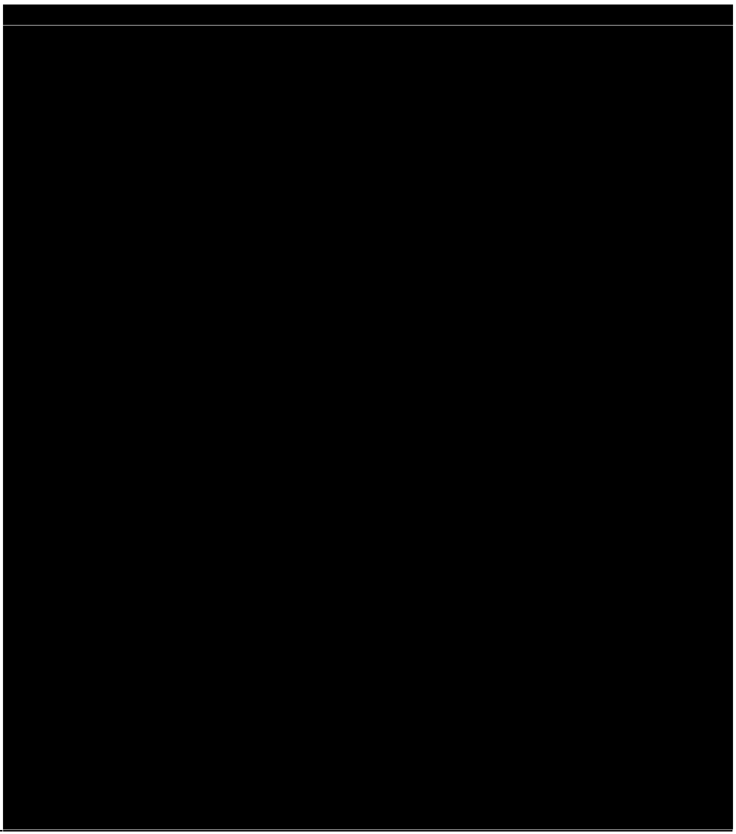
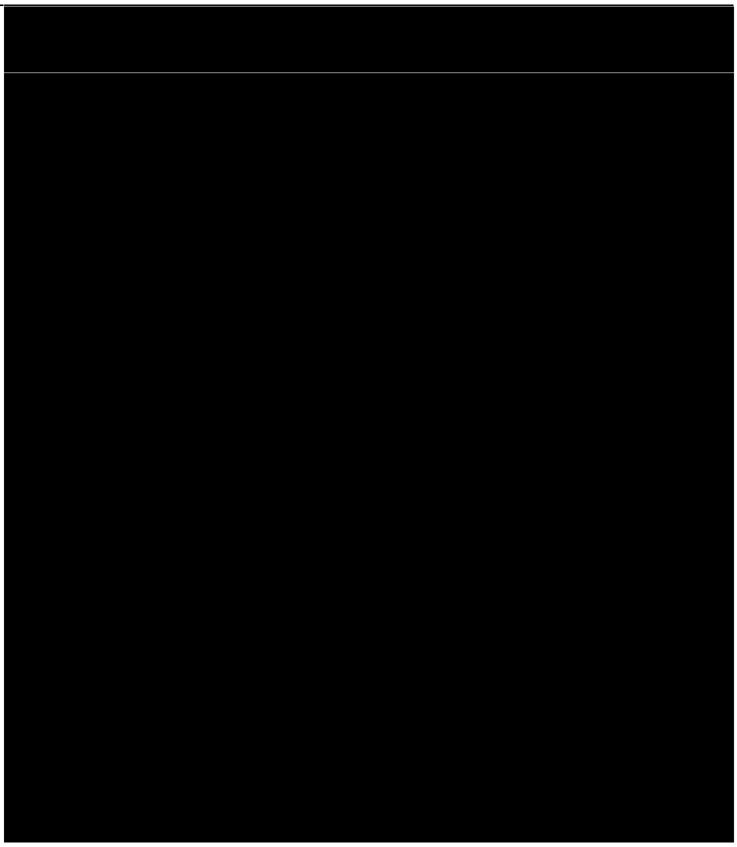


Eden Forest Resource And Management System Report

A report undertaken for the NSW CRA/RFA Steering Committee

12/5/98



EDEN FOREST RESOURCE AND MANAGEMENT SYSTEM REPORT

STATE FORESTS OF NSW & BUREAU OF RESOURCE SCIENCES

A report undertaken for the NSW CRA/RFA Steering Committee
Project numbers: NE 09/FRA, NE 10/FRA, NE 11/FRA, NE 12/FRA, NE 13/FRA, NE 14/FRA, NE 15/FRA, NE 20/FRA, NE 22/FRA

12/5/98

Report Status

This report has been prepared as a working paper for the NSW CRA/RFA Steering Committee under the direction of the FRAMES Technical Committee. It is recognised that it may contain errors that require correction but it is released to be consistent with the principle that information related to the comprehensive regional assessment process in New South Wales will be made publicly available.

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This project has been jointly funded by the New South Wales and Commonwealth Governments. The work undertaken within this project has been managed by the joint NSW / Commonwealth CRA/RFA Steering Committee which includes representatives from the NSW and Commonwealth Governments and stakeholder groups.

The project has been overseen and the methodology has been developed through the FRAMES Technical Committee which includes representatives from the NSW and Commonwealth Governments and stakeholder groups.

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APPENDICES

EXECUTIVE SUMMARY

This report has been prepared for the joint Commonwealth/State Steering Committee which oversees the comprehensive regional assessments of forests in New South Wales.

