1)		6,865 (p3)	1,310	1	0
Japan			15,700		1	1
Korea			4,000	1,598	4	1
Latvia				300	1	1
Lithuania			7,500	300	1	0.75
Luxembourg			~1,800	50	1	1
Netherlands			3,622	99	1	0.5
New Zealand			889	7,005	1 or 4	1
Norway		16,522		900	4	Some
Poland					1	1
Portugal	355,737		6,478	525	1	0
Romania			29,000		4	0.83
Russia			~150,000			
Slovak Republic	12,268	1,486	1,161	731	1	0
Slovenia		778	778	1,600	5	1
Spain			95,327	27,258	1	1
Sweden					4–12	~0.6
Switzerland	165,000		~7,000		1	1
USA (ex. Alaska)		325,812	91,988	2,400	4	1

Circular plots, often with multiple concentric components, are used by more than 90% of NFIs, although square and rectangular plots are used, as are both transect and angle count sampling (Tomppo et al 2010). FT uses nested clusters of angle-count sampling where it is efficient to do so, and fixed-area plots otherwise. FT adds about 300 temporary plots per year. FT's cluster sizes of 3 – 6 are within the range of the cluster sizes reported in Table 7. The field procedures for the establishment and (re-) measurement of permanent and temporary plots are well documented (Mannes & Bennett 2002; Mannes 2003). We comment on these procedures below.

4.3 Resource mapping

The United Kingdom NFI (underway) uses 1:10,000 aerial photographs[5]. Belgium, Cyprus, France, Greece, Hungary, Ireland, Italy, Latvia, Luxembourg, and Romania use some aerial photography to define forested area. In France, sample points are analysed on aerial photographs (scale between 1:17,000 and 1:20,000) to determine the type of vegetation (stand type and main species). Table 7 provides some information about the number of interpreted photo plots used in different NFI systems. FT uses 100% cover, as does Great Britain.

4.4 Operation monitoring

We have been unable to locate examples of the approaches that other forestry jurisdictions use towards operational monitoring and the reconciliation exercises that it enables. The steps that FT takes to assess future harvest are assessed in Section 5 below.

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[5] http://www.forestry.gov.uk/website/forestry.nsf/byunique/infd-89r9tq, last accessed 25/11/2011.

5. Assessment

In this section we provide an overview and discussion of the strengths and weaknesses of the FT forest estate sustainable yield system as it applies to the projection of the wood resource scenarios relevant to the IGA.

5.1 Personnel and certification

The FT team that performs the yield projections comprises qualified, long-term staff (Table 8). FT uses similarly appropriately qualified, competent consultants (Dr Philip West, SciWest Consulting) and reviewers (Dr Cris Brack, Chair of Forestry, Waiariki Institute of Technology, New Zealand; Professor Jerry Vanclay, Southern Cross University) as needed. The forest management process has been certified nationally and internationally[6].

Table 8 **List of staff involved in sustainable yield exercises**

Name	Highest Qualification	Years	Responsibilities
Kelley, Tom	M. Geog.	23	Wood planning, resource analysis, GIS
McLarin, M.	BForSci (Hons)	25	Forest estate modelling
Mannes, D.	BForSci	19	Inventory, yield projection, mensuration, LiDAR
Musk, R.	PhD	5	Remote sensing, biometric analysis, mensuration
Osborn, T.	BSc (For) DipOR	31	Operations analysis, management systems
Stamm, L.	BAppSciFor (Hons)	7	Wood planning, research
Stone, M.	BSc (For)	34	Yield projection, inventory, API, GIS, management systems
Wood, M.	BSc (For)	26	Policy, business development, commercial negotiations.

5.2 Continual process improvement

A number of the key elements of the forecasting system have been published in peer-reviewed literature: the overall sustainable yield algorithm (Whiteley 1999), the process of forest mapping (Stone 1998), the plantation growth model (Candy 1997; McLarin et

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[6] Australian Forestry Standard (AFS) (AS4708); the International Standards Organisation standard for environmental management systems (ISO14001) and the Australian Standard for the management of Occupational Health and Safety (AS4801). FT has not sought FSC certification.

al. 2006), and the taper model used for native forests and plantations (Goodwin 2009). The components of documentation that have not been published are identified in Table 9.

FT undertakes continual investigations and improvements in response to internal and external recommendations. For example, FT documented the operational adjustment factors process in response to the Turner and Brack (2002) review, and undertook validation and modification of growth and yield systems in response to the Brack (2007) review (West 2007, 2008a–c). The changes made in the growth and yield model substantially improved the yield projections (West 2008b) (see Section 3.2).

FT is taking advantage of new technologies, for example, moving towards adopting LiDAR to replace API for forest class determination.

FT has detailed internal documentation of its processes (Table 9). As noted above, some of the documentation has been published in peer-reviewed literature.

Table 9 **Summary of operational documentation for projection of sustainable yield, along with flags that report whether the document is publicly available, and if so, whether it has been published in peer-reviewed literature.**

Component	Document	Public / Published
Forest Inventory		
Field Procedures: Temporary Plots	Mannes (2003)	No
Field Procedures: Permanent Plots	Mannes and Bennett (2002)	No
Field Procedures: Quality Audit	Hodge (2010)	No
Growth Modelling		
Plantation Growth Model	Candy (1997)	Yes
Taper Model	Goodwin (2009)	Yes
Plantation Model Implementation	McLarin et al (2006)	Yes
Native Forest Growth & Yield Model	West (2008c)	No
Native Forest Growth & Yield Model Test	West (2008b)	No
Resource Mapping		
API	Stone (1998)	Yes
API Audits	Osborn (2004, 2007)	No
Operational Monitoring		
Volume Reconciliation Analysis	Anonymous (2011)	No
Area Discount Analysis	Stamm (2011a)	No
Coupe Confidence Classification	Stamm (2011b)	No

5.3 Growth and yield modelling

The forest growth models and the system in which they are embedded are commensurate with the models and systems used by other forestry jurisdictions. The representation of different components of growth and yield by empirical (statistically fit) curves is a standard approach for models of complex biological systems. The models are at least as well tested as many other models. The use of imputation for recruitment instead of complicated and unstable regeneration modelling is a strength of the system. The models comprise plausible functional forms that are fitted to observed growth and mortality data (see Section 3.2).

The model concludes with an empirical bias correction due to West (2008c). This bias correction was introduced in response to a recommendation by Brack (2007). The calculation and implementation of the correction was appraised positively by Brack and Vanclay (2011). We provide our assessment below. We reviewed the documentation that motivates, develops, and implements the bias correction (West 2007, 2008a–c) and found the correction to be both necessary and appropriate (see Section 3.2).

As noted above, taper and bark thickness models are used to convert projected standing volume into products. Both models are species specific. The product volume estimate is constructed from cubic volume taper functions that are documented in Goodwin (2009). The functions are flexible so that if product specifications change, the model can produce projections that reflect the new specifications.

As noted above, the mortality model works by reducing the weight of the cohort, which smooths out variability. Mortality encompasses both endemic and self-thinning components. We do not know of empirical assessments of how well the endemic and self-thinning components work.

5.4 Forest inventory

FT has an arguably representative inventory of coupes, using variable sampling intensities within strata defined by IA and photo-interpreted forest cover type groups (FC). Base API re-mapping is repeated at least every 20 years, and the API mapping is updated at least annually from GPS survey and local spot-photography to reflect all recent logging and wildfires. This ensures a reliable basis for stratification for inventory sampling, and for delineation of operational coupes. Review of coupe boundaries is continuous.

A permanent sample plot (PSP) database is maintained and the plots are regularly remeasured. Whiteley (1999) reported that the permanent plots were originally installed at two plots per 500 ha, and remeasured on a 10-yearly basis. Since then, the sampling rate of PSPs has been significantly reduced, with FT now basing its inventory overwhelmingly on more efficient temporary plots, whose sampling intensity is varied with the growth-rate and site potential of each Forest Class.

As noted above, FT's inventory quality assurance policy (Hodge 2010) requires a minimum of 5% of all strategic inventory plots completed by FT staff undergo a Quality Assurance Check (QAC). As noted above, of the 89 plots assessed, one failed.

We reviewed the installation and measurement instructions provided to field crews (Mannes & Bennett 2002; Mannes 2003). The inventory and measurement principles and practices conform to best practice, as laid out in, for example, Schreuder et al. (1993), Avery and Burkhart (2002), Bell and Dilworth (2002), and Husch et al (2003).

The essential features of these systems, implemented in FT procedures, include;

- random location of transect (linear) clusters of plots
- GPS for installing and relocating plots
- variable radius plots where possible, fixed-area plots otherwise

- nested plots for a range of tree sizes
- no plot relocation for certain landscape features (e.g. roads and streams)
- tree dimension measurement (diameter, height, bark, merchantable status, age class, crown) protocols to reduce bias and variability
- measuring of boundary trees in variable radius plots
- efficient point-to-plant inventory systems for regeneration.

The selection criteria of those data do not reference endemic insect or fire damage. While it always possible for selection bias to occur, FT were satisfied based on discussions with Dr West that the data represented a sample of the full range of site factors and site conditions. Sampling the range of site factors and conditions should be verified. It is important that the stratified, essentially random sample of CFI plots has been integrated into growth and yield calculations in such a way that will not generate any substantial biases (see below).

Sample plots are distributed among forest classes and inventory areas approximately proportionally to area (Figure 9). The way that FT uses the plots is important. The growth projections for a coupe are based on stratified samples. Any given coupe is divided into different forest classes (strata), which are delineated by API (and supporting systems). The growth projections are performed class by class. That is, the model used for each class within the coupe is fitted to sample plots that belong to the same class (and usually the same inventory area). Therefore the ideal allocation of the plots used for initial conditions and for the growth model would be to provide a representative sample of the forest class and inventory area that they inhabit. The way that the projection system uses the inventory data means that bias in the allocation of plots towards certain forest classes cannot translate into bias for the growth projections. The model verification and correction exercise reported in West (2008b), in which FT corrects inventory projections based on comparisons with volumes actually harvested from coupes (see Section 5.6 and Section 3.2), should eliminate bias from other sources.

5.5 Resource mapping

The API outcomes have been internally quality-assessed twice, in 2004 and 2007, using ground-truthing (Osborn 2004, 2007). At each occasion, the API outcome was reported by the audit as sufficiently accurate. Specifically, in 2004, 775/789 (98.2%) ground truth plots were found to be consistent with the API data in terms of the assigned forest class (Osborn 2004), and in 2007, 1333/1358 (98.2%) ground truth plots were found to be consistent with the API data (Osborn 2007).

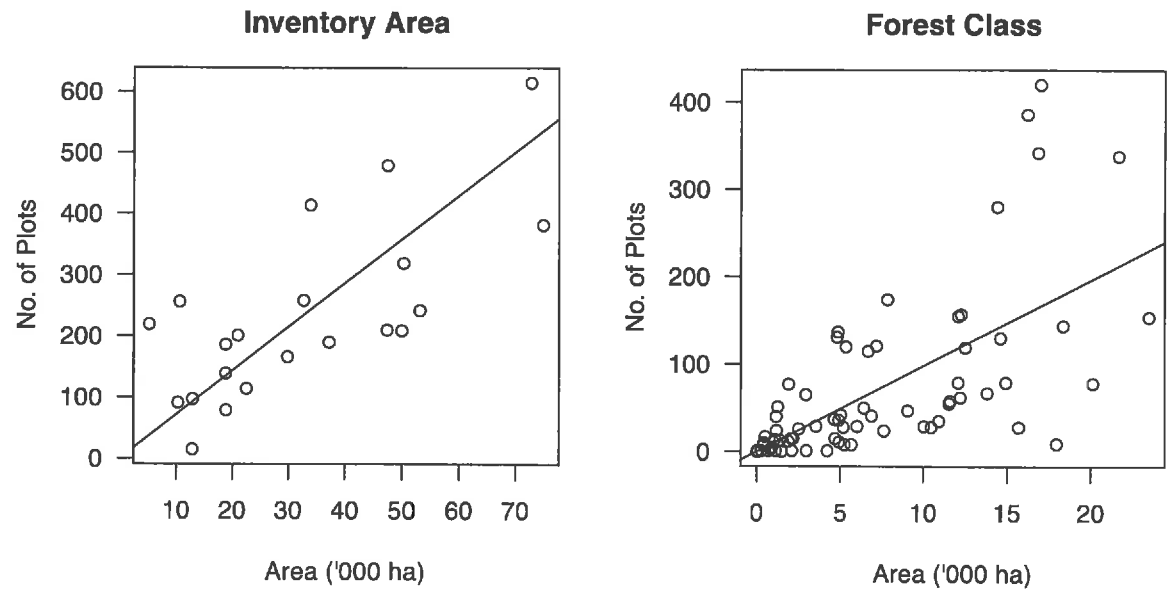

Figure 9 **Sample plot allocation against area for forestry classes and inventory areas. Each panel has a line representing the average allocation. Each point in the left panel represents an inventory area, each in the right a forest class.**

Acquisition of aerial photographs and broad scale API are repeated only every 20 years. As well as this periodic remapping, the API is updated at least annually to reflect forest harvesting and significant wildfires. As well as being used for stratification, the photography and API are used to assist the delineation of coupes. However, coupe boundaries are reviewed and updated by field foresters to reflect recent operational experience, field surveys, and changes to forest practices guidelines.

5.6 Operational monitoring

The use of data that arise from operational monitoring to correct estimates of timber extraction and productive area provides substantial comfort that the projected yields are as good as they can reasonably be. A key outcome of the VRE and the ARE is that many potential sources of bias, which could otherwise be the source of quibbles about prediction suitability, are collected and corrected in a single elegant operation. The VREs and AREs are carried out on an approximately five-year cycle.

As noted above, coupes are also distinguished by operational likelihood (Stamm 2011b). This provides a coupe weighting (CCC) that reflects the probability that the coupe can be harvested, that is, that a range of economic, environmental and social factors will not prevent achieving a successful operation. The Eucalypt Estate Model excludes coupes with a CCC of 0%, and by default counts all coupes with CCC > 0%. From there the coupes can be included or excluded and/or woodflow reported by CCC. The CCC system has been in full operation since November 2010, and no formal audit system is in place. If field judgements turn out to be informative, it would make sense to adjust the expected volume of a coupe by the percentage probability that the coupe will be available, providing an estimate of the expected volume.

5.7 Overall

Our overall assessment of the sustainable yield system is that it provides reasonably accurate assessments of sawlog and pulp wood, conditional on the following points.

1) Headroom should be higher than 10%, and sufficiently high to accommodate the possibility of future changes in the Forest Practices Code.
2) Volume and area adjustments are appropriate.

Several improvements in transparency are possible;

1) Peer view of the growth and yield models
2) Publication of Operational Monitoring data
3) Publication of plot inventory audit information

6. Scenarios

6.1 Evaluating assumptions

An independent systematic analysis of projections of wood supply has been undertaken to evaluate how the proposed forest conservation plans affect expected yield estimates. The analysis evaluates how meeting the minimum wood supply guarantees and/or the contract guarantee would affect estimates of conservation values and how conservation claims, if met, would impact on expected wood supply yield estimates. They include scenarios that evaluate how FT can meet the wood supply guarantees in Clauses 17 of the IGA and the contract guarantees in Clause18 of the IGA (i.e. meeting the existing contracts for native forest wood supply in existence at the 7th of August, 2011). The scenarios also evaluate meeting the requirements of regional sawmills.

More generally, the purpose of the scenarios is to evaluate how best to meet the IGA's wood supply and conservation objectives and to scope the flexibility of options to deliver satisfactory outcomes when there are competing objectives and limited resources. Scenarios incorporate the following considerations, where relevant and possible:

- The suitability of timber for different uses, including sawmill and speciality timber requirements (accounting for existing contracts).
- The silvicultural practices to be applied including how the silvicultural practices fulfill environmental and timber outcomes through time and space at coupe level and landscape level, as appropriate.
- The timber specifications included in the existing contracts or as defined in the *Forestry Act 1920*, and other options, as appropriate and agreed.
- Simulation outputs will include maps and tables of product by region over time, and summaries such as volumes per hectare of different products from different forest classes.
- Where scenarios require new constraints, the analyses will re-optimise to accommodate them, and will evaluate the use approximations based on arithmetic adjustments.

The IGA guarantees the supply of a minimum of 155,000 m^3 of high quality sawlog and 265,000 m^3 of peeler billets. Several of the scenarios outlined below don't seek to deliver those volumes. They are included here in the spirit of enquiry, to scope the problem and the sensitivity of potential solutions to alternative constraints, even if they may lie outside the bounds of agreements.

6.1.1 Headroom

As noted above, area discounts calculated through the Area Reconciliation Evaluation consider each harvested coupe in isolation. Environmental discounts included in the ARE process include streams, rockiness and forest practices constraints. Other factors, including those listed by Forestry Tasmania (2011, p. 9) are treated by headroom allowances. Headroom refers to the reduction that wood supply planners apply to account for unanticipated constraints and constraints that go beyond the existing Forest Practices Code. That is, headroom accounts primarily for future, unanticipated changes, and also for tactical and operational constraints that are known at present but are not captured by area discounts.

Future reductions may arise from mandatory coupe dispersal constraints, prescriptions to retain additional mature forest in wood production areas, water supply requirements, scheduling requirements to ensure 'smooth' volume supply, the need to protect habitat for threatened species and important cultural or geological features. FT have provided two example analyses that adjust the volume of wood available for peeler billets in the north and south of the State (Figure 10 and Figure 11). These scenarios account for forest practices implemented since 2007, reflecting future aspirations of the Forest Practices code in these areas.

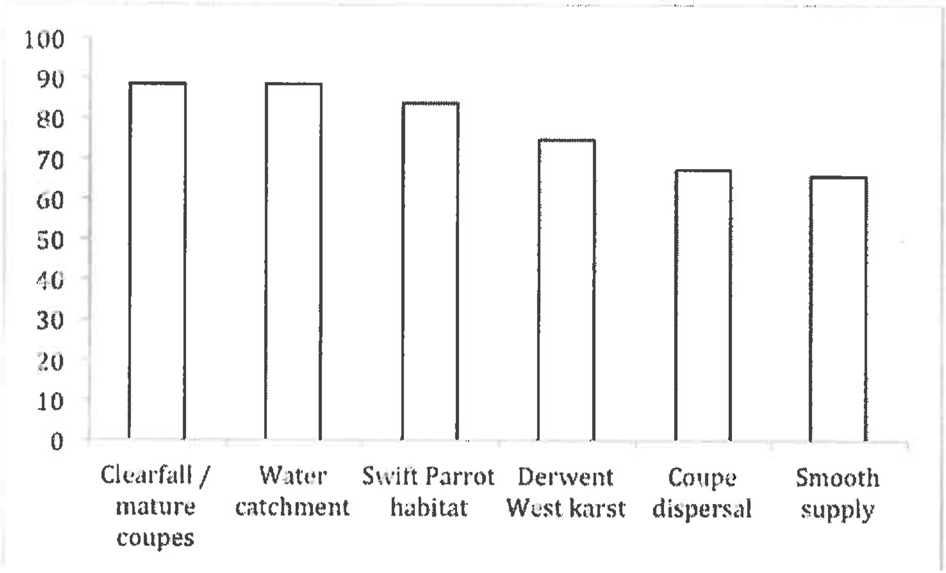

Figure 10 **Southern Forests Peeler Supply, 2009 (Forestry Tasmania 2011), accounting for operational constraints. The figure shows the percentage (on the y-axis) of the total native forest area in the Southern area theoretically available for the production of peeler logs, when various operational and conservation constraints are applied.**

The estimates begin by removing about 12% of the volume putatively available for peeler log supply because this volume is from mature forest, and is therefore unsuitable for peeler billets. This volume is not included in the headroom. The subsequent reductions, which are included, accommodate water catchments (no reduction), two environmental constraints and two operational constraints. While some environmental constraints are included in area discounts, these were not. The total reduction in available peeler log volume is about 26%.

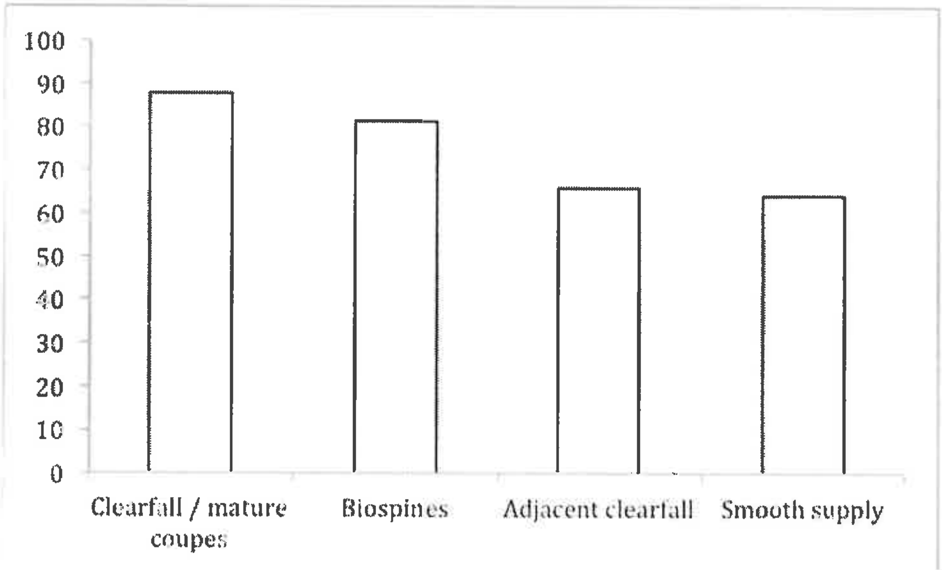

Figure 11 **Murchison Peeler Supply, 2010, accounting for operational constraints. The figure shows the percentage (on the y-axis) of the total native forest area in the Southern area theoretically available for the production of peeler logs, when various operational and conservation constraints are applied.**

As for the Southern Forest estimates, removing mature forest in the Murchison area from consideration results in removing about 13% of the peeler log volume potentially available for harvest. Constraints arising from environmental demands, adjacency and supply result in a reduction of the peeler log volume of about 27%. As above, while some environmental constraints were included in the area discounts, these features were not. Adjacent clearfell is an expression of mandatory coupe dispersal beyond the current Code. Biospines are an FT device, primarily to retain connectivity of native forest in areas previously considered for plantation conversion.

Anecdotally, 10% headroom was considered by most experts to be insufficient. These calculations support that intuition. If advice from the Forest Practices Authority extends beyond the *Forest Practices Code 2000* and is applied as it has been implemented in these scenarios, headroom close to 30% is more realistic, based on the two analyses above. However, the need for additional constraints is likely to be reduced if further areas of native forests are reserved. In the scenarios developed below, this report assumes that if no new reserves are proclaimed, then headroom calculations ranging from 20% to 40% will encompass future forest management changes. If new reserves are proclaimed, headroom calculations from 10% to 30% are more appropriate.

6.2 Scenario outcomes

6.2.1 Scenario #1: Maximum yield from native forests, no new reserves, no plantations[7]

6.2.1.1 Description

The purpose of this scenario is to analyse the potential of existing public native forests currently available for wood production to supply annual levels of 265,000 m^3 of peeler billets (noting that the current contract for peeler billets is for the period to 2027), at least 155,000 m^3 of HQSL (as defined) and 12,500 m^3 of specialty timbers from all existing public native forests available for wood production. There were insufficient data on growth and yield of specialty timbers to include specialty timber objectives in subsequent analyses. This scenario ignores the potential for up to 572,000 ha of new reserves. It determines the potential productive capacity of the existing public native forests currently available for wood production to supply the guaranteed existing volumes (Clause 17) and/or the guaranteed existing contracts (Clause 18), documenting the spatial distribution of the wood resource, and accounting for the uncertainty of supply through appropriate headroom calculations. The scenario will also report on the potential for the existing public native forest area available for wood production to supply the saw log requirements of regional saw mills (information generated by the companion report to the IVG of timber demand), in addition to the guaranteed minimum HQSL volume of 155,000 m^3 in Clause 17 of the IGA. Scenario output is in 10 year intervals, but supply has been optimised over a 20 year horizon, to maximize wood flow.

6.2.1.2 Output

If no new reserves are proclaimed, sawlog supply from native forests remains above the committed minimum volume of 155,000 m^3/yr if headroom discounts of 30% or less are applied (Figure 12 and Table 10). Headroom estimates reflecting Forest Practices Authority policy aspirations are of the order of 30%, making the supply of 155,000 m^3/yr of high quality sawlogs from the native forest estate possible but challenging in the short and medium terms. Peeler log supply will decline dramatically from 2031. Supply of approximately 25,000 m^3/yr of sawlogs to regional 'country' mills and 265,000 m^3/yr of peeler logs over the next 20 years from public native forests is unlikely under all headroom assumptions.

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[7] This scenario was termed the 'Base Case' in Forestry Tasmania (2011). This analysis excludes consideration of the public plantation estate. The 'Base Case' in Forestry Tasmania (2011) included an assumption that 39,000 m^3 of peeler billets would be obtained from other sources. These have been removed from this scenario for consistency.

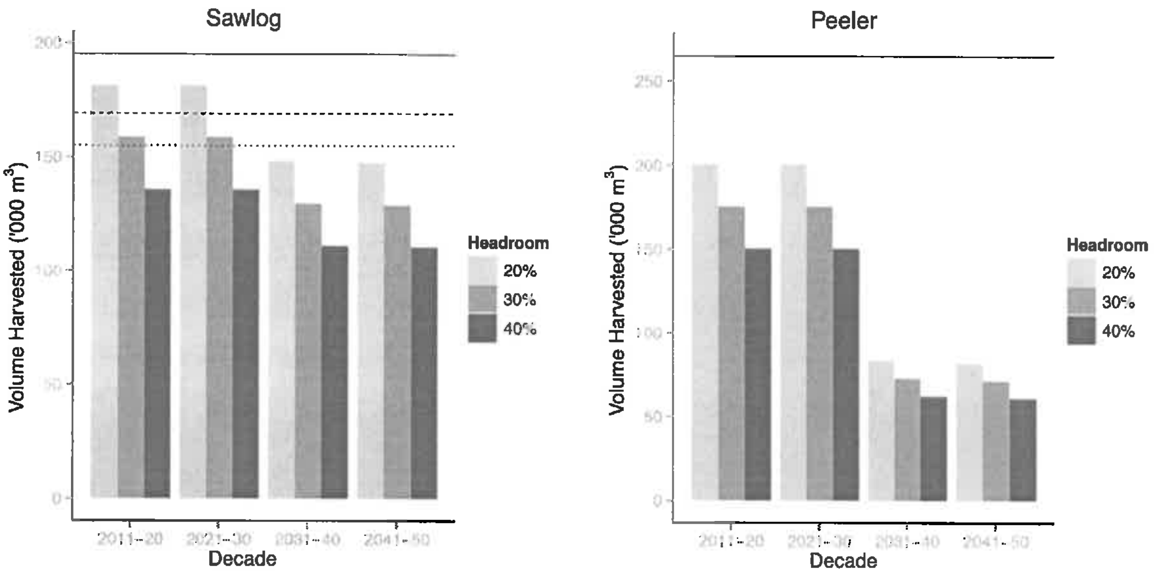

Figure 12 **Scenario #1: No New Reserves: state-wide sawlog and peeler supply from public native forests accounting for different levels of headroom. Y-axis is in '000m^3. Dotted line: minimum sawlog commitment in the IGA. Dashed Line: Total Contracted Volumes. Solid Line: All Demand, including regional ('country') sawmills.**

Table 10 **Regional output for Scenario #1: No new Reserves: regional sawlog and peeler supply from public native forests accounting for different levels of headroom. Units are in '000m^3.**

Region	Decade	HQ Sawlog			Peeler		
Headroom		20%	30%	40%	20%	30%	40%
State	2011-20	181	159	136	201	176	151
	2021-30	181	159	136	201	176	151
	2031-40	148	130	111	84	73	63
	2041-50	148	129	111	82	72	61
NE	2011-20	40	35	30	24	21	18
	2021-30	40	35	30	24	21	18
	2031-40	30	26	23	26	23	19
	2041-50	29	26	22	24	21	18
NW	2011-20	26	23	19	44	38	33
	2021-30	26	23	19	44	38	33
	2031-40	27	23	20	22	19	17
	2041-50	26	23	19	22	19	17
S	2011-20	116	102	87	133	117	100
	2021-30	116	101	87	133	117	100
	2031-40	92	81	69	36	32	27
	2041-50	92	80	69	36	32	27

6.2.1.3 Commentary

These results assume that no new reserves are created. Existing native regrowth and mature forest supply estimates can meet the goals for the minimum volumes of high-quality sawlog stipulated in Clause 17 of the IGA, if headroom estimates of 30% or less are applied. If other contracted sawlog volumes and the demand from regional ('country') sawmills are included, total current demand cannot be met from public native forest. Sawlog supplies to regional (country) sawmillers, who lack long-term contracts, may be difficult to meet from native forests. However, supply of sawlogs and peeler billets for some regions, beyond about 2030, is even more limited.

Native forests cannot satisfy demand for peeler billets under any headroom assumptions. Significant volumes of peeler billets will have to be sourced from outside public native forests before 2027, the period covered by existing contracts for peeler billets. This was previously acknowledged by Forestry Tasmania (2011) by inclusion of supply from other than public native forests. Contracts for peeler billets include clauses providing options for operators to extend wood supply agreements for peeler supply beyond 2027. The scenario outputs above (Figure 12) show clearly that native forests cannot supply the majority of the demand of 265,000 m^3 of peeler billets beyond 2027. The contracts do not stipulate that native forests should be the only source of supply, emphasizing the importance of developing the plantation resource appropriately, if these goals are to be met. Regional supplies will decline most substantially in the south (Figure 13).

Each region includes industries with contracts that may have implications for wood supply management. These were unavailable at the time the report was produced.

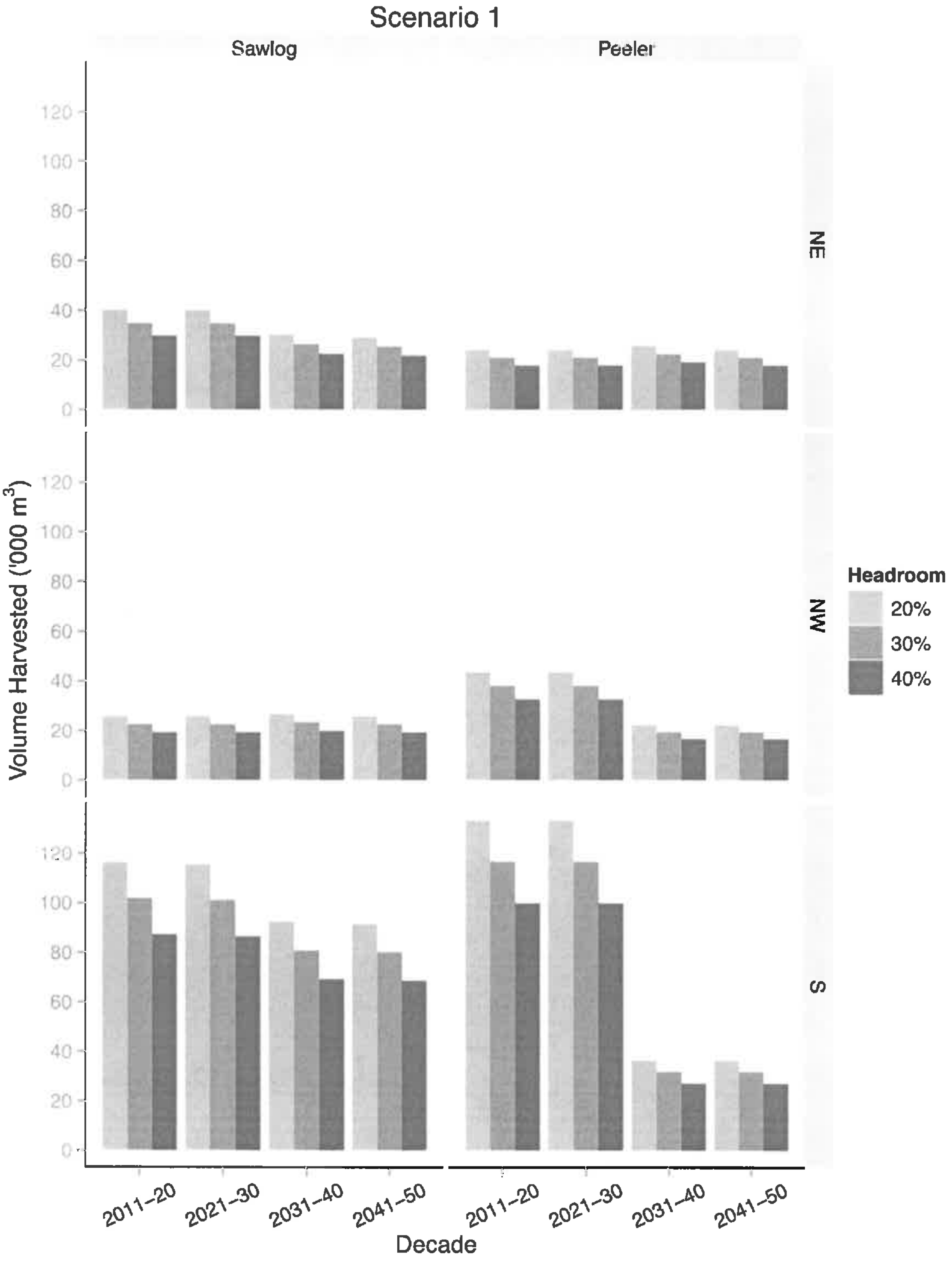

Figure 13 **Regional results for Scenario #1: No New Reserves: regional sawlog and peeler supply from public native forests accounting for different levels of headroom. Y-axis is in '000m^3.**

6.2.2 Scenario #2: Maximum yield from public native forests, new HCV reserves established, no plantations

6.2.2.1 Description

The purpose of this scenario is to estimate the wood supply volumes that might be harvested sustainably from existing native forests assuming that 572,000 ha of estimated HCV forests are excluded from future harvest, and applying 10%, 20%, and 30% headroom assumptions. This scenario replicates the specifications for the equivalent scenario that appeared in FT (2011). These calculations differ in that wood supply has been optimised with the ENGO-mapped HCV areas excluded, rather than wood supply being a direct subtraction from the base case. The scenario is replicated with headroom allowances ranging from 10% to 30%. The lower headroom estimates, compared to Scenario 1, reflect the assumption that the creation of reserves will reduce demand for environmental constraints in area adjustments and headroom calculations. For example, the aspiration for mandatory coupe dispersal constraints and prescribed levels of mature forest retention in and around coupes may be reduced if significant further reservation occurs.