The comprehensive regional assessments (CRAs) provide the scientific basis on which the State and Commonwealth governments will sign regional forest agreements (RFAs) for the major forests of New South Wales. These agreements will determine the future of the State's forests, providing a balance between conservation and ecologically sustainable use of forest resources.

This report details the objectives, methods and outcomes of the Forest Resource and Management System (FRAMES) projects that were undertaken as part of the Eden CRA.

Various projects were carried out to determine the currently available wood resources in the forests of the Eden CRA Region and the expected future yields which can be sustained over time.

The timber resource in the Eden CRA Region can be categorised into two main components, the multi-aged forest, and regrowth forest.

The multi-aged forest resource is expected to provide the majority of sawlog supply in the Eden CRA Region over the next 20 years until about the year 2015. From around 2016 onwards, it is anticipated that sufficient area of the regrowth resource will have reached a size where it alone can supply the pulpwood and sawlog commitments previously obtained from the multi-aged forest.

The timber currently available for harvesting is shown in Table Ea. The volumes have been calculated using the current land tenure and applying current management prescriptions but do not take account of fauna moratorium areas which will be considered as part of the RFA.

There is potential impact from wildfire which was not taken into account in tables Ea and Eb and applying current management prescriptions. Table Eb shows total predicted harvestable volume for the multi-aged forest by species group and diameter class. This data has been extracted from the Eden FRAMES database.

The FRAMES Technical Committee recognised that the certainty of these estimates varies with time period. The relevant time periods are:

- from 1997 to 2019 estimated yields are drawn primarily from the multi-aged forest;
- from 2020 to 2040 estimated yields are largely drawn from fire regrowth and thinning of logging regrowth.

There are many uncertainties in estimating timber yields from forests with high inherent variability, such as the Eden forests. In considering the scenarios, FRAMES estimates of mean sawlog yields per hectare from the multi-aged forest for the period 1997-2020 have confidence limits of +/- 30%. Although some of this variability cancels out as compartments are aggregated to produce an annual yield, that annual yield may still have reasonably wide confidence limits. There is some uncertainty regarding areas and growth rates for regrowth stands harvested up to 2040 and no confidence limits can be assigned.

Beyond 2040 estimated yields are drawn primarily from logging regrowth which has not been well sampled. Estimates are indicative only.

TABLE Ea ANNUAL WOOD RESOURCE VOLUMES FROM NATIVE STATE FORESTS IN THE EDEN CRA REGION

Period	Current land tenure including any areas from which harvesting has been deferred	
	Sawlog[1] (m^3) per annum	Pulp[1] (t) per annum
1997-2019	28 300	403 000
2020-2040	28 300	444 000
2040+	>30 000	~500 000

[1] From the multi-aged forest and regrowth, including thinning

TABLE Eb: TOTAL PREDICTED HARVESTABLE VOLUME (m^3) FROM THE MULTI-AGED FOREST BY SPECIES AND DIAMETER CLASS

	Sawlog diameter class (centre diameter under bark)	
Species Group	**<40 cm (m^3)**	**≥40 cm (m^3)**
Silvertop Ash	10 000	134 000
Stringybarks	15 000	149 000
Messmate	3 000	56 000
Spotted Gum	3 000	12 000
Monkey Gum	5 000	68 000
Tablelands spp[1]	3 000	64 000
Specials[2]	1 000	3 000
Other	3 000	26 000

[1] Mountain gum, brown barrel, shining gum, manna gum
[2] Grey box, grey gum, ironbark, white box

Based on this information, allowable cut calculations can be estimated for the current planning horizon (Forest Essentials Pty Ltd, 1997b).

Eden FRAMES identified a need for more inventory data for future evaluations of the regrowth resource.

1. INTRODUCTION

1.1 PURPOSE

To develop an RFA for Eden it is necessary to understand the currently available wood resources in the Eden CRA Region's forests, and the expected future yields which can be sustained over time.

To this end, a Technical Committee was established, with representatives from State and Commonwealth Governments and various stakeholder groups, to develop methods and oversee assessment work. The Forest Resource and Management System (FRAMES) Technical Committee in its Technical Framework identified its aims as:

- determining ecologically sustainable wood flows and expected sawlog sizes and qualities for a range of management options and a varying resource base for use in RFA integration;
- providing reliable ecologically sustainable yield figures as a basis for an RFA between the Commonwealth and NSW;
- providing a basis for ongoing ecologically sustainable management of wood flows by State Forests of NSW;
- providing information on resource characteristics for use in long term planning by wood-based industries in NSW; and
- providing information on and validation of the modelled effects of environmental and silvicultural options for use in developing proposals for ecologically sustainable forest management.

The ecological sustainability of wood flows was primarily addressed by the ESFM (Ecologically Sustainable Forest Management) Technical Committee.

1.2 FRAMES AND THE EDEN CRA

A detailed Forest Resource and Management System (including detailed inventory) is currently being applied to State forest areas which are included in the other New South Wales Comprehensive Regional Assessments (CRAs).

However, in setting out to establish wood flows over time for the Eden CRA Region, the FRAMES Technical Committee decided in January 1997 that there would not be sufficient time to complete a full strategic inventory for Eden, as is being carried out for the rest of the State. Separate Eden-specific projects were therefore developed, with the expectation that a revised and externally validated wood resources database, plus improved associated models, would provide a reasonable foundation for estimates of harvestable log volumes and sustained yield. This combined assessment is referred to as Eden FRAMES.

The work carried out for Eden has included:

- refinement and independent review of existing information on wood resources;
- revised estimates of forest growth rates to enable the prediction of future wood resources;
- revised calculations of potential future sawlog and pulpwood yields from the Eden region.

This report details the methods used and the results of the Eden FRAMES projects.