6.2.2.2 Output

If 572,000 ha of new reserves are proclaimed, high quality saw log supply from native forests would be below about 120,000 m^3 for the first twenty years, even if headroom factors as low as 10% are applied. Supply increases after 2030 because of recruitment of regrowth forests. Supply of peeler billets would be below 160,000 m^3 for the next 20 years for all headroom assumptions (Figure 14). Peeler supply will decline most significantly in the south (Figure 15).

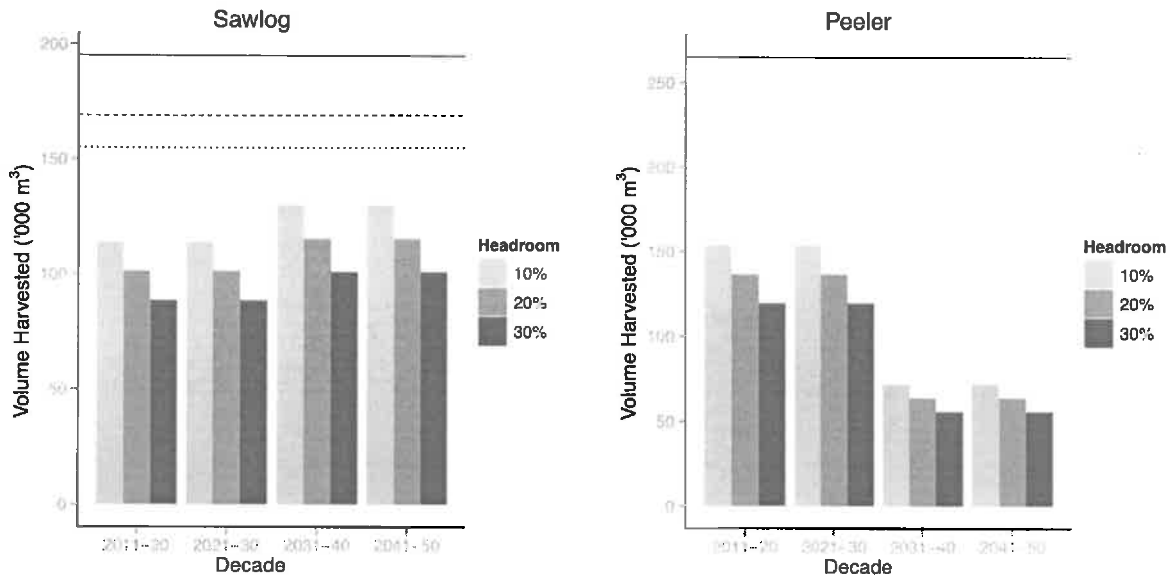

Figure 14 **Scenario #2: Maximum Yield, New HCV Reserves Established, No Plantations: State-wide sawlog and peeler supply accounting for different levels of headroom. Y-axis is in '000m^3. This output does not include the 39,000 m^3 of peeler billets assumed to be sourced from private land and public plantations over the period up to 2030 (Forestry Tasmania 2011).**

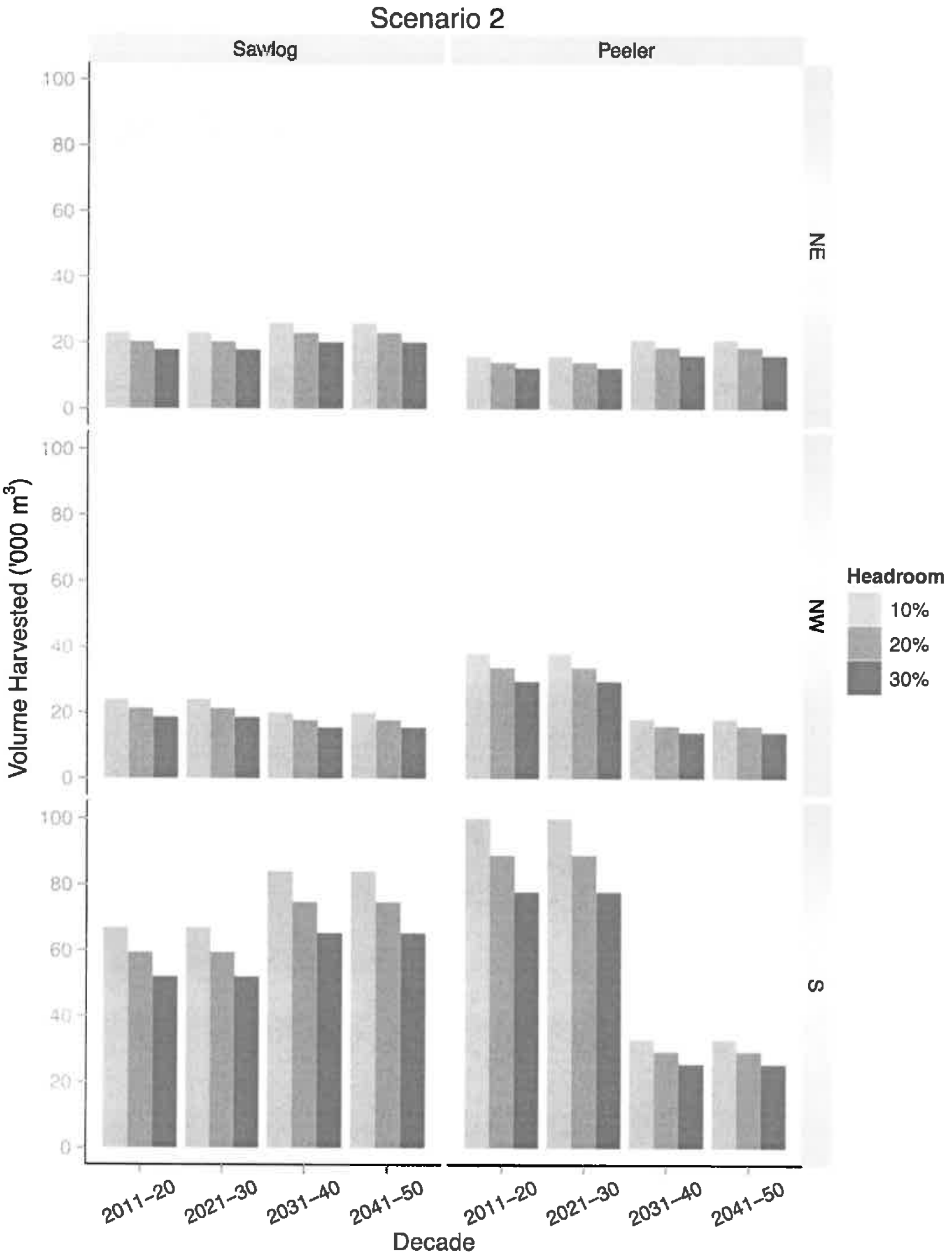

Figure 15 **Regional output for Scenario #2: New Reserves: regional sawlog and peeler supply from public native forests accounting for different levels of headroom. Y-axis is in '000m^3.**

Table 11 **Regional output for Scenario #2: New Reserves: regional sawlog and peeler supply from public native forests accounting for different levels of headroom. Units are in '000m^3/yr.**

Region	Decade	HQ Sawlog			Peeler		
Headroom		10%	20%	30%	10%	20%	30%
State	2011-20	114	101	89	154	137	120
	2021-30	114	101	89	154	137	120
	2031-40	130	116	101	72	64	56
	2041-50	130	116	101	72	64	56
NE	2011-20	23	20	18	16	14	12
	2021-30	23	20	18	16	14	12
	2031-40	26	23	20	21	19	16
	2041-50	26	23	20	21	19	16
NW	2011-20	24	21	19	38	34	30
	2021-30	24	21	19	38	34	30
	2031-40	20	18	16	18	16	14
	2041-50	20	18	16	18	16	14
S	2011-20	67	60	52	100	89	78
	2021-30	67	60	52	100	89	78
	2031-40	84	75	65	33	29	26
	2041-50	84	75	65	33	29	26

6.2.2.3 Commentary

Existing native regrowth and mature forests could supply only reduced volumes of high-quality saw log and peeler billets, amounting to about 64%-75% of the minimum agreed saw log production and 56%-74% of peeler production, if headroom calculations of between 10% and 30% are applied. These figures do not account for the demand from regional 'country' saw mills or other contracted sawlog volumes (see Figure 12). These results emphasize the importance of careful consideration of the plantation resource and the exact locations of reserve areas and boundaries, in planning and negotiations.

6.2.3 Scenario #3: Maximum yield from public native Forests, no new reserves, existing FT plantations

6.2.3.1 Description[8]

The purpose of this scenario is to analyse the potential of existing public native forests currently available for wood production and existing suitable public plantations (a total area of 36,674 ha; 35,171 of *E. nitens* or *E. globulus*, of which 6,973 ha are unpruned) currently available for wood production to supply annual levels of 265,000 m^3 of peeler billets (noting that the current contract for peeler billets is for the period to 2027), at least

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[8] This case is equivalent to the scenario presented by Forestry Tasmania (2011), Figures 5 and 6, with additional headroom estimates. The figures can be obtained by summing Tables 4, 5 and 9 of the June 6 report. In all likelihood, the headroom for the plantation volumes (Table 9) should be at 10% or less.

155,000 m^3 of High Quality Sawlog (as defined) and 12,500 m^3 of specialty timbers from all existing forest areas. As in the scenarios above, there were insufficient data to include specialty timber forests in subsequent calculations. The scenario ignores the potential 572,000 ha of new reserves. It ignores the view of the current sawlog and peeler industry that they cannot process and market plantation timber competitively, especially *E. nitens* which is the predominant species. Output is in 10-year intervals but wood supply is optimised over 20 years, to maximize wood flow. The inclusion of plantation timber in this scenario requires a number of important assumptions about wood quality and utility. See Appendix 2 of this report for further details.

6.2.3.2 Output

Figure 16 is derived from Table 12. It shows the maximum sustainable yield of high quality sawlog and peeler billets for the estate managed by FT over two management periods, 2011–2030, and 2031–2050, and assuming 20%–40% headroom applied to native forest wood supply and 10% to plantation wood supply. Minimum sawlog commitments (155,000 m^3) can be met from native forests, reflecting the result in Figure 16. The existing FT plantation estate may be able to meet high quality sawlog demand after 2030, if timber industry concerns about the utility of this resource for sawlog production can be satisfied, either though altered silvicultural practices or technological advances. Similarly, if concerns about resource suitability can be satisfied, the production of peeler billets from plantations and native forest is expected to satisfy demand for peelers until 2030. Under the same caveats about the utility of plantation timbers, supply of peeler billets from *Eucalyptus nitens* and *E. globulus* plantations is expected to exceed current demand for peeler billets after 2030.

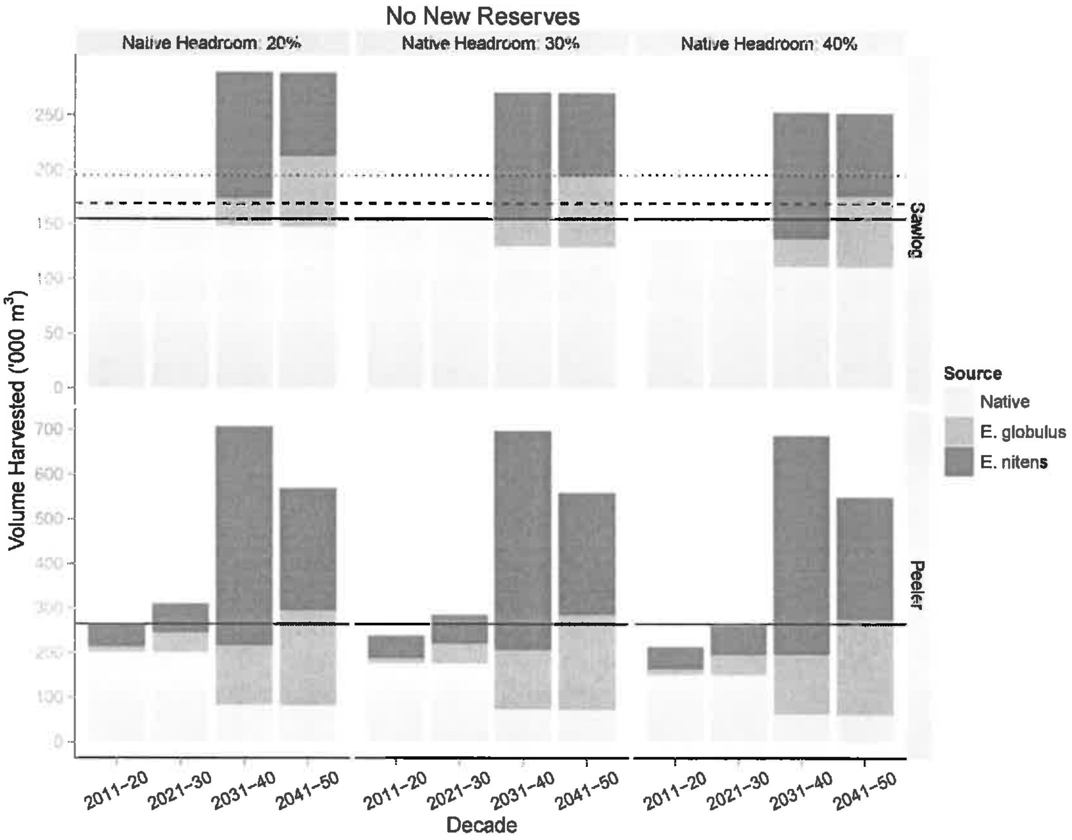

Figure 16 **Scenario #3: Maximum Yield from Public Native Forests, No New Reserves, Existing FT Plantations. Wood supply expectations from native forest and plantations, with no new reserves, 10% headroom for plantations, and various headrooms applied to native forest supply. Horizontal lines represent IGA agreed supply volumes of two forest products.**

Table 12 **Wood supply expectations from native forest and plantations, with no new reserves and 10% headroom applied to plantation volumes and 20%, 30% and 40% headroom applied to native forest supply (derived from Forestry Tasmania 2011, Tables 4, 5, and 9)*. Units are in '000m^3/yr.**

	Plantation Contribution (10% Headroom)		**Total NF, with Headroom**		
	E. globulus	***E. nitens***	**20%**	**30%**	**40%**
HQSL (000 m3/yr)					
State					
2011 – 2020	0	0	181	159	136
2021 – 2030	0	0	181	159	136
2031 – 2040	25.2	116.1	290	271	253
2041 – 2050	64.8	76.5	289	270	152
NW					
2011 – 2020	0	0	26	23	19
2021 – 2030	0	0	26	23	19
2031 – 2040	13	27	66	63	60
2041 – 2050	31	15	72	68	65
NE					
2011 – 2020	0	0	40	35	30
2021 – 2030	0	0	40	35	30
2031 – 2040	2	68	100	97	93
2041 – 2050	28	36	93	90	86
S					
2011 – 2020	0	0	116	102	87
2021 – 2030	0	0	116	101	87
2031 – 2040	11	22	125	113	102
2041 – 2050	6	26	124	113	101
Peeler billets (000 m3/yr)					
2011 – 2020	13	51	265	240	215
2021 – 2030	45	66	312	286	261
2031 – 2040	133	491	708	698	687
2041 – 2050	213	275	570	559	549
NW					
2011 – 2020	5	8	56	51	45
2021 – 2030	10	9	62	57	52
2031 – 2040	52	107	182	179	176
2041 – 2050	98	48	168	165	162
NE					
2011 – 2020	3	19	46	43	40
2021 – 2030	8	44	76	73	70
2031 – 2040	24	282	332	329	325
2041 – 2050	86	140	250	247	244
S					
2011 – 2020	5	25	164	147	131
2021 – 2030	27	13	173	156	140
2031 – 2040	57	102	195	190	186
2041 – 2050	29	88	153	149	144

NB This value excludes the 39,000 m^3/yr of supply assumed in Table 1 to be sourced from plantations.