1.3 OBJECTIVES

FRAMES for Eden was designed to:

- produce estimates of harvestable volumes of the older multi-aged forest by quality, size and species classes as well as overall value ($);
- provide models for growth and yield of the regrowth resource;
- combine multi-aged forest volumes and regrowth volumes to estimate sustained yields of timber;
- provide data and methods for calculating sustained yield for Commonwealth accreditation;
- identify wood supply potential by area;
- provide information (harvestable wood volume, sustained yield, and information on

size, species and quality mix) for assessment of industry development potential;

- provide capacity to simulate some of the effects on wood flows of harvesting intensity, so that this information may be used with other models to assess the consequent impact on other environmental values;
- derive an estimate of gross and net harvestable area for each management unit;
- allow resource information to be displayed spatially;
- provide a scheduling tool for combining and averaging the flow of wood from specific harvesting operations; and
- provide resource information as inputs into the Forest Resource Use Model (FORUM) to enable modelling of economic and social impacts.

1.4 SCOPE

Due to time limitations and the features of existing data, FRAMES for Eden was designed to build upon the forest resource information system in use in the Eden CRA Region.

Existing data were used to the fullest extent possible. A suite of projects was developed specifically to match the data and time availability, and requirements for the region. These projects were designed to provide a revised and externally validated database and a predictive model for use in estimating potential yields under alternative land use scenarios.

1.5 DESCRIPTION OF THE EDEN CRA REGION

The Eden CRA Region adopts the same boundary as State Forests of NSW (SFNSW) Eden Management Area. Its area totals about 800 000 hectares and extends, in broad terms, from Bermagui and Nimmitabel in the north to Delegate and Cape Howe in the south.

1.5.1 Native forests

The timber resource in the Eden CRA Region can be categorised into two main components:

- the multi-aged forest; and
- the essentially even-aged regrowth forest.

The multi-aged forest resource includes unlogged forests and forest areas which have been selectively harvested in the past and represent a currently available bank of wood resource.

The regrowth forest in the Eden CRA Region includes regrowth originating from fires (where the fires have been of sufficient intensity to kill most overstorey trees) as well as from integrated harvesting. The regrowth resource will be an important future source of wood for the region's industries. There have been four major fire seasons affecting the resource, 1952, 1968, 1972 and 1980. Since 1967, approximately 170 000 hectares have been burnt.

Even where trees have not been killed, the long history of wildfire in the region has affected log quality in the multi-aged forests. Due to the younger average age and reduced exposure to damaging wildfire, the regrowth resource is anticipated to be of considerably higher quality than the multi-aged forest sawlogs. The STANDSIM growth model (refer Section 4.1) predicts that the regrowth resource will produce higher volumes per hectare of sawlogs than the multi-aged forest.

All data was collected for area units known as coupes which are the area basis for planning harvesting operations. Each coupe has an area of approximately 50 hectares.

The alternate coupe harvesting system is applied in Eden. This is a planning strategy to spread the environmental impacts of logging over space and time by dividing a compartment into smaller areas (coupes) and logging the coupes in an alternating pattern (SFNSW, 1994). Logging of alternate coupes is intended to be separated in time as far as practicable and is generally around 15 years.

Younger regrowth areas result from harvesting operations conducted from 1970 onwards. About 120 000 hectares have been harvested by integrated harvesting operations since 1970.

The multi-aged forest resource is expected to provide the majority of sawlog supply in the Eden CRA Region over the next 20 years until about the year 2015. From around 2016 onwards, it is anticipated that sufficient area of the regrowth resource will have reached a size where it alone can supply the pulpwood and sawlog commitments previously obtained from the multi-aged forest.

There is also estimated to be around 90 000 hectares of private forest in the CRA Region. Management of this resource and its potential yields are not clear.

1.5.2 Plantations

SFNSW plantations of *Pinus radiata* in the Eden CRA Region have a net area of 31 000 hectares. Most are concentrated in the Bombala area, between Craigie, Rockton, Towamba and Cathcart, with smaller plantations in the Glenbog and Glen Allen areas. Most of the resource is less than 25 years old, with some areas reaching second and third thinning age. Significant increases in harvest volume are planned over the next decade (see Table 1a).

The area of privately owned pine plantations in the Eden CRA Region is around 2 000 to 3 000 hectares.

About 1 100 hectares of eucalypt plantations have been established in the area. Most are less than 10 years old and principally targeted at the pulpwood market. These include 800 hectares of predominantly *Eucalyptus nitens* plantation and about 300 hectares of smaller farm woodlots recently planted as joint ventures between farmers and SFNSW, comprising *E. nitens, E. botryoides, E. saligna and E. agglomerata*. Yields are unknown.

TABLE 1A SOFTWOOD RESOURCE VOLUMES FROM PLANTATIONS IN THE EDEN CRA REGION

Period	Sawlogs (m^3) per annum	Pulpwood roundwood (t) per annum	Sawmill residues (t) per annum
Current Harvest	50 000	35 000	-
Potential 2002 [a, b, c]	290 000	200 000	87 000
Potential 2010 [a, b, c,]	380 000	270 000	114 000
Potential 2020 [a, b, c]	550 000	270 000	165 000

a) Potential 2002 level of yield based on current plantation resource; Potential 2010 and Potential 2020 levels of yield assume an expansion of the plantation estate by 10,000 hectares and 20,000 hectares respectively.
b) Sawlog availability predicated on the sale of all pulpwood.
c) Potential yields represent sustained annual levels assuming an even distribution of age classes, which is not currently the case.

Source: SFNSW, BRS (Social and Economic Technical Committee).

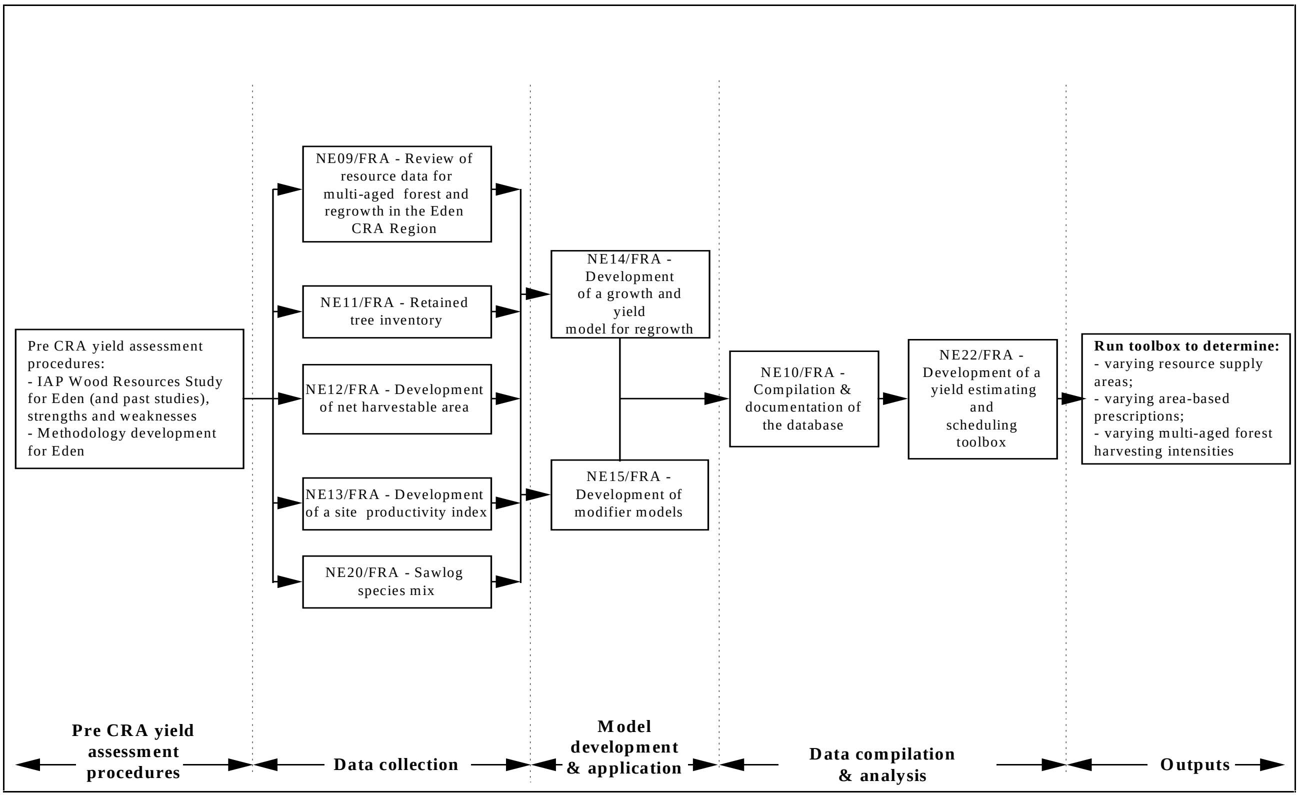
1.6 METHODS

The FRAMES Technical Committee developed methods and oversaw projects. Figure 1a shows the methodology used for Eden FRAMES. The assessment consisted of the following phases:

- pre CRA yield assessment procedures;
- data collection;
- model development and application;
- data compilation and analysis; and
- outputs.

The following chapters outline what was involved in each of these phases.

FIGURE 1a EDEN FRAMES METHODOLOGY



2. PRE CRA YIELD ASSESSMENT PROCEDURES

2.1 EXISTING DATA

In the course of its normal forest management activities, SFNSW has been carrying out projects to improve its estimates of the timber volumes per hectare which can be expected from the multi-aged and regrowth components of the resource.

Existing available SFNSW data includes:

- inventory data (broad based and compartment level); and
- actual historical yields for harvested coupes dating back to 1970.

A major inventory of the resource was undertaken in 1987. This 1987 timber inventory was built upon the recognition that the management practice of alternate coupe harvesting in the Eden CRA Region allows for actual volumes per area and species and size mix to be cross-referenced to adjoining unlogged coupes. As a result, future wood volumes can be estimated in adjacent unlogged coupes, recognising that adjustments need to be made for differences between current and historical net harvestable area and tree retention prescriptions.

2.2 PREVIOUS STUDIES

The results of a 1987 timber inventory formed the basis for the 1994 Eden Environmental Impact Statement (EIS) predictions and the 1996 Interim Forest Assessment (IFA) Wood Resources Study (WRS).

The following sections present the outcomes of both the EIS and IFA.

2.2.1 Summary of EIS Outcomes

The outcome of the Eden EIS was that wood resource volumes were set at 59,000m^3/yr of sawlog and 504,000t/yr of pulpwood. It was determined that actual wood resource volumes were to be reviewed in five years.

2.2.2 Summary of DFA/IFA Outcomes

The Deferred Forest Agreement (DFA) between the Commonwealth and New South Wales Governments (signed January 1996) provided that commercial timber harvesting operations were permitted to take place only in compartments identified in the DFA. Approximately 340 compartments in the Eden CRA Region were listed under the DFA.