The regional information for the base case is available in Appendices 4–6 of Forestry Tasmania (2011).

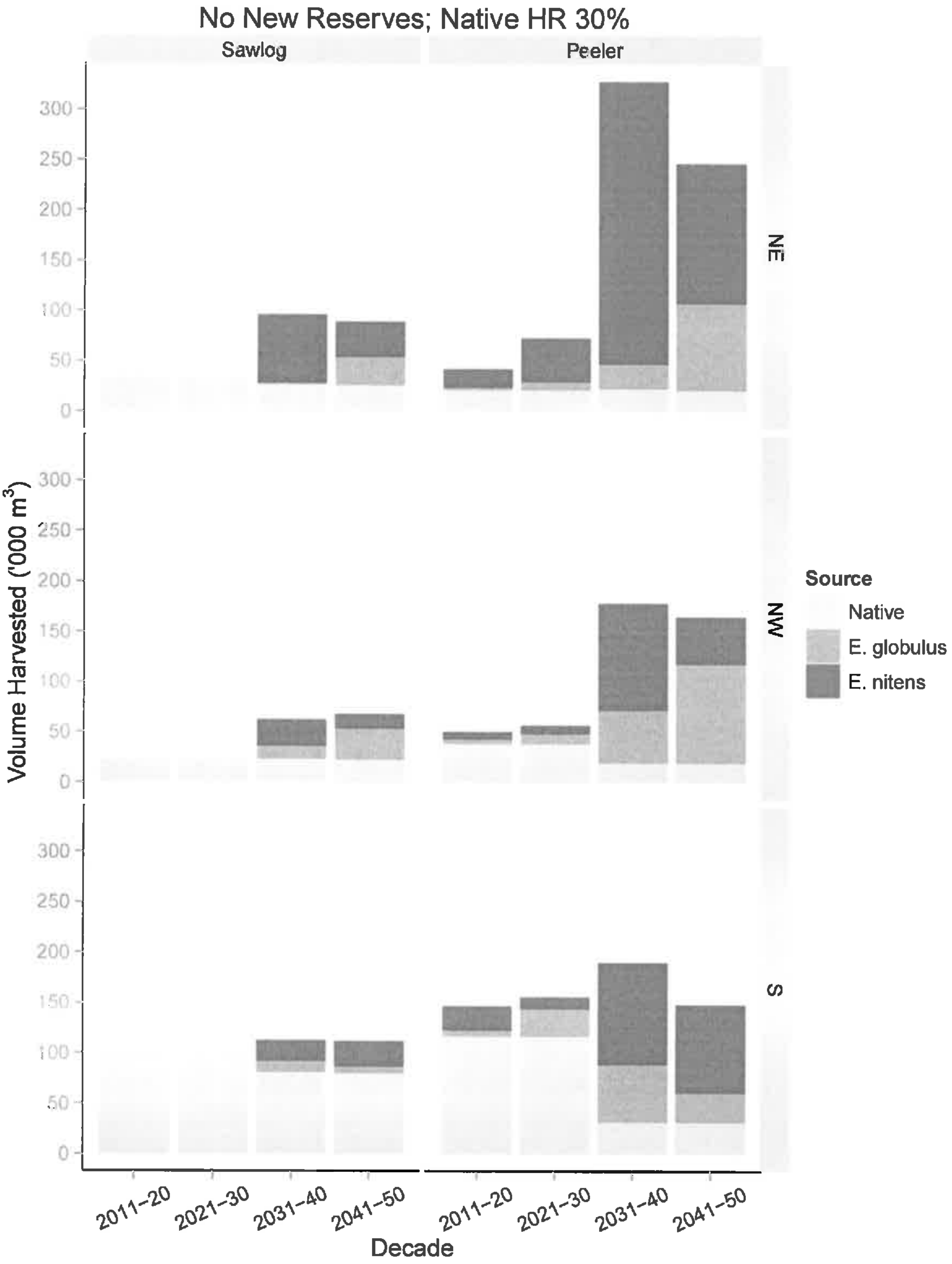

Figure 17 **Scenario #3: Sawlog supply within regions with 30% headroom discount applied to native forest and 10% to plantations.**

6.2.3.3 Commentary

These results suggest that current commitments in the IGA could be met from the existing resource base in the absence of new reserves, although there are significant constraints on the supply of sawlogs to regional (country) sawmills, even when plantation resources are taken into account. That is, supply of approximately 25,000 m^3 of sawlogs to regional 'country' mills over the next 20 years is unlikely under all headroom assumptions. These supply expectations assume the existing plantation resources will be suitable for high quality sawlog and peeler billet production, which depends on appropriate, ongoing silvicultural treatment, and also on technical advances to ensure wood characteristics are appropriate for these uses (see Appendix 2). These results are not spatially explicit. Full, detailed analyses will need to consider the spatial arrangement of supply, in relation to larger production facilities for peeler billets and sawlogs, and in relation to regional sawmills.

6.2.4 Scenario #4: Maximum yield from public native forests, new HCV reserves, existing FT plantations

6.2.4.1 Description

The purpose of this scenario is to estimate the wood supply volumes that might be harvested sustainably from existing native forest and existing suitable public plantations (a total area of 36,674 ha. As noted above, a proportion of these plantations may be unsuitable for sawlog or peeler production). This analysis assumes that 572,000 ha of estimated HCV forests are excluded from future harvest. The scenario takes the largest possible volume from the plantation resource, and makes up the shortfall from native forests. These analyses assume headroom estimates ranging from 10% to 30%, to reflect the fact that they encompass the establishment of significant new conservation reserves. This scenario delivers the commercially optimal plantation harvest regime (delaying harvest to maximize volumes per ha). It does not necessarily reflect the plantation harvest regime that delivers the optimal conservation outcome (advancing plantation harvest to avoid logging in reserve areas in the next twenty years). Wood supply outcomes may be appreciably different if plantation wood was used as early as possible, forgoing some expected yield in the future, which would also have implications for economic returns on investment and longer term sustainable yield, especially for sawlog supply.

6.2.4.2 Output

Figure 18 is derived from Table 13. Wood supply expectations from native forest and plantations, with new reserves, plantations and 10%-30% headroom applied to native forests indicate that the existing public plantation estate is not sufficient to offset the sawlog and peeler billet supply forgone if the estimated HCV reserves are established. These calculations ignore industry concerns regarding the suitability of these plantations to supply high quality sawlogs and peeler billets (see Appendix 2). The residual production estate is insufficient to supply IGA agreed volumes of high quality sawlogs or peeler billets over the next 20 years. Regional estimates are shown in Figure 19.

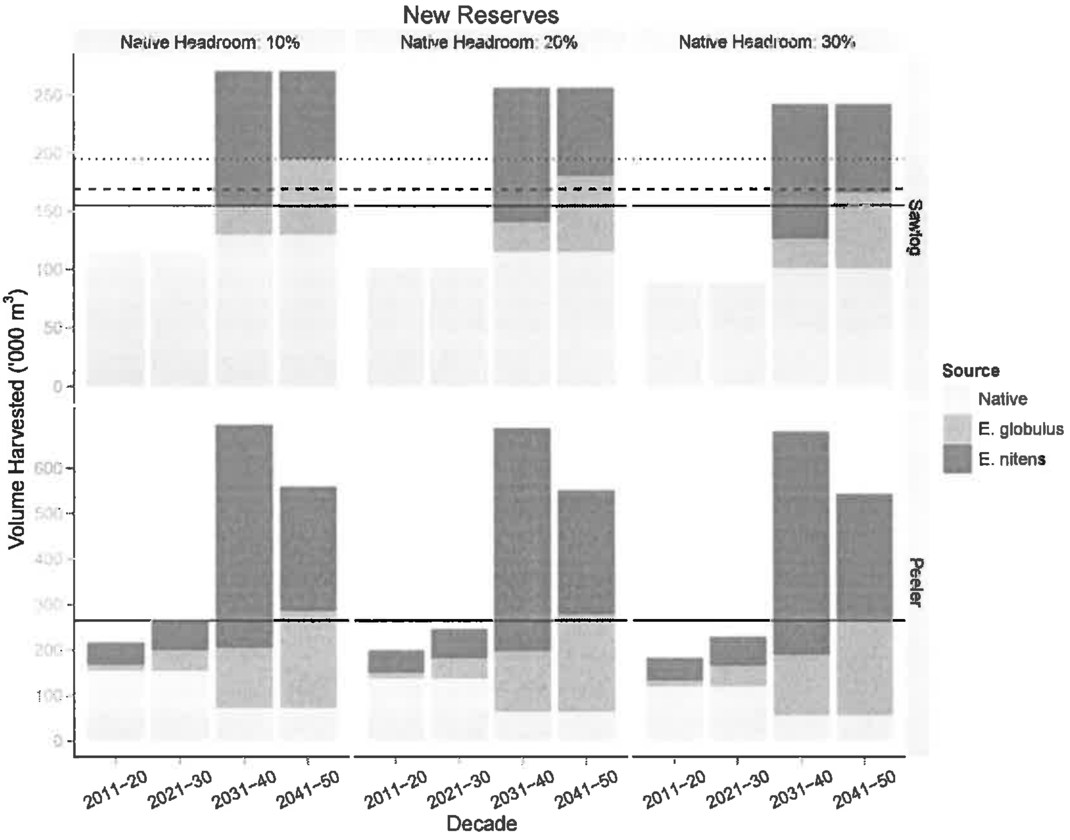

Figure 18 **Scenario #4: Maximum Yield, New Reserves, Plantations. Wood supply expectations from native forest and plantations, with no new plantations and various headrooms applied to native forest supply. 10% headroom was applied to plantation volumes. Horizontal lines represent IGA agreed supply volumes of two forest products. This analysis uses 10-year time steps for plantation supply, and 20 year time steps for native forest wood supply.**

Table 13 **Wood supply expectations from native forest and plantations, with new reserves established and various levels of headroom applied to native forest supply (derived from Forestry Tasmania 2011). Units are in '000m^3. 10% headroom applied to plantation timber.**

	Plantation Contribution (10% Headroom)		**Total, with NF Headroom**		
	E. globulus	***E. nitens***	**10%**	**20%**	**30%**
HQSL (000 m3/yr)					
State					
2011 – 2020	0	0	114	101	89
2021 – 2030	0	0	114	101	89
2031 – 2040	25	116	271	257	242
2041 – 2050	65	77	271	257	242
NW					
2011 – 2020	0	0	24	21	19
2021 – 2030	0	0	24	21	19
2031 – 2040	13	27	60	57	55
2041 – 2050	31	15	66	64	61
NE					
2011 – 2020	0	0	23	20	18
2021 – 2030	0	0	23	20	18
2031 – 2040	2	68	96	93	90
2041 – 2050	28	36	90	87	84
S					
2011 – 2020	0	0	67	60	52
2021 – 2030	0	0	67	60	52
2031 – 2040	11	22	116	107	98
2041 – 2050	6	26	116	107	98
Peeler Billets (000 m3/yr)					
State					
2011 – 2020	13	51	218	201	184
2021 – 2030	45	66	265	248	230
2031 – 2040	133	491	697	689	681
2041 – 2050	213	275	560	552	544
NW					
2011 – 2020	5	8	51	46	42
2021 – 2030	10	9	57	53	48
2031 – 2040	52	107	177	175	173
2041 – 2050	98	48	164	162	160
NE					
2011 – 2020	3	19	38	36	34
2021 – 2030	8	44	68	66	65
2031 – 2040	24	282	327	325	322
2041 – 2050	86	140	247	245	242
S					
2011 – 2020	5	25	131	119	108
2021 – 2030	27	13	140	128	117
2031 – 2040	57	102	191	188	184
2041 – 2050	29	88	150	146	143

Table note: Native forest values exclude the 39,000 m^3 of supply assumed in Table 1 to be sourced from plantations and / or private land.

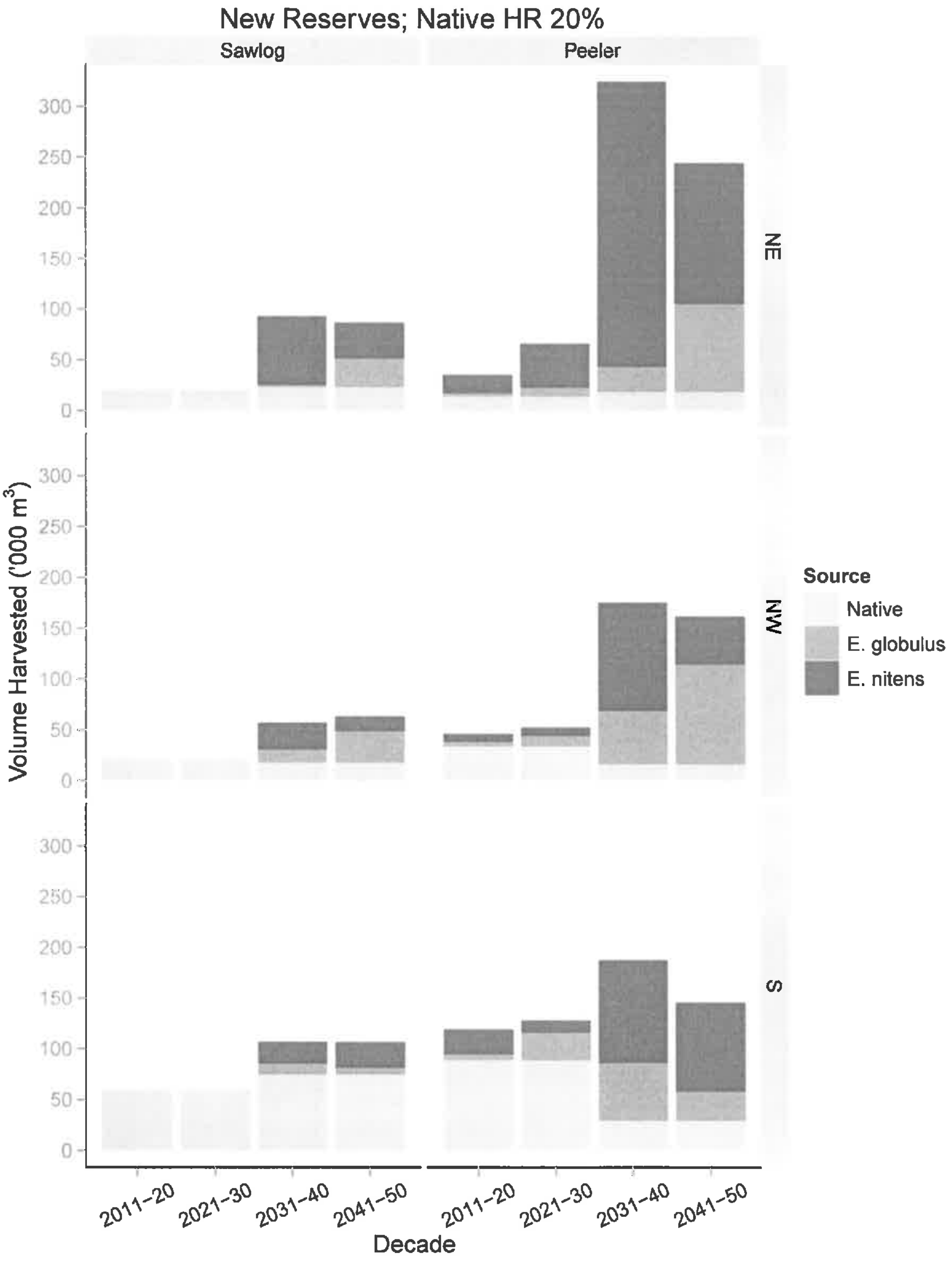

Figure 19 **Scenario #4: Wood supply within regions**

6.2.4.3 Commentary

These results suggest that current commitments in the IGA could not be met from the existing resource base in the presence of new reserves. These supply expectations assume the existing plantation resources will be suitable for high quality sawlog and peeler billet production, which depends on appropriate, ongoing silvicultural treatment, and also on technical advances to ensure wood characteristics are appropriate for these uses (see Appendix 2). That is, a plausible, economically viable strategy for using plantation grown *E. nitens* and *E. globulus* timber from sources outside the existing FT estate is necessary if both IGA agreed sawlog and peeler billet supply and the proposed HCV reserves are to be established (See Appendix 2). As in Scenario 3, these results are not spatially explicit beyond providing a regional breakdown of supply. Full, detailed analyses will need to consider the spatial arrangement of supply, in relation to larger production facilities for peeler billets and sawlogs, and in relation to regional sawmills.