The 1996 IFA was concluded subsequent to the DFA. Some of the key conservation initiatives of the IFA that relate to the Eden CRA Region were:

- the reservation of approximately 45,000 hectares of new national park in the southeast forests;
- approximately 42,000 hectares were included in the Interim Deferred Forest Area (IDFA). Of this, 36,000 hectares (approximately) of State forests in the Eden section of the IDFA was to be considered during the CRA for addition to the South East Forests National Park. In addition, approximately 64,000 hectares of State forests were included in a Commonwealth DFA, pending the CRA/RFA outcome.

Some of the key industry initiatives in the IFA relating to the Eden CRA Region included:

- quota grade sawlog supply will be 26,000m^3 until the completion of the CRA, and then maintained at a minimum of 20,000m^3 per year for the length of the agreement negotiated for revised sawlog arrangements for the Eden CRA Region;
- timber commitments to be supplied from outside IDFA and Commonwealth DFA

compartments in the Eden CRA Region until the RFA is completed.

A discussion of the IFA WRS study is provided in Appendix 1. For further information about the IFA, reference should be made to the Draft Interim Forestry Assessment Report (RACAC, June 1996).

2.3 CONCLUSION

The pre-CRA methodology had a number of limitations as identified in the following chapter and Appendix 1.

The CRA assessment of Eden timber resources detailed in this report comprised a review of existing data and studies, significantly refining the methods used in the IFA Wood Resources Study to essentially rebuild the multi-aged forest database and construct a regrowth database and scheduling tool.

3. DATA COLLECTION

3.1 REVIEW OF RESOURCE DATA

Review of Resource Data for Multi-aged Forest and Regrowth in the Eden CRA Region
Project No. NE/09 FRA

3.1.1 Project objectives

The objective of this project was to quantify the reliability and limitations of work which had been undertaken to predict the resource available per hectare in the current multi-aged and regrowth forests in the Eden CRA Region. The project expanded to include improved methods for defining base resource data for both multi-aged forest and regrowth.

3.1.2 Methods

The resource data for multi-aged and regrowth forests was independently reviewed by Forest Essentials Pty Ltd and their report *Validation of Eden Wood Resource Data* (1997a) is included in Appendix 2. References from that report are shown in italics in Sections 3.1.2 and 3.1.3.

Multi-aged forest

The project involved:

- documentation, review and refinement of the methodology for predicting harvestable volumes; and
- a statistical analysis of the relationship between predicted yields (from the 1987 inventory) and actual yields.

INVENTORY OF THE MULTI-AGED FOREST (MAF)

A significant problem with evaluating the methodology was the lack of documentation on techniques at the time when the inventory was planned and executed. The following description of methods was obtained by discussion with staff at Eden.

Compartment boundaries for the Eden Management Area (EMA) were delineated in the early 1970s, and coupe boundaries were determined for all productive forest in 1977 They were revised to comply with Preferred Management Priorities (PMPs) in 1981.

The assessment of the MAF currently used for the Area was carried out in 1987. At this time, the EMA included three Districts. This division of responsibility resulted in differences in approach and contributed to a lack of adequate documentation.

The merchantable volumes of both sawlog and pulpwood available on all uncut coupes were estimated in the 1987 assessment by comparison with actual yields from the neighboring utilised coupe. A cruise of the uncut coupe was carried out by an experienced supervisor to confirm or modify the estimate that had been based on utilisation yield. Where yield information from a utilised coupe was not available to assist estimation, an estimate was made from cruising alone. In work since, the estimated yields for unpaired coupes have been amended as utilisation data became available.

In operations up to about 1985, selective logging was carried out in some (a total of 198 out of the 3076 coupes cut at that time) adjacent uncut coupes to supplement yields from integrated logging. Adjustment for this reduction in yield was made during the cruise of the uncut coupe.

The information obtained was stored in a Dbase III+ coded database, since updated to the current Access coded 'Cricket' database.

Regrowth forest

The limited time available for the completion of the Eden CRA meant that existing data was used. Inventory of the regrowth by SFNSW was already under way and this was used as the basis for this project. This data was supplemented by measurement of additional plots in strata with limited information.

INVENTORY OF THE REGROWTH FOREST

A major problem with evaluating the regrowth inventory was the lack of documentation on methodology for both the API stratification and the methods used in plot measurement. An outline of the proposed work dated August 1993 was examined. This provided general instructions only; it did not, for example, describe procedures for selecting which stands of regrowth should be sampled and how plots should be located in the stands. Guidance as to methods was also obtained from the State Forests Field Methods Manual. While this document is excellent for basic methodology, it does not provide sufficient detail for specific tasks such as this inventory. The following description of methods was obtained by discussion with staff at Eden.

Objectives

As given in the August 1993 outline:

- *To measure the volume of regrowth available for thinning, and the volumes of sawlog and potential sawlog available in each stratum, in order to determine the priority of regrowth stands for thinning.*
- *To determine whether enough thinning resource exists to sustain another tree harvester in Southern region.*

An unstated objective that has become more important since 1993 and is implied by projects within the current RFA process is the need for information to calculate a reliable sustainable yield for the resource as a whole.

Aerial photo interpretation (API) was used to locate and delineate boundaries of regrowth. Judging from the strata chosen (categories of number of stems/ha, stand mean diameter, mature tree density and shrub density), it was expected that some stand data could also be obtained from API. Plot measurements were carried out both before and after the strata were delineated.

Selecting stands for sampling

Colour aerial photographs (1:15,000 scale) taken in 1993, were available for the southern part of the EMA. Two different techniques were used to select stands for plot sampling; one technique used before the API stratification of the resource was complete and a different technique subsequent to that.

The first technique concentrated sampling effort into regrowth known to be the oldest available in the eastern part of the EMA, because, as specified in the 1994 EIS, these would be the first stands to be thinned. Maps showing the regrowth in the nominated compartments were prepared from the 1993 airphotos and the sampling crew was directed to sample these stands.