6.2.5 Scenario #5: Maximise volume, calculate minimum production area, no new reserves, no FT plantations

6.2.5.1 Description

The purpose of this scenario is to determine the area of forest required to supply the guaranteed volumes established by the Clause 17 of the IGA and / or meet the existing contracts (Clause 18 – IGA) on a sustainable forest management basis, including contracted log specifications, documenting the spatial distribution of the wood resource, and accounting for uncertainty of supply through appropriate headroom calculations (i.e., 10%, 20% and 30%). The specification is to analyse the potential of existing public native forests available for wood production and existing formal and informal reserves on State Forest to supply annual levels of 265,000 m^3 of peeler billets, at least 197,350 m^3 of HQSL (as defined) and 12,500 m^3 of specialty timbers from all existing forest areas (initially ignoring any new reserves and proclaimed National Parks and World Heritage Areas) on a sustainable forest management basis. The 197,350 m^3/yr assumed 17,350m^3/yr under additional contracts (the estimate available at the time this analysis was conducted) and 25,000m^3/yr for regional (country) sawmills. As in the analyses above, there were insufficient data to accommodate specialty timbers in all of the calculations. The analysis reports on the forest area required to supply the annual demand from all sawmills including regional (country) sawmill requirements that are in excess of the guaranteed minimum HQSL volume of 155,000 m^3 in Clause 17 of the IGA.

This scenario has been interpreted as follows:

- Determine the minimum area of native forest required for an annual production of 197,350 m^3 of HQSL, 265,000 m^3 of peeler and 12,500 m^3 of special timbers until 2030 from State forest. Assume no new reserves are established. An assessment with longer time horizons is developed below.
- Areas should be consistent with the areas made available to the eucalypt forest estate model, i.e. eucalypt and eucalypt-special timbers coupes with a coupe confidence classification > 0.

- The projected yield of 265,000 m^3 of peeler in Forestry Tasmania (2011) includes a supply of 39,000 m^3 from plantations and/or private native forest in northern Tasmania. The current analysis removes this separately sourced quantity, resulting in a shortfall in the Northwest, because this scenario assumes plantation resources are unavailable.
- Headroom calculations should be applied to the eucalypt native forest resource, but because much of the special timbers zone has not been couped and FT does not forecast future supply of special timbers in the way it does for eucalypt products, it is inappropriate to use the concept of headroom for special timbers.
- In the first instance disregard the regional breakdown (particularly, the sawlog deficit in the North), assuming HQSL can be shipped from South to North economically.
- Secondly, include a regional breakdown with annual targets for HQSL and peeler as shown below:

Region	HQSL	Peeler
Northwest	27,500	88,000
North	72,950	27,000
South	96,900	150,000

6.2.5.2 Output (statewide)

The calculation of area required to achieve this case was based on the scenario from the report by Forestry Tasmania (2011, their Table 1):

- The eucalypt native forest coupes required to achieve the 199,000 m^3 of HQSL and 226,000 m^3 of peelers in the Industry Scenario (including 10% headroom) = 408,000 ha.
- The area of the Special Timbers Zone that is not in the eucalypt forest estate model and therefore does not contribute to the HQSL and peeler targets = 77,000 ha.
- For 10% headroom, as described above, there is a shortfall of 39,000 m^3 of peeler billets. To deliver this quantity for 20 years it is estimated that a net area of approximately 9,750 ha of productive regrowth forest are needed. This estimate is based on an assumption of a linear relation between forest area and sustainable yield such that 39,000 / 9,750 = 4 m^3ha^{-1} annually. However, it would require at least a 50% forest practices and operational discount, resulting in additional production area of approximately 19,500 ha.
- 20% and 30% headrooms are constrained for sawlogs, not peelers because peelers are not creating a constraint. We base this scenario on the eucalypt native forest coupes required to achieve the 199,000 m^3 of HQSL and 226,000 m^3 of peelers in the Industry Scenario (including 10% headroom), which is 408,000 ha.
- 20% and 30% headrooms require additional HQSL volumes of 20,350m^3 (= 197,350 – 199,000 / 0.9 × 0.8) and 42,350m^3 (= 197,350 – 199,000 / 0.9 × 0.7) respectively. To deliver these volumes for 20 years it is estimated that net areas of approximately

20,350 ha and 42,350 ha are needed, now assuming a 1:1 linear relation between forest area and 20-year sustainable yield, and as above it would require at least a 50% forest practices and operational discount resulting in additional production areas of approximately 40,700 ha and 84,700 ha.

The estimated areas required are presented in **Table 14**. To provide context, the total area of production forest is 560,000 ha (Figure 4) but the total area of coupes in the eucalypt native forest production estate model is 418,000 ha, so including the Special Timbers Zone the total statewide available native forest area is 495,000 ha.

Table 14 **Approximate minimum area of public native forests required to supply IGA guaranteed volumes of sawlog, peeler and specialty timber.**

Headroom	Eucalypt area required (ha)	Special Timbers area required	Total (ha)
10%	427,000	77,000	504,000
20%	449,000	77,000	525,000
30%	493,000	77,000	570,000

6.2.5.3 Output (regional)

Using a similar approach to that described above at a regional level requires considering complex regional deficiencies of peeler and sawlog. The estimated areas required are presented in **Table 15**. The much larger area at 10% headroom is explained by the need to achieve an increase of 28,950 m^3 of HQSL in the North. At 30% headroom, the total area required would be 604,000 ha, ie 527,000 ha of eucalypt and 77,000 ha of special timbers – a deficit of about 109,000 ha.

Table 15 **Approximate minimum area of public native forests required to supply IGA guaranteed volumes of sawlog, peeler and specialty timber (using a regional approach)**

Headroom	Eucalypt area required (ha)	Special Timbers area required	Total (ha)
10%	485,000	77,000	562,000
20%	506,000	77,000	583,000
30%	527,000	77,000	604,000

6.2.5.4 Commentary

Accounting for 30% headroom, the total area required would be 570,000 ha, ie 493,000 ha of eucalypt and 77,000 ha of special timbers. The extra 75,000 ha required would need to be sourced from outside State production forest, be relatively productive and if it were to address headroom issues around peeler supply would need to include a considerable amount of eucalypt regrowth forest. To assist with regional supply issues, additional areas should be sourced primarily from the north of the state. It must be emphasised that this minimum area scenario potentially results in a complex, highly fragmented arrangement of small patches and strips of remnant habitat that may not be a workable conservation reserve design.

6.2.6 Scenario #6: Lonely Tree

6.2.6.1 Description

Recent evaluations by timber industry representatives have established a preferred plantation management protocol called 'lonely happy tree' silviculture. This approach thins initial plantings to 100-200 stems per hectare after approximately 10 years of growth. It is anticipated to result in high quality timber, but low densities mean low productivity on an area basis but may produce a significant opportunity to reduce tension wood in *E. globulus*. This scenario was developed to further explore the potential of new plantations to provide appropriate quality timber, serving major sawmill demand, regional sawlog demand and peeler billet demand. This report does not assess the economic viability of this option, or the availability of suitable land to implement it.

6.2.6.2 Output

Greaves (2010a) approximated the 'lonely happy tree' silvicultural treatment with Farm Forestry Toolbox, estimating that about 32,000 ha of appropriately managed plantations would be required to produce about 150,000 m^3 of pruned peeler logs. Similarly, Greaves (2010b) estimated that about 32,700 ha of appropriately managed plantations would be required to produce about 150,000 m^3 of sawlogs.

6.2.6.3 Commentary

The New Plantation Scenario developed by Forestry Tasmania (2011) estimated that a plantation estate of about 130,000 ha would be required to produce 155,000 m^3/yr of high quality eucalypt sawlogs and a minimum of 265,000 m^3/yr of appropriate peeler quality billets. Producing the same quantity using Greaves' (2010a, 2010b) models would require approximately 90,000 ha of appropriately managed plantations. The difference between these outcomes is due to different assumptions about the site index of the available plantation land; the scenarios performed by FT assumed a site index of 23, and Greaves a site index of 27. It is likely that the FT assessment is more accurate as it is based on direct knowledge of the relevant areas whereas Greaves' assessment was based on a less direct estimate.

6.2.7 Scenario #7: Effect of peeler constraint on area of forest harvested, reserves, no plantations

6.2.7.1 Description

The purpose of this scenario is to determine what the effect is upon the harvest schedule of the 265,000 m^3/yr peeler supply contract. This question will be addressed by comparing the output of two scenarios:

1) what is the smallest forest area that can be harvested in order to sustainably produce 155,000 m^3/yr of HQSL (155,000 m^3/yr with 30% headroom).
2) what is the smallest forest area that can be harvested in order to sustainably produce 155,000 m^3/yr of HQSL (this is 155,000 m^3/yr with 30% allowance for headroom) and 265,000 m^3/yr of peeler billets.

In both cases, the 572,000 ha of HCV forest will be avoided if at all possible. The existing plantation estate and assumptions outlined in Scenario #3 should be included. This scenario was difficult to implement as specified and it wasn't practical in the time available to generate these area estimates. In order to deliver at least some potentially useful results as efficiently as possible, the scenario was re-interpreted as the following: how much extra sawlog can be sourced from Scenario 1 if the regional peeler constraints are removed? This interpretation provides similar information without needing to change the estate scenarios so that forest area is in the objective function instead of a constraint. If a great deal more sawlog is available then the peeler constraint is significant. If only a small amount of extra sawlog is available then the result is reasonably robust to the introduction of the peeler constraint.

6.2.7.2 Output

Figure 20 shows that the extra sawlog that can be obtained by removing the peeler constraint from Scenario 1 is negligible.

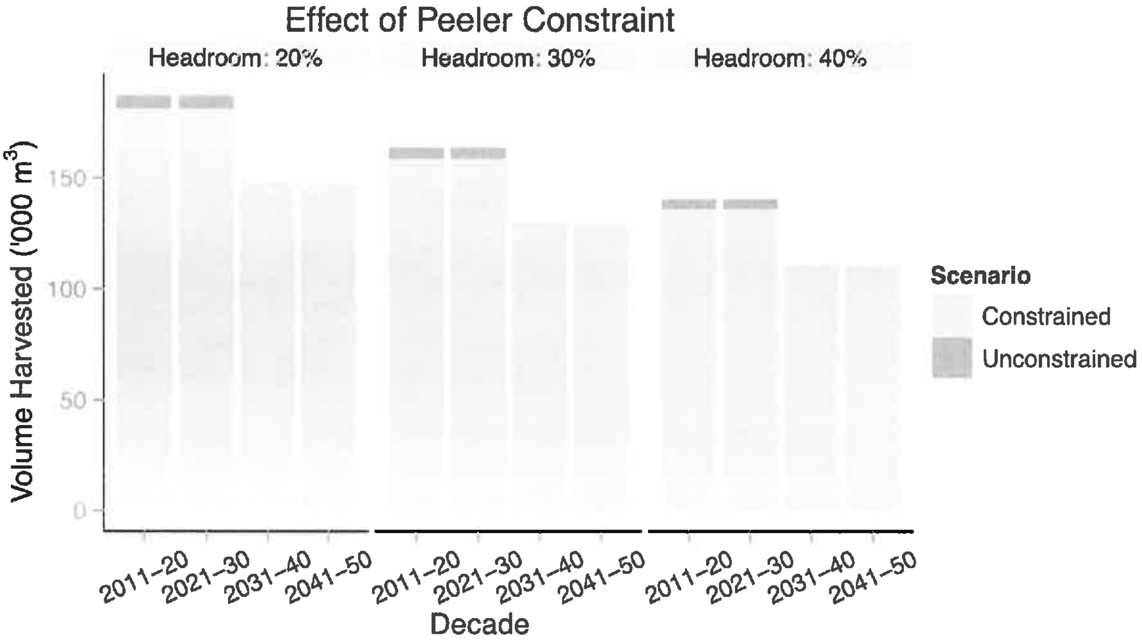

Figure 20 High Quality Sawlog volume, with no new reserves, both with and without the constraint to obtain 226,000 m^3/yr of peeler billets for a range of headrooms.

6.2.7.3 Commentary

The peeler constraint makes very little practical difference to the maximum amount of sawlog that can be obtained under Scenario 1. However, the output does not address the questions originally specified, that is, the smallest forest area that can be harvested sustainably to produce agreed volumes of sawlog and peeler billets.

6.2.8 Scenario #8: Maximise new reserves, plantations

6.2.8.1 Description

The purpose of this scenario is to provide information about the potential of FT-owned plantations to produce timber products in the near term to enable as large a conservation area as possible. It explores a scenario in which some sawmills have been compensated to reduce or cease demand of potential wood supply from public native forest. Specifically, the question addressed in this scenario is, what is the rate of harvesting within FT-owned plantations and native forests that delivers the largest conservation reserve (i.e. smallest area of native forest harvested) subject to the constraint of sustainably producing 115,000 m^3/yr of HQSL from native forests and plantations. Interpretation of the output of this scenario should account for the uncertainties that surround the processing and marketing of plantation timber (see Appendix 2).

We interpret this scenario as: minimize the net area of harvested native forest subject to the constraint that net HQ sawlog volume from native forests and plantations be 115,000 m^3/yr and that all timber sourced from native forests be subject to 30% headroom, and timber sourced from plantations be subject to 10% headroom. In order to deliver useful results as efficiently as possible, the scenario was re-interpreted as the following: can the native forests (excluding the regions identified as HCV by ENGO) and FT owned or partially owned eucalypt plantations deliver 115,000 m^3/yr of HQSL subject to the above headroom discounts? The reason for the re-interpretation is that the FT estate optimiser is not configured to be able to minimize forest area for a given volume. Accordingly we decided to determine whether the non-HCV identified area would suffice.

6.2.8.2 Output

The results are summarised in Figure 21. At the level specified (115,000 m^3/yr), which is below the guaranteed minimum of 155,000m^3/yr, sawlog supply can be provided from native forests excluding the identified HCV regions alone for the next 20 years, after which sufficient volumes may be available from plantations, subject to the very important caveats in Appendix 2.

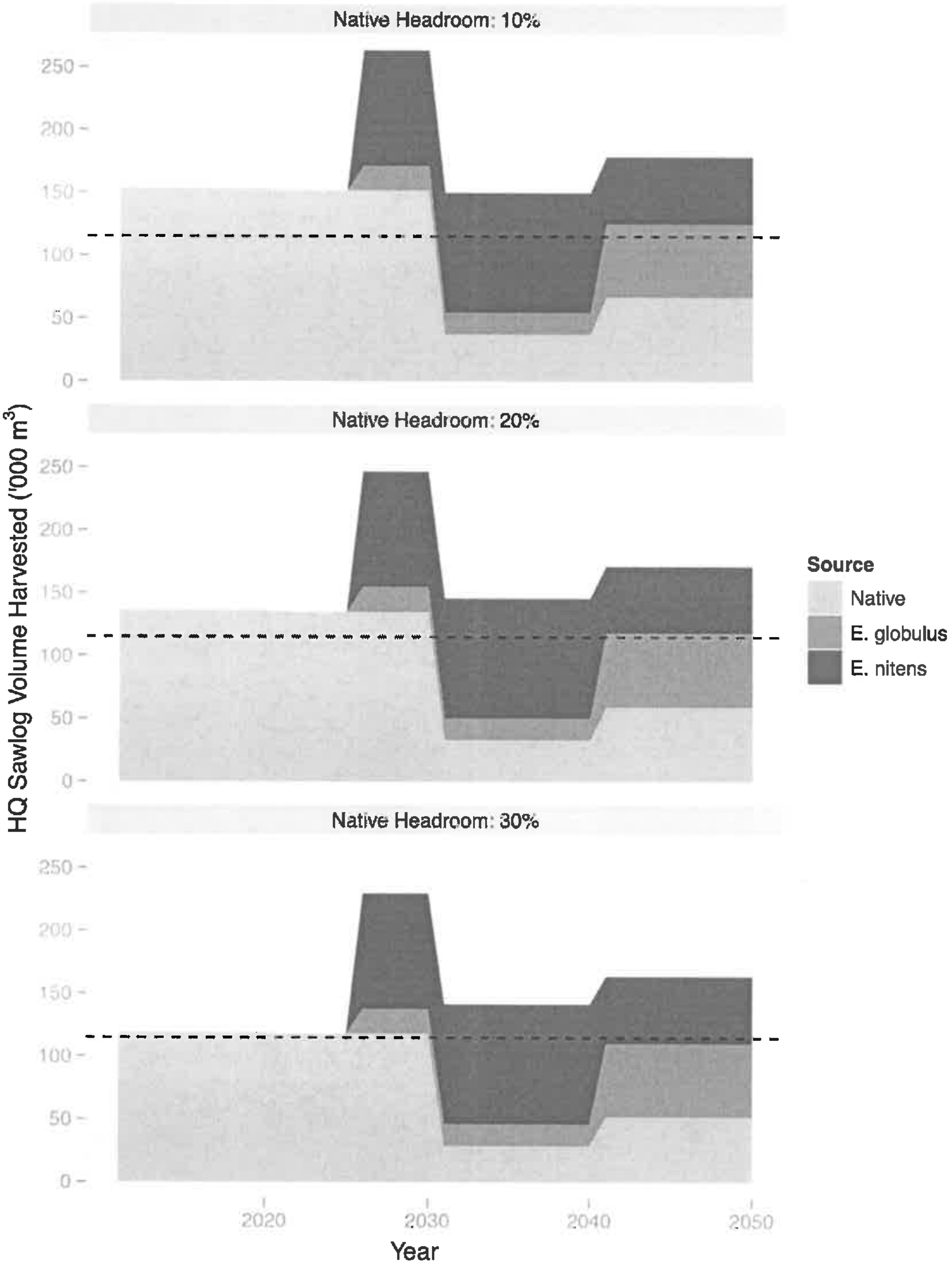

Figure 21 **Scenario #8: Maximise New Reserves, Plantations, sawlog yield. 10% headroom applied to plantation timber.**