When the API stratification became available, the plots measured to date were allocated to the API strata and sampling effort was then directed to strata that had not been sampled or where the coefficient of variation of mean total stand volume was greater than 30% of the mean.

Refer to full report in Appendix 2 for discussion on plot measurement procedure and analysis.

Over 1,000 field plots in fire and harvesting regrowth were measured for basal area, stocking rate and height, and tree diameter for a proportion of plots. For those plots, where bole height (not dominant height) for typical codominant trees near the sample point was estimated, mean dominant heights were estimated using a relationship between tree diameter and tree height (Bi unpublished).

The extent of fire regrowth was derived from aerial photograph interpretation (API) of compartments and from compartment history records elsewhere. The area of harvesting regrowth was derived from compartment history records.

3.1.3 Results

Multi-aged forest

The method has the advantages that it is cheap, requiring minimal field work compared with a traditional plot-based inventory, and is directly associated with the real world, through comparison with actual utilisation of the neighboring coupe. The disadvantages are that the method assumes the same products will be removed, using the same technology and in the same conditions of market demand, as the first coupe, all conditions that may have considerable influence on the yields obtained. The considerable time separation between the two operations (up to fourteen years) accentuates these disadvantages.

The method also depends heavily on the presence of an adjoining utilised coupe for reference *purposes. When a nearby coupe is not available. the method becomes just another cruise estimate.*

A further disadvantage is the requirement that the cruise be carried out by a person, usually a logging supervisor, who must have sufficient experience to make a reliable estimate of merchantable volumes in the highly variable forests concerned.

The reliability of the data has been assessed using a comparison of the predicted and actual yields per hectare obtained using the method over a long time period, shown in Figure 1 [refer Appendix 2] *for sawlog and Figure 2* [refer Appendix 2] *for pulpwood. For the period between about 1977 and 1994, there is a consistent relationship, particularly for sawlog volumes, of underestimation. For that period, sawlog volume was underestimated by 8% and pulpwood volumes by 29%. However, from 1994, the relationship appears to break down, with sawlog yields dropping to about the same level as predictions and pulpwood production also dropping substantially. A range of theories have been proposed for these changes including increases in stream buffer width, the beginning of utilisation in the uncut coupes of alternate coupes (which are the very small coupes of the late 1970s), changes in market conditions etc. However, there is no way to determine which if any of these alternatives is the real reason for the change.*

While the graphs of mean yield per hectare for the many coupes (about 50) utilised per year shown in Figures 1 and 2 are relatively smooth and level, they represent relatively consistent means that have large variations. Confidence limits (95%) have been calculated for the actual and estimated yields and they are shown as vertical error bars on Figures 1 and 2. They indicate that the sawlog estimates were significantly different in only one year (1982) and that pulpwood yields were significantly greater than estimated for five years (1982-93). The confidence range in most years was around 30% of the mean, although individual years varied from 20% to 100%. These results are good for forests of this type.

Refer to the full report (Appendix 2) for discussion on the alternatives to the above method. The report indicates that alternative processes could have been used but with significantly greater costs and more time required.

Conclusion

Given that the alternative methods available may produce some extra benefits, but at significant extra cost, without appreciably improving the precision of estimates of merchantable yields, the current method is considered to be an appropriate way to estimate wood volumes in the multi-aged forest concerned.

However, attention needs to be directed towards finding the reasons why the yields obtained since 1994 have been less than those in previous years. If the yields continue to be low, there may be a need to refine the existing predictions. A reliable estimate of the remaining utilisable volume in the MAF is a crucial requirement in estimating the sustainable yield for the Regional Forest Agreement.

Cruising estimates made in future could be improved by the application of simple basal area count methods that allocate count trees to categories such as regrowth, advance regrowth, overwood trees and merchantability classes. The methodology for these surveys needs to be developed, tested and documented before widespread application.

Regrowth forest

API stratification

The inclusion of stand variables into the API stratification provides the opportunity to derive estimates of area for the different strata directly. However, if in fact the strata cannot be effectively separated using API, then a significant amount of work will have been done with no useful result. The separation of strata was examined (during this review), by comparing mean stand variables obtained from plot measurements within the designated strata. Table 1 gives the results of this comparison[refer to Appendix 2 for Table 1].

The table shows that the stem stocking results in all strata except one (4a), were outside the nominated target ranges and that the mean values are mostly not significantly different (the confidence ranges overlap). For mean diameter, six out of eight sample mean diameters fell outside the target ranges and only one mean, in the 1a stratum, was different from the other ranges in the same stocking class. While retrieval of useful data may be possible through pooling of some categories, the API stratification can only be regarded as unsatisfactory in providing useful *stand data. It does however effectively delineate the boundaries of regrowth stands.*

An alternative approach would be to select simpler API categories that were demonstrably able to be delineated successfully. This will achieve the main task of API - deriving a reliable estimate of location and area with a simple subdivision into density categories. Stand variables can then be estimated using plot measurements. Using simpler API strata may also make possible the use of smaller scale airphotos, that may provide complete coverage of the area of interest without the delay involved in new photography.

Refer to full report in Appendix 2 for discussion on plot measurement techniques.

Effectiveness of the plot sampling scheme in representing the resource

The resource includes a range of different forest types, age classes, productivity classes, types of regrowth origin and geographic locations. An appropriate sampling scheme must efficiently sample the variation in each of these categories. There has been no formal consideration of these requirements, sampling has been directed towards the older stands because it is recognised that information is most urgently required for these stands, since these will be available for utilisation first.