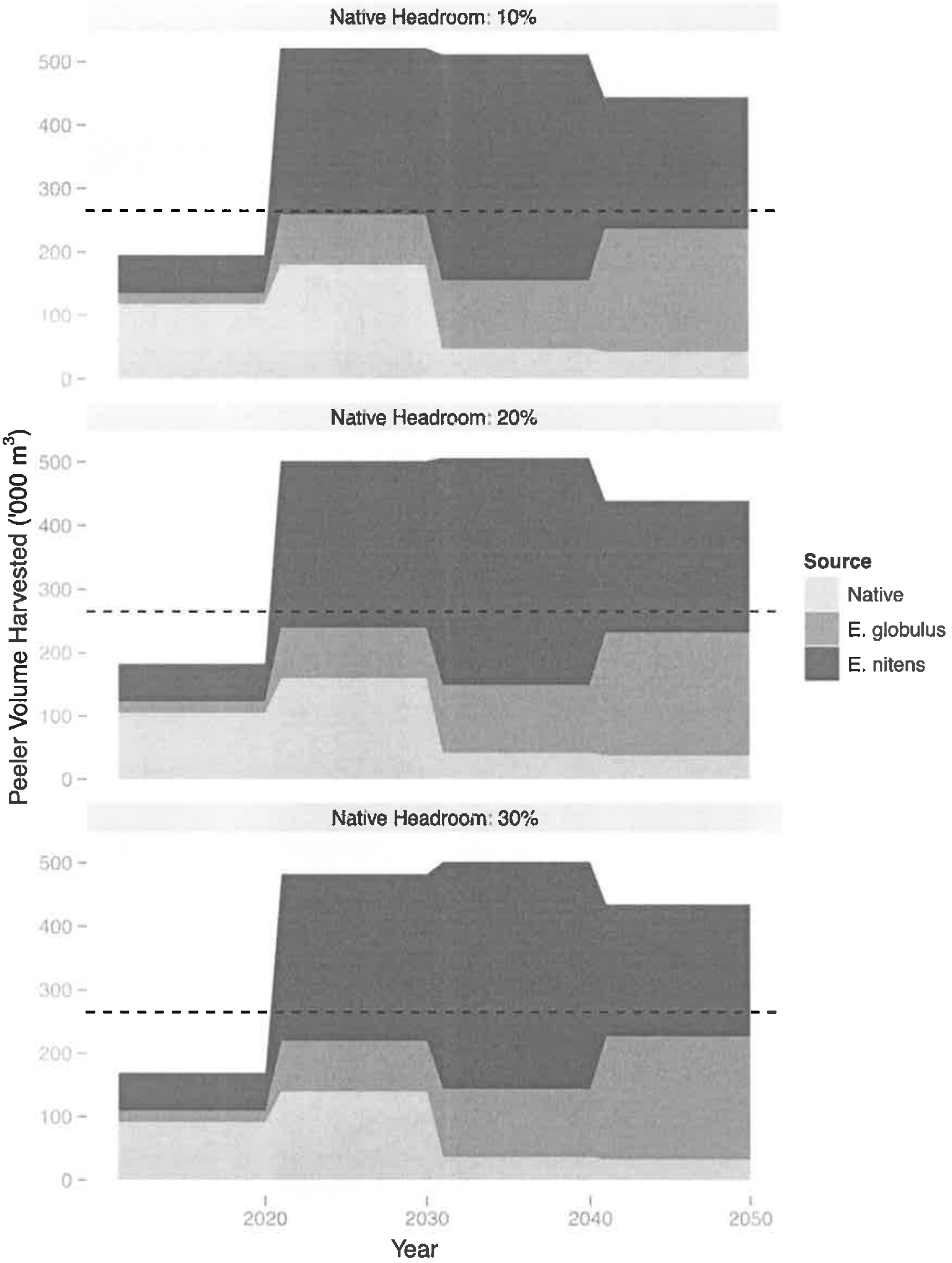

Figure 22 Scenario #8: Maximise New Reserves, Plantations, Peeler yield. 10% headroom applied to plantation timber.

6.2.8.3 Commentary

The plantation volume in this scenario is taken from Forestry Tasmania (2011, p. 30) but here is subject to 10% headroom. The results suggest that there may be some prospects for redistributing wood supply from the three sources to provide a more even and higher volume of sawlog over the first 20 years.

The scenario provides a demonstration of the temporal flexibility of the estate. Using the same land base as Scenario 2, and satisfying a HQSL volume constraint higher than the expected return for that scenario, has the effect of sharply reducing future sawlog production. This scenario provides the maximum early HQSL that can be found by all means attempted, including early entry into silvicultural regrowth. Peelers may be taken from the sawlog supplied in excess of demand. We had discussions with FT staff about the possibility of simulating the implementation of thinning in aged regrowth to obtain early peeler and accelerate the growth of sawlog-yielding trees. We learned that the conditions under which thinning could be implemented at the coupe level are very difficult to capture reliably at the estate level (the factors are economics, access, and physiographical characteristics of the coupe), and that the quantum effect is likely to be small although this was not calculated due to the limitations noted above.

The scenario should be interpreted taking into account all of the caveats and uncertainties outlined in Appendix 2 of the current document. This scenario also includes implications for the longer-term sustainability of forest production and forest age structure. Increased intensity of harvesting in the residual area may have implications for *Forest Practice Code* restrictions and headroom estimates, as may many of the other scenarios developed here.

6.2.9 Scenario #9: Non-declining yield at IGA level, with and without reserves

6.2.9.1 Description

The purpose of this scenario is to evaluate the capacity of native forests to deliver wood supply for as long as possible, without support from plantation inputs. For how long could the state's native forests sustain a non-declining annual yield of 155,000 m^3 of high quality sawlog and 265,000 m^3 of peeler billets (*without* the 39,000 m^3 separately sourced), starting in 2012 (assuming a notional 100 year period)? This specification has two area variations:

1. including 572,000 ha of new reserves
2. excluding 572,000 ha of new reserves

Calculations should include four headroom variations: 10%, 20%, 30%, and 40%. The overarching goal is to maximize the wood supply level that can be sustained with a non-declining annual yield under the different combinations of assumptions.

6.2.9.2 Output

No new reserves

- The Base Case from the 6 June Report indicates that 265,000 m^3 of peeler can be supplied from public native forest and plantations until 2030, and in order to supply that level, 204,000 m^3 of HQSL are produced.
- The 265,000 m^3 of peeler billets includes the 39,000 m^3 of supply sourced outside public native forests. This scenario removes this separately sourced quantity resulting in a peeler shortfall in the North.
- The Base Case indicates that HQSL can be maintained above 155,000 m^3 until 2030 up to the 30% headroom level.
- The Base Case can be used as a basis for estimating the total pool of peeler availability up to 2030.
- Coupes modeled after 2030 are too young to be brought forward.

Excluding the 572,000 ha of proposed new reserves

- The ENGO Scenario from the June 6 Report can be used as a basis for estimating how many years the supply levels described above can be maintained if the forests within the 572,000 ha of proposed reserves are unavailable.
- It showed that at 10% headroom, State forests were able to supply 117,000 m^3 of HQSL and 191,000 m^3 of peeler to 2030 (including 39,000 m^3 from sources outside native forest).

The results are shown in Tables 16 and 17.

Table 16 Year to which the South can supply its portion of the 265,000m^3 of peeler

Headroom	Including the 572k ha	Excluding the 572k ha
10%	2030	2023
20%	2028	2022
30%	2026	2020
40%	2023	2019

Table 17 Year to which the North can supply its portion of the 265,000m^3 of peeler (without the 39,000 m^3 of separately sourced)

Headroom	Including the 572k ha	Excluding the 572k ha
10%	2023	2019
20%	2021	2017
30%	2019	2016
40%	2017	2014

6.2.9.3 Commentary

It must be noted that although the timeframes in the tables above are mathematically possible, there is a significant risk that reduced timeframes make for operationally infeasible solutions. When levels of production and therefore areas subject to harvesting remain fixed, but the number of years is reduced, the intensity of operations is likely to be unacceptable not only to the Forest Practices Authority but also to the public.

6.2.10 Scenario #10: 100-year non-declining yield

6.2.10.1 Description

The motivating question for this scenario was: what is the maximum sawlog and peeler billet production that can be achieved on a non-declining basis in perpetuity. The scenario was implemented by modelling supply for 100 years from native forests, including a breakdown by regions.

6.2.10.2 Output

This question was answered by calculating the maximum initial non-declining yield level. The non-declining yield increases at various times for different log products in different regions, from about 60 years onwards, as a consequence of the current forest age class distribution. However, the yield for the first 40 years is relatively constant for sawlogs (about 137,000 m^3 per year) and peeler logs (about 89,000 m^3 per year) (see Tables 18 and 19).

Table 18 Maximum 100-year non-declining yield for high-quality sawlog and peeler with no new reserves, for a range of headroom values

Headroom	20%	30%	40%	20%	30%	40%
Region		**Sawlog**			**Peeler**	
State	**156.8**	**137.2**	**117.6**	**101.6**	**88.9**	**76.2**
NE	33.6	29.4	25.2	20.8	18.2	15.6
NW	24.8	21.7	18.6	23.2	20.3	17.4
S	98.4	86.1	73.8	57.6	50.4	43.2

Table 19 Maximum 100-year non-declining yield for high-quality sawlog and peeler with 572,000 ha of new reserves, for a range of headroom values.

Headroom	10%	20%	30%	10%	20%	30%
Region		**Sawlog**			**Peeler**	
State	**108.9**	**96.8**	**84.7**	**78.3**	**69.6**	**60.9**
NE	21.6	19.2	16.8	14.4	12.8	11.2
NW	20.7	18.4	16.1	19.8	17.6	15.4
S	66.6	59.2	51.8	44.1	39.2	34.3

6.2.10.3 Commentary

Long-term, sustainable, non-declining supply of sawlogs from public native forests of about 137,000 m^3 per year and of peeler logs of about 89,000 m^3 per year are significantly less than the volumes currently expected to be supplied from these sources for both sawlogs and peelers, and are less than the volumes stipulated in the IGA. Under the RFA and TCFA outcomes, FT was required to adopt a strategy of sustained yield that relied on both native forests and plantations. Contracted peeler and sawlog harvests cannot be sustained from native forest alone. The RFA and TCFA agreements were designed to be sustained from both native forests and plantations.

6.2.11 Supporting tasks

The following tasks were considered when developing plans to provide additional information to support further refinement of the scenarios above. The demands of the completed scenarios precluded the completion of several of these potential tasks.

1. Analyse a range of processing options, opportunities and constraints to achieve better value add to timber resources, in particular, new plantation hardwood processing operations. Scenarios should explore both current industry expectations and new processing techniques and technologies, especially for plantation timbers, that a new industry might take up. An analysis of the processing properties of the existing plantation resource will be required to establish whether options are technically and economically viable.
2. Identify the full suite of options for optimising peeler billet recovery including suitable plantation sources, thinning operations, early harvest of silvicultural regrowth, incorporating lower spec HQSL and LQSL and other pulp logs, changed processing and product development and merchandising improvements whilst recognising a requirement to utilise all harvested wood for its highest

possible use and to meet the saw log guarantees under Clauses 17 and 18 of the IGA and the requirements of regional saw mills.

3. Incorporate a range of silvicultural options including ecological restoration in silvicultural regrowth and various plantation options such as changing species, trees on farms and 'lonely happy tree' silviculture.
4. Provide a detailed assessment of options for increased special timber recovery including improved salvaging (on an economically viable basis), a species by species précis on its distribution, and alternative sustainable harvest options, sustainable yields and standing volumes and economically viable supply. Species distribution should be overlayed with the boundaries of the proposed reserve areas.
5. The IVG will, as required by the clause 20 of the Intergovernmental Agreement and paragraph 2 of the Terms of Reference, assess and verify stakeholder claims with respect to sustainable timber requirements, including those for specialty timbers and regional sawmillers. This should include verification of the actual demand relating to wood supply, including the wood supply that has been delivered to sawmillers. It would also include an analysis of historical supply trends to processors from public and private land tenures.
6. Undertake a desk top audit of the processing capabilities of the existing plantation estate as a direct substitute for native forest resource especially in regard to the production of high value appearance grade products and the viability of that production.

It is important to note that several of these scenarios depend on appropriate information from other sources being made available. The work will make full use of all previous studies conducted by others, wherever this is possible and appropriate.

7. Static relative volume maps

7.1 Motivation

The scenarios developed in Section 6 each require considerable computational effort. They provide a reliable guide to resource expectations, given constraints, but they are unwieldy in assisting dynamic discussions and negotiations because they take too long to compute. To address this pragmatic issue, we asked FT to prepare a representation of the value of public native forests for sawlog and peeler billet production.

A layer representing the standing volumes of trees would be insufficient for routine assessments because it would not account for growth and yield over the time periods considered above. FT created a classification of forest compartments that accounts for these aspects, approximating the *relative* volumes of sawlog and peeler billets that might be yielded from each compartment over time. Thus, they approximate what might be derived from a full, optimised forest harvest scenario. They provide a guide for discussions about tradeoffs between conservation, economic and social factors.

7.2 Map development

Current volume classes were recalculated to include a component of growth for regeneration and young regrowth over 30 years. Sawlog and peeler volumes are represented in 6 classes (1–6) and a value of 0 is the same as a null, that is, no sawlog or peeler value. The factors below explain the relationship between classes. Specifically, they relate how much greater (in terms of volume per unit area) each class is than Class 1. In each case, Class 6 includes all values above a certain level. The factors will allow users to aggregate area and volume per unit area and evaluate the importance of trade-offs for alternative management and reserve options.

Sawlog class factors:

Class 2	Class1 * 3
Class 3	Class1 * 6
Class 4	Class1 * 10
Class 5	Class1 * 14
Class 6	Class1 * 18

Peeler class factors:

Class 2	Class1 * 3
Class 3	Class1 * 5
Class 4	Class1 * 7
Class 5	Class1 * 9
Class 6	Class1 * 11

7.3 Maps

Figure 23 Sawlog value classes by compartment

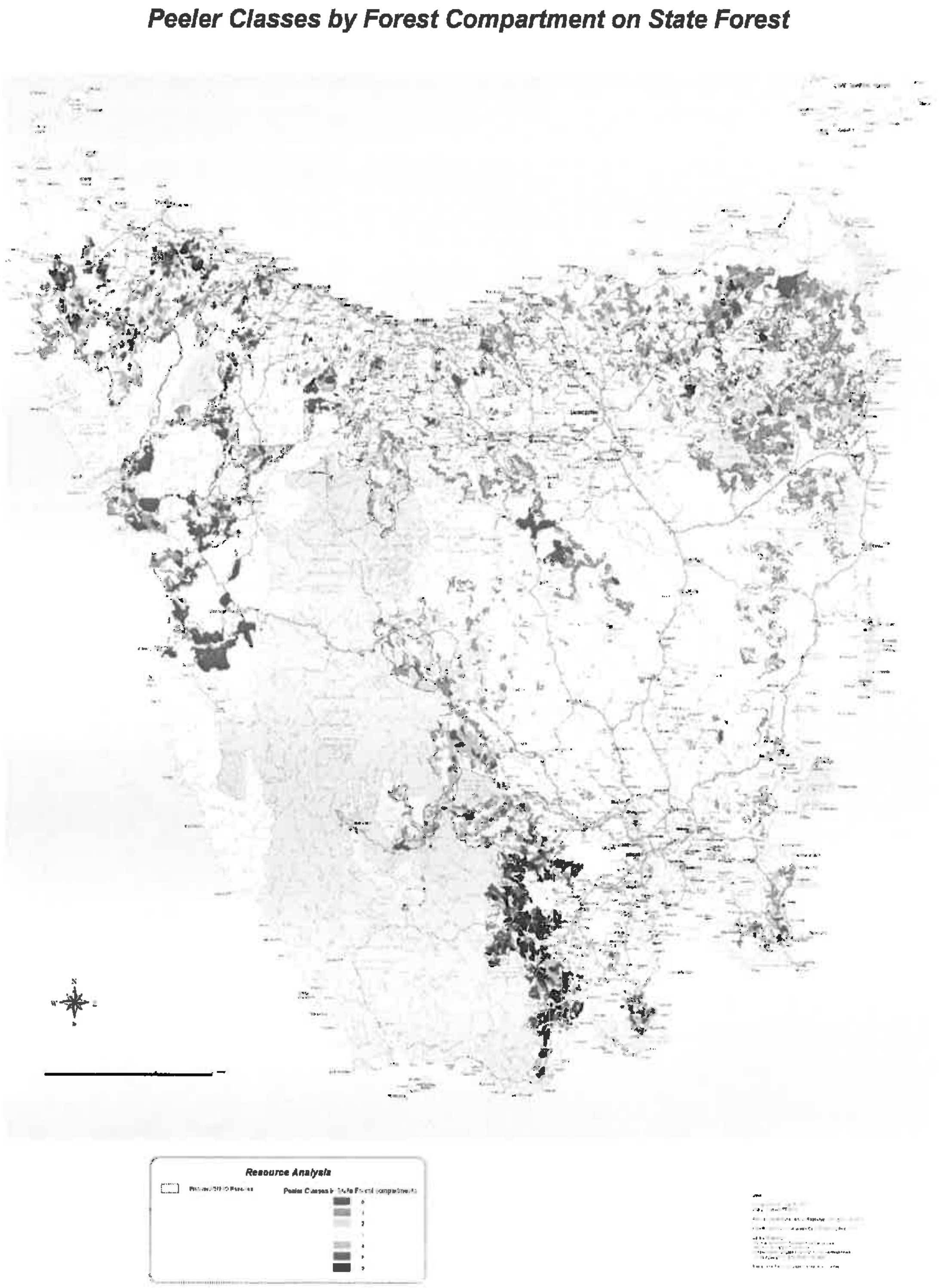

Figure 24 Peeler billet value classes by compartment

8. Discussion

FT is developing plans to retain ecologically resilient landscapes by committing to the long-term retention of unharvested forest within a 1km radius of the centroid of every coupe proposed for harvest. The minimum retention level is planned to be set at about 20%. This approach may mitigate the need for other landscape conservation prescriptions including biospines, variable retention in old growth and mandatory coupe dispersal. The imperatives for such measures will depend on whether new reserves encompassing verified, HCV forests are proclaimed.

Long-term sustainable yields of sawlogs and peeler billets from native forests alone are much less than the volumes of these products currently committed to industries until 2027, although the minimum sawlog supply can be met for this period. As noted above, under the RFA and TCFA outcomes, FT was required to adopt a strategy of sustained yield that relied on both native forests and plantations. Contracted peeler and sawlog harvests cannot be sustained from native forest alone. The existing RFA and TCFA agreements were designed to be sustained from both native forests and plantations. The analyses above indicate gaps between supply and demand, which are larger under the proposed new reserves. The prospects for using plantation timber to offset any new reserves or to supplement shortfalls that arise depend critically on sufficient investments to maintain appropriate management of existing plantations, new technology for using plantation grown timbers, new markets for timber products, and significant new investments in plantations that produce native forest-quality timber. Each of these strategies has its own limitations and challenges.

The analyses above scope a range of outcomes but many others are possible. The intention was to provide sufficient information that realistic, negotiated outcomes for conservation and timber industry objectives could be outlined, discussed, and then assessed in detail for their conservation, economic and social implications. This will require additional analysis, once participants are close to identifying a mutually tolerable outcome. The results of these assessments indicate clearly that the joint objectives articulated in the IGA cannot be accommodated in Tasmania's native forests. The individual scenarios bound the problem adequately. Any negotiated settlement will lie inside the limits of the scenarios presented here.

Following Forestry Tasmania (2011), we have used a deterministic linear discount, called headroom, to buffer against uncertainty about future forest policy, growing conditions, spatial constraints, and other unknowns. We recognize that such an approach provides only an approximation to a highly complex cluster of interacting influences. Ideally, a stochastic simulation could be undertaken that would capture the extent and shape of uncertainty about the impacts of these unknowns using probability models, but it was beyond the scope and resources of the current project. Such an analysis could be performed using raw data gathered for this project, and indeed might influence the expected levels of volume from those projected here.

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10. Appendix 1: Strategic plot locations

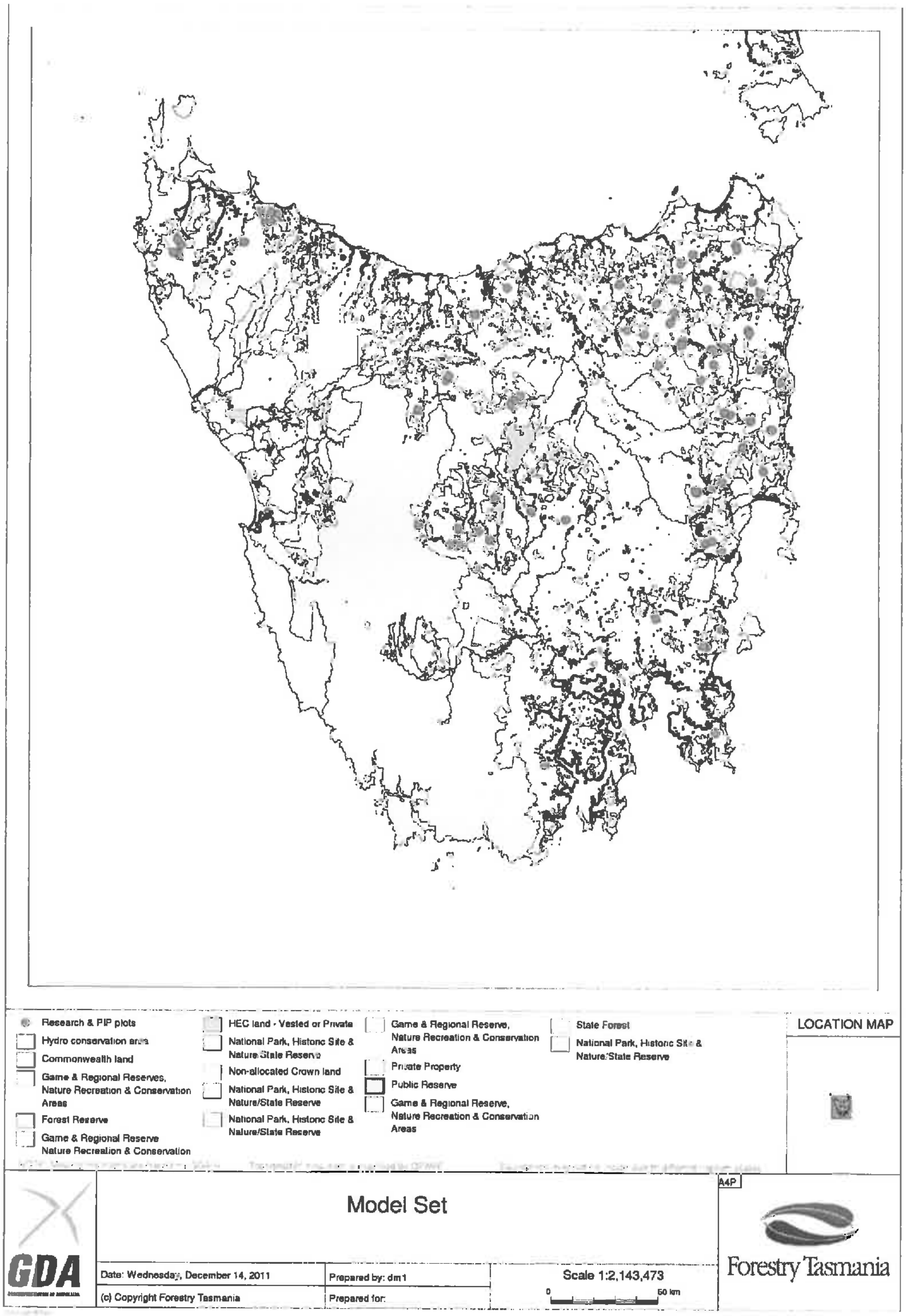

Figure 25 Locations of plots used for original FT native forest growth model

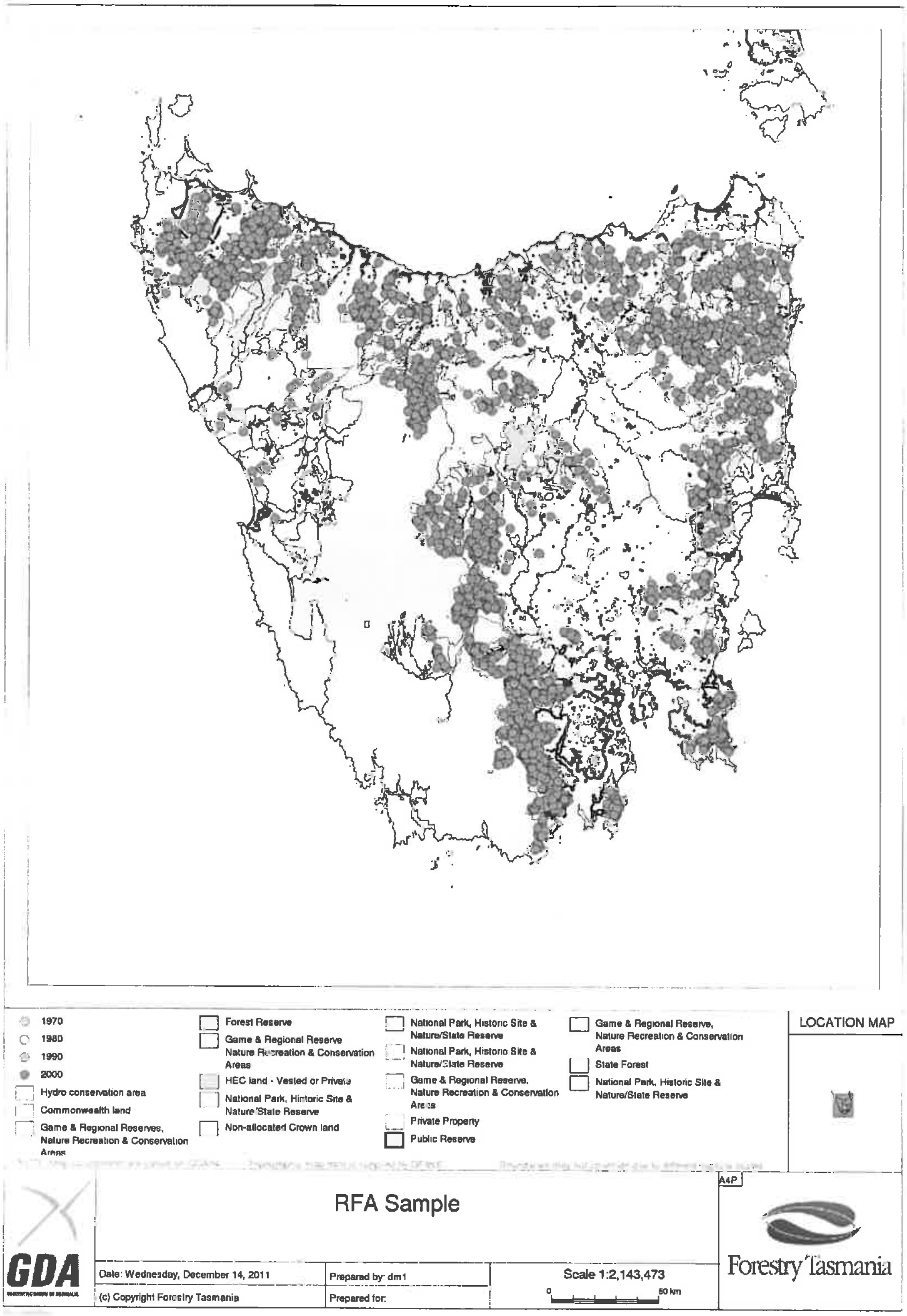

Figure 26 Locations of plots used by West (2007, 2008a-c) for model assessment and bias correction

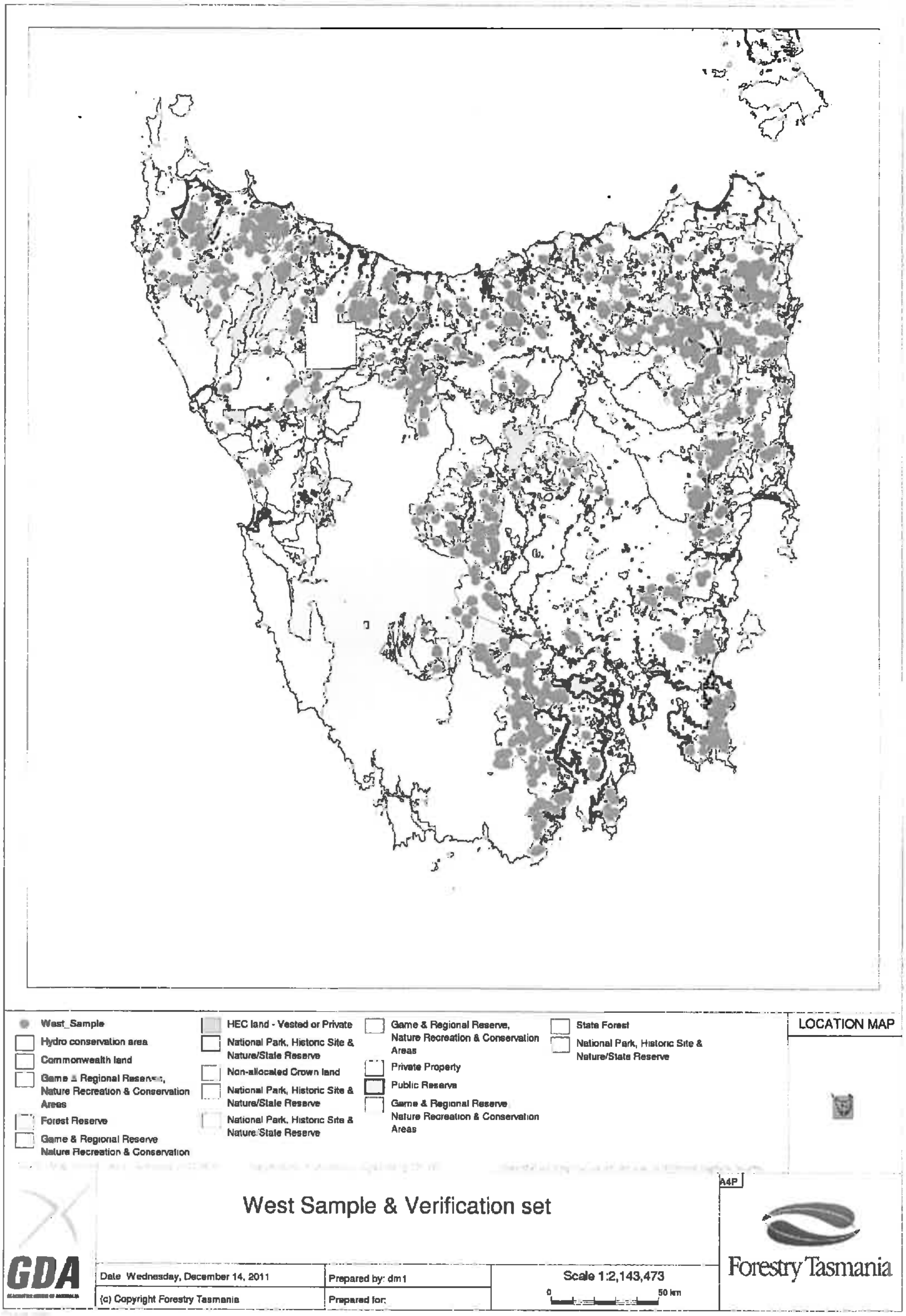

Figure 27 Locations of 'active' sample plots, coloured by year of last measurement

11. Appendix 2: Plantation timber

11.1 Introduction

The purpose of this section is to provide contextual information on the possibility of plantation-grown hardwood trees to augment or even replace sawlog and peeler billet supplies from native forest trees. It is critical to keep in mind that our use of the reported research is speculative. The existing plantations haven't begun to be harvested for sawlogs, so the projected product volumes haven't been subjected to the kind of detailed reconciliation exercise that has been performed for native forest eucalypts. The success or failure of the economic provision of sawlogs from plantations will depend on a complex array of interactions between wood quality, sawmill capacity, and market forces, only some of which can possibly be anticipated with any reliability.