An indicative examination of the coverage of the resource by the current set of regrowth plots was carried out using maps of forest type, date of coupe utilisation and plot location (Figures 3 to 5 respectively)[Refer Appendix 2 for figures]. *The compartments sampled to date are indicated on Figure 3, shaded red. The samples cover the limits of geographic spread of the resource. However, there are gaps in the coverage within these limits, for example, in Yambulla, Nullica State Forests. Forest types in the resource include Dry Shrubby, Dry Grass, Moist and Intermediate Shrubby (Figure 3). Dry Shrubby, dominated by* <u>E. sieberi</u>*, covers the largest area, occurring in the south east of the EMA and including the majority of plots established so far. Moist forest occurs in the northwest of the EMA and includes the next largest number of plots. Dry Grass forest occurs in the south west of the EMA and contains only a few plots.*

Figure 4, indicating regrowth age, shows when compared with Figure 5, that stands logged between 1980 and 1990 are not well represented by sample plots. This, and other gaps in representation, should be corrected by the continuing measurement of sample plots.

The site productivity layer is not yet available and distribution of plots within it cannot be determined. This layer was available subsequent to this analysis; see Section 3.4.

Table 2 [refer to Appendix 2 for Table 2 - Number of plots in different types and ages of regrowth] *indicates a majority of plots in the fire regrowth, in accord with the expressed priority to gather data in those stands first. Future sampling should redress this imbalance, since all stands will eventually take part in production and this must be considered in the calculation of sustainable yield. The distribution of regrowth plots to stands needs to be done in proportion to resource area, with some modification if necessary to achieve similar precision for measurements in different strata. This allocation of plots to strata cannot be done until a detailed area statement for the regrowth resource has been prepared. It is currently assumed that, because regeneration is usually successful, logged area is equal to new regrowth area. This may or may not be an accurate assumption.*

Quality of baseline inventory information provided by the regrowth inventory

In this context, 'baseline inventory information' is interpreted to mean data that is necessary for predicting the development of regrowth and estimating merchantable outturn from it for a minimum of one rotation. This will provide data to determine how long the MAF resource needs to last before production from the resource can be reliably provided from regrowth stands.

To meet this criteria, inventory plots need to be established in appropriate strata, as described above, and the plot measurement techniques need to provide appropriate and reliable data.

It is difficult to quantify the effect on data reliability that the shortcomings outlined above will cause. Because the methodology has not been clearly specified, operators have the latitude to develop their own techniques that may or may not be appropriate (it is not suggested that they <u>have</u>*, merely that it is* <u>unknown</u>*). An assessment carried out with trialed and documented methods will have greater precision, but it is impossible to say how much greater. With the qualifications* *expressed above, subsets of the existing data set are suitable for use, provided they are supplemented with new data that is representative of currently unsampled strata. The existing data can be reallocated to any new API stratification that is developed for the resource as a whole.*

3.2 RETAINED TREE INVENTORY

Retained tree inventory

Project No. NE/11 FRA

3.2.1 Project objectives

Timber harvesting during some periods has resulted in significant numbers of trees left standing in harvested coupes to provide seed trees, fauna habitat and some future sawlogs. Retained trees can affect future yields in that:

- some future sawlog volumes may be available from previously retained trees; and
- there may be an impact on regrowth growth rates.

3.2.2 Methods

This project involved capturing the harvesting prescriptions which related to each harvesting event.

As the records in compartment histories often give only a general description of what was retained and not an actual figure of how many trees or what volume was retained, the following data was collated and reviewed:

- actual measurements from compartment histories and Permanent Growth Plots (PGP) in harvested areas was used to determine the stocking rate and basal area of trees retained after harvesting;
- Post logging surveys carried out in the past. These have been:
  1. Regeneration surveys. These surveys focussed on the stocking levels of regeneration. Some of these surveys included a basal area sweep for a measure of retained trees. There were about 560 coupes that fell into this category, they covered the logging years from 1972 to 1996.
  2. Specific retained tree surveys. Due to the various objectives of the surveys at the time, different parameters were measured. About 100 coupes were measured, 25 with stocking of retained trees only and 75 with basal area measured. The logging year covered ranged from 1977-1996.
  3. As part of the IFA, field validation of a small number of coupes for retained trees was carried out. All retained trees were measured with stocking, basal area and volume recorded.

3.2.3 Results

After the data had been collated, there was not a measure of statistical significance through time to be able to provide a statistically valid measure of retained trees for each logging year. However, the descriptions of harvesting prescriptions combined with actual measures of tree retention provided a trend in harvesting events. These trends show an increase in tree retention rates over time.

Retained tree rates were derived from different sources: actual basal area measurement from inventory, actual number per hectare from inventory, or retained tree prescriptions applied to the stand and assumed to be implemented. The retained tree rates were entered into the Eden FRAMES database (refer Section 5.1).

In the conclusions of the IFA retained sawlog report (refer Appendix 3) it states that future sawlog trees were only retained in any large way for areas logged during the period from the mid 1980s to 1990. The analysis of the retained tree data showed that retained basal area for this period varied from 3 to 8m^2/ha. For the period 1990 to 1996 the range was also 4 to 8m^2/ha. These figures add weight to the conclusion that trees retained at the time of logging would be required to meet current and future prescriptions.

Therefore, previously retained trees are likely to be required for ongoing habitat, thus are unable to significantly contribute to sawlog volume during future harvesting operations.

The impact of retained trees on regrowth growth rates is dealt with in the discussion of STANDSIM (Section 4.1).

3.3 DEVELOPMENT OF NET HARVESTABLE AREA

Future Net Harvestable Area
Project No. NE/12 FRA

3.3.1 Project objectives

The objective of this project was to develop a quantitative and repeatable assessment of the net area available for harvesting under current prescriptions at the coupe level and across the Eden CRA Region.

This assessment was required to convert gross harvestable area into net harvestable area so that future yields from thinning and harvesting operations could be predicted. The project also allows for an assessment of the variation that future management prescriptions might cause to the net harvestable area.

3.3.2 Methods

The net harvestable area project generated a digital layer of areas available/unavailable for harvesting within State forests under current management prescriptions. The following sections describe the method used.

3.3.3 Identification of exclusions from harvesting

In order to determine the net harvestable area, the area of forest in which harvesting is excluded was specified and mapped. The following data layers and attributes were used to generate the net area available for harvesting under current prescriptions.

These exclusions constitute ‘hard exclusions’ to harvesting (ie those exclusion areas that can be readily mapped); ‘soft exclusions’ (exclusion areas that cannot be easily mapped) include additional areas for soil and water protection that do not show on maps of the area.

PMP

Excluded - SFNSW Preferred Management Priority (PMP) categories:

- 1.1.2 - Special Emphasis (Recreation);
- 1.1.7 - Flora and Fauna Protection;
- 1.1.9 - Aboriginal Sites;
- 1.2 - Undeveloped Natural Forest;
- 1.3 - Preserved Natural Forest;
- 3.1 - Cleared; and
- 3.2 - Special Development.

Rainforest and a protective buffer

Excluded - All areas within the NSW National Parks and Wildlife Service (NPWS) ‘FLORISTICS’ coverage where the item SYMBOL contained R or RE; plus a 20 metre buffer.

Rocky area & buffers

Excluded - All areas within the NSW NPWS ‘FLORISTICS’ coverage where the item SYMBOL contained Qb01, WI02, Wr, Ws, Sw01, or Td01; plus a 20 metre buffer where area was between 0.1-0.5 hectares or 40 metre buffer where area was greater than 0.5 hectares.

Swamp (wetlands) & buffers

Excluded - All areas within the NSW NPWS ‘FLORISTICS’ coverage where the item SYMBOL contained Qf01, or Wh01; plus a 10 metre buffer where area was between 0.1-0.5 hectares or 40 metre buffer where area was greater than 0.5 hectares.

Heath & buffers

Excluded - All areas within the NSW NPWS ‘FLORISTICS’ coverage where the item SYMBOL contained Sr01, Sk01, Td02, Td03, Tt01, Tw01, or Tw02; plus a 20 metre buffer where area was between 0.2-0.5 hectares or 40 metre buffer where area was greater than 0.5 hectares.

Slope

Excluded - All areas greater than 30 degrees.

Fauna stream buffers

Excluded - 1:25 000 scale streams were buffered according to Conservation Protocols (29 November, 1996). Buffers on streams depended upon their stream order : first order stream buffer, 10 metres; second order stream buffer, 20 metres; third and greater order stream buffer, 40 metres. Note, only 80% of third and greater order streams are required to have a 40 metre buffer, the remainder may have a 20 metres wide buffer. In this instance, a 40 metre buffer was applied to all third and greater order streams.

PCL stream buffers

Excluded - As per the *Pollution Control Act 1970*. See Section 3.3.4 for a description of the method.

Erosion hazard category 4

Excluded - All area of hazard category 4 were excluded from harvesting.

3.3.4 Derivation of erosion hazard categories and stream buffers

Soil regolith stability

1:100 000 mapscale soil landscapes units were available for the Craigie and Bega mapsheets. For areas outside these two mapsheets, dominant lithology was used to define soil landscape units consistent with the Bega and Craigie mapsheets. Each soil landscape was reclassified by the Department of Land and Water Conservation (DLWC) into soil regolith cohesion and soil regolith sediment delivery potential according to "Soil erosion and water pollution hazard assessment for logging operations" (EPA / SF NSW / DLWC, August, 1997).

Slope

Slope was calculated from the 1:25 000 Digital Elevation Model (DEM).

Rainfall erosivity

A rainfall erosivity surface was provided by DLWC according to Rosewell and Turner (1992)

Calculation of erosion hazard for each compartment

- Slope, rainfall erosivity and soil regolith stability grids were overlayed and classified according to "Soil erosion and water pollution hazard assessment for logging operations" (EPA/SFNSW/DLWC, August, 1997) in order to obtain a hazard class on a cell by cell basis. A hazard class was then calculated for each compartment based on the proportions of each hazard category.
- Compartment level hazard classes were then overlayed with streams attributed with their stream order and specific catchment area in order to reclassify the hazard class according to a threshold of 100 hectares.
- Using rules defined by the Pollution Control Act (1970) streams were differentially buffered according to the compartments hazard class, stream order and specific catchment area.

The above data allows determination of the impact of changes in prescriptions or moratorium areas on available areas for harvesting.

3.3.5 Results

An accredited fully documented geographic information system (GIS) database was generated at 1:25 000 scale. The above exclusions were combined within the GIS to produce the following outputs:

- a combined coverage including all harvesting exclusions;
- a binary coverage of Net Harvestable Area;
- database tables summarising the area of each exclusion on a coupe by coupe basis according to current prescriptions; tabular summaries were also generated for the whole CRA Region (Table 3a); and
- database tables summarising the cumulative increase in excluded area per prescriptive exclusion on a coupe by coupe basis.

It should be noted that Fauna Moratorium Areas were not included in calculations.

Current net harvestable area without excluding fauna moratorium areas was calculated as around 75% of the total State forest area. The areas of exclusion are as follows in Table 3a.

TABLE 3A: EXCLUSIONS IN THE EDEN CRA