The concomitant uncertainty about the ability to grow, process, and market sawlogs from plantations creates substantial risk around the forecasting of forest estate scenarios. In an ideal world, the FT eucalypt plantation resource is sufficiently large to provide a very substantial supply of sawlogs; ultimately enough to satisfy Clause 17 of the IGA without use of native forest products (Forestry Tasmania 2011). However, uncertainties about the following points all combine to suggest that a discount from projection to product could be anywhere from 0 to 100%:

- the effectiveness of current, possible, or future silviculture for producing sawlog-quality trees
- the availability of suitable processing infrastructure to economically extract high-quality products from sawlog-sized trees
- the uptake of such products by existing markets.

Each of the contributions of uncertainty also points to action required by organizations within the supply chain. Forestry Tasmania would need to develop, implement, review, and refine silvicultural practices across the existing eucalypt plantation resource, the great majority of which is presently being managed for production of sawable logs and pulpwood (cf. Nolan). Implementation would have to be done very quickly and possibly selectively in order to enable the best outcome in terms of wood quality and quantity. Sawmills would need to invest in new equipment or suitable upgrades that would permit the efficient and economic handling of the differently sized and textured logs that arise from plantation forests. A recent review shows that sawmills vary considerably in structure and process (de Fégely 2004b), so solutions will have to be tailored to individual circumstances. Both of these investments face risk; if the markets are unavailable or the growth or yield projections are too ambitious, then the organizations will be exposed to shortfalls on their investment.

The uncertainty can be accommodated in a number of ways, but it is important to note that different accommodations will expose different players to greater or lesser risk. For example, one strategy is to apply a headroom – that is, to discount the projected plantation product volumes by a percentage to reflect uncertainty about the future supply, much as is done with native forest projections to accommodate current and anticipated *Code of Forest Practice* provisions. Using such a headroom amounts to claiming that we are confident that there will be some volume, but we are unsure about how much. Hence, headroom provides a buffer against the risk of ambitious growth projections, but not against market failure, or the volume being available in the wrong place. Other, possibly complementary, strategies are to develop insurance products, or investment subsidies, to share the risk more broadly.

The question of how much risk is acceptable, who should bear the risk, and what are efficient mechanisms for sharing the risk, are critical ones that the participants of the process must resolve if the eucalyptus plantations are to be considered among the sources of product.

11.2 Background

As yet, only two species are considered suitable as plantation species for Tasmania: *Eucalyptus globulus*, which is native to Tasmania and elsewhere in Australia, and *Eucalyptus nitens*, which is native to SE Australia but not to Tasmania. Within Tasmania, *E. globulus* plantations occur in the low-elevation, warmer sites because *E. nitens* is the more cold tolerant (Harwood 2010). The native sawlog species are predominantly *E. obliqua* (stringybark or messmate), *E. delegatensis* (gum-topped stringybark or alpine ash), and *E. regnans* (swamp gum or mountain ash). A review of the relative attributes of the major eucalypt species available for plantations in Tasmania can be found in Nolan et al. (2005, p. 43).

Research into the use of plantation-grown trees has been underway for decades (see e.g., Gerrand et al. 1997a). Considerable research has been done on the use of both *E. globulus* and *E. nitens* for plantations in Australia; indeed these are two of the three most referenced species in Lott (2001), and Tasmania has as many publications as does Victoria or Queensland.

11.3 Challenges

FT's original objective was to grow a resource that would produce logs that met the size and defect specifications of a Category 3 sawlog. The silviculture employed involved a commercial thin for pulpwood at around age 10 years, which was expected to improve the overall economic viability of the plantation. Optimum silviculture for producing sawlog-specification logs is now generally considered to involve multiple early non-commercial thinning, rather than waiting until age 10 to undertake a commercial thin for pulpwood, however this increases the cost of grown sawlogs.

The primary issues that must be considered in making plantation timber as useful as native timber for sawlogs are:

- **Pruning**. In native forests, trees regenerate in dense patches, and self-prune. This does not happen in plantations, which are planted with wide spacing.

Branches that do not die, or die late, or are not pruned, reduce the utility of the grown wood for higher value sawn products.

- **Thinning**. In order to accelerate diameter growth of plantation trees, to make them large enough to produce sawlog-quality wood, plantations need to be thinned. Such operations are often not economic when the product is comparatively low value.
- **Checking**. Plantation-grown *E. nitens* is particularly prone to checking, which is a drying defect. The effects may be ameliorated by appropriate treatment (Harwood 2010).
- **Tension Wood**. Plantation-grown E. globulus is less prone to checking than E. nitens, but more prone to the formation of tension wood. Tension wood can cause shrinkage and distortion of boards during drying. Suitable silviculture, such as early thinning, may ameliorate the occurrence.

Washusen et al. (2004) provide a useful overview of these challenges. Methods for reducing growth stress in trees include: girdling, genetics, silviculture, and speedy processing (de Fégely 2004a). de Fégely (2004a) does not particularly mention checking, but touches briefly on tension wood. In a survey of sawmillers, de Fégely (2004b) identified considerable challenges with plantation-grown timber, including "…extensive kino pockets and veins, knots and brown stain. Growth stresses were so severe that as sawn sections were unloaded from the headrig carriage they were splitting lengthwise on impact." Problems of growth stress on sawing are commonly overcome by provision of large logs (Walker 1984, cited in Gerrand et al 1997b; de Fégely 2004b).

Further research has been done on the elimination or amelioration of damage done by checking, especially by the CRC for Forestry. We provide some background material as follows.

Checking is a defect that occurs during the drying process, and may affect the surface and therefore appearance of the product. Internal checking can reduce the value of the sawn boards from select grade to high-feature grade. Importantly, internal checking becomes obvious only late in the process, after much of the processing cost has been borne (Innes et al. 2008). Blakemore and Northway (2009) provided a review of the causes, potential measures and preventive or ameliorative strategies for checking for a number of native species. Nolan et al (2005) characterised *E. nitens* as a collapse-prone and high shrinkage species. Briefly, the outcome of this work is that checking is a key impediment to the marketing of sawlogs from *E. nitens* plantations, and two strategies have been suggested for reducing its effect.

1. Use quarter sawing instead of back sawing. These two different labels refer to different patterns to be used for cutting the log (see e.g., Nolan et al. 2005, p.27). Quarter sawing requires larger logs (de Fégely 2004b notes 40 cm small-end diameter, but other sources suggest 40 cm dbh) and reduces defect levels in sawn boards.

2. Make the boards thinner[9].

Washusen et al. (2008a) undertook an experiment to determine the effects of stocking and current sawing technique on sawn product recovery for plantation-grown *E. nitens* sawlogs. The trees were felled at age 21 years, had been high pruned (to 6.4 m.), and thinned to stocking levels ranging from 100 to 400 stems per hectare (sph), plus an unthinned control. The tree-to-tree differences were substantial, even relative to differences due to stocking, suggesting that careful tree selection during thinning operations might play a role. The total volume recovery of select, standard, and utility grade boards was less than 30% (of tree volume), and depended on sawing method (see below).

In the second phase of the same experiment, Blakemore et al (2010a) evaluated the potential of alternative sawing and drying strategies to reduce the levels of checking in plantation-grown *Eucalyptus nitens* wood. The authors found that "Surface and internal checking in boards of plantation-grown *E. nitens* can be reduced substantially, but not eliminated, by appropriate sawing and drying strategies. Internal checking was much less obvious following reconditioning." Their results were substantially more encouraging than those reported in the first phase of the experiment (Washusen et al. 2008a), although none of the treatments eliminated the defects[10].

Blakemore et al (2010b) reported a follow-up pair of experiments on the effect of reducing sawn board thickness (to 9 mm) upon checking and the utility of *E. nitens* for supplying peeler billets. The plantation was pruned to 6.4 m. at age 6 (considerably later than is considered optimum age of pruning, being around age 3 years), thinned to several stockings (100 – 600 plus control) at age 9, and clearfelled at age 22 years. The results were very encouraging for the production of thin boards[11]. The authors found no surface checking on thinner quarter-sawn boards, and the levels of internal checking were very low. Recovery of appearance-grade (A,B) veneer sheets was 12% of total veneer volume for pruned logs, and 6% for unpruned logs.

Britton Timbers has undertaken a sawing trial of plantation-grown *E. nitens*, including production of 8mm thick boards. This trial is ongoing; the product is about to be kiln dried, and some surface check is still evident. The intermediate conclusions are that the costs of sawing and handling 8mm thick boards with current technology are prohibitive relative to the known value of alternative products (Shaun Britton, pers. comm., 2012). The significant concern is that the equipment cannot handle the thin product.

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[9] Some commentators believe that thinner boards are currently not desired by the market, however, no data have been provided to support this view.

[10] The drying techniques employed in the experiment are considered in the Tasmanian sawmilling industry to be not commercially feasible, however, no data have been provided to support this view.

[11] It is important to note that there is no evidence that there is a market for such a product.

Furthermore, an in-house market survey by Britton Timbers indicated that there is presently no market for commercial quantities of 8mm-thick low-hardness boards, although there is a strong market for quality hardwood (Shaun Britton pers. comm., 2012). Engineered flooring (floating floorboards) are of similar dimension but the *E. nitens* product is insufficiently hard.

Gluing the boards together to make a thicker board is possible but it is also costly. That operation doubles the cost, which then exceeds market value of Tasmanian Oak. For example, Tasmanian Oak is $1200 cu m and the cost of production and gluing thin boards is 1500-2000 cu m. Notably, small volumes of *E. globulus* have looked quite good, with no tension wood, felled at ages 21-22.

Finally, eucalypt plantation that has been managed for pulpwood production, i.e. maximum biomass production without thinning and pruning intervention, yields no face-grade veneer on peeling (Farrell et al. in press). Plantation-grown *E. nitens* produces peeled veneer with a significantly lower stiffness (expressed as MOE: modulus of elasticity) than Tasmanian native forest eucalypts: 12 GPa compared to 16 GPa, which limits its application in structural plywood (Harwood 2010). Further, plantation-grown *E. nitens* has a lower hardness than Tasmanian native forest eucalypts: 4.5 kN compared to 7 kN, which limits its application for working surfaces such as flooring because it is too easily dented (Harwood 2010).

In summary, the research shows that it is possible that plantation-grown *E. nitens* can be marketed for sawlogs in the future, but substantial impediments must be overcome around the processing and marketing of the products. Washusen (2011) provides an overview of earlier research. His conclusion was that given appropriate infrastructure, it is possible that the production plantation-grown sawlogs could be economically viable. The major impediments are that existing processors are not suitably equipped to handle hardwood plantation sawlogs, and that market outlook for the kinds of sawn products that can be viably produced and marketed without checks from *E. nitens* (*viz.*, thin boards) is uncertain. Longer-term approaches are to use tree breeding to reduce the level and hopefully the significance to product value of internal checking in *E. nitens* and improved silviculture to reduce the effect of tension wood upon drying and sawing defects in *E. globulus*. Finally, Washusen and Harwood (2011) provide an economic modelling exercise for a mill optimised to work with timber sourced from plantations under appropriate silviculture and products.

Ta Ann Tasmania (2011) note that unpruned plantation peeler has been tried and failed. "Unpruned plantation billets do not meet the WSA specifications but pruned plantation billets do. Furthermore, unpruned plantation billets are not suitable for the TAT veneer product because dead knots give very low % (recovery) of long gain veneer and such veneer is of low D Grade quality; unpruned veneer has proven to have roughness and gluing problems (delamination); and the numerous knots create defects in the tongue and groove joints. Some pruned plantation is suitable with *E globulus* (Blue Gum) having good veneer density characteristics (over 700 kg/m3), but pruned *E nitens* plantation billets give mixed results. Some *E. nitens* has low MOE (bending) properties of less than 15 GPa, has low veneer density (less than 550 kg/m3), has poor sheer (pulling apart) properties, and behaves more like *Pinus radiata* than regrowth billets. Some pruned *E. nitens* appears to be OK. Product resource mapping would help identify suitable pruned

E. globulus and *E. nitens* for the Huon and Smithton mills and allow TAT to include this material as part of TAT's billet supply."

11.4 Other relevant experiments

We briefly review a collection of other recent experiments that indicate silvicultural approaches, growth rates, and product recovery rates.

Gerrand et al (1997b) report growing sawlog-sized *E. nitens* trees in Tasmania with pruning and two thinnings under a 30 – 40 year rotation; dbh 50 – 60 cm. The initial planting was 1,000 sph, thinned down to a final crop of 250 sph. The stands were subjected to different silviculture based on their quality. In good stands, the best 300 sph were low-pruned to 2.7 m. when trees were 7 m tall. The stands were commercially thinned at 10 – 12 years old. The sawlog products were 15% of the total stand volume for low-pruned stands and 30% for high-pruned stands. See also Harwood (2010).

Washusen at al. (2004) report a processing trial of plantation-grown *E. globulus* held in Victoria and Western Australia. The operation achieved harvest volumes for sawlogs around 210 – 220 m^3ha^{-1} at 21 – 22 years (equivalent to an MAI of sawlog production of around 10 $m^3ha^{-1}year^{-1}$), most of which was C-grade or better, using Victorian log grades[12].

Innes et al. (2008) undertook a processing study for thinned and pruned *E. globulus* and *E. nitens* with available milling technology. The authors concluded that "the value of solid products recovered from the thinned and pruned *E. globulus* logs and probably logs salvaged from the fibre-managed *E. nitens* stands, is likely to be sufficient for the both the grower and processor to make a suitable return." This return was despite board distortion. Unfortunately, the thinned and pruned Tasmanian *E. nitens* proved marginal or uneconomic with available equipment and technology because of internal checking (a drying defect). The silviculture was similar to that used for clearwood log production. Internal check was less in the top log.

Washusen et al. (2008b) evaluated and compared solid wood quality and mechanical properties of eucalypts grown in clearwood plantations across the medium-high rainfall zone of southwest Western Australia. Percentage yields of C-grade sawlogs and better from the pruned portion of the stem for *E. globulus* were 94%. Recoveries of select grade boards as a percentage of log volume were 20.7%, although the weighted average recovery of select grade pieces greater than 1.8m long and greater than 12.5cm wide (as per AS 2796.1) was only 11%. The authors concluded that "In general the results are encouraging given that better results could be expected from the best trees/larger diameter logs and with the application optimal drying strategies. Therefore, the results are in line with previous work in similarly managed stands. The management was similar to that described elsewhere as happy lonely tree, with the exception that the trees were pruned progressively to 10 m.

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[12] C-grade or better is equivalent size specification of Tasmanian Category 3 sawlogs.

11.5 Other relevant jurisdictions

Volker et al (2010), in an extensive review of international eucalypt plantation operations, found that *E. nitens* was as yet unsuitable due to checking, and that *E. globulus* was being used successfully for sawlogs in a number of locations, albeit with a silviculture similar to the "lonely happy tree" silviculture. It was unclear whether quarter sawing had been used for *E. nitens.* Pöyry (2011) reviewed the major impediments to the transition of Victoria's hardwood processing industry from native forest to plantations. Some points raised are relevant to the situation in Tasmania: for example, to convert an otherwise pulpwood plantation estate to a sawlog-producing plantation estate, pruning should be undertaken very early, and *E. globulus* is described in the report as 'not a good sawlog species'. It must be noted that the preferred temperate native forest sawlog species such as *E. regnans*, *E. delegatesis*, and *E. obliqua* have thus far not been successfully domesticated to plantation systems, with plantations of these species suffering unacceptable levels of insect damage and thus much reduced growth (see e.g. Nolan et al. 2005). Concerns, echoed elsewhere here, are raised about the use of plantation timber for appearance-grade products. If the quality of the wood is poor then it will be competing in a very different segment of the market: the stiffness of plantation grown *E. nitens* sawn timber is only marginally better than radiata pine (Harwood 2010), and as a structural timber *E. nitens* would not be competitive with radiata pine due to its significantly higher cost and its poorer builder-friendliness: the eucalypt yields many more splinters than does the pine. The Pöyry (2011) review noted that success in sourcing high-value products from plantation-grown eucalypts is usually found in regions with "… higher plantation growth rates than occur in Australia, lower labour costs than Australia and with strong markets for the residue material from the sawmills." (Pöyry 2011)

11.6 Conclusion

We conclude that it is certainly possible for eucalyptus plantations to provide sawlog products, given the right infrastructure and circumstances, but there are presently several critical impediments that must be overcome. Without further investment in focused research, to follow up the excellent work that has already been done for the CRC for Forestry and other contributors, reliance upon high-value products being sourced from eucalyptus plantations in future scenarios is highly optimistic.

We note, "This is not the first time that Australia's timber producers and users have adapted to a new wood resource. In the 1970s researchers, producers and the market had to deal with a plantation softwood resource that presented seemingly insurmountable challenges. Eventually, these were overcome as perception changed, opportunities were exploited and new technology imported or developed and implemented. This provides useful lessons in adapting to a plantation hardwood resource." (Nolan et al. 2005). However, considerable work needs to be done to identify, measure, ameliorate and share the risk.

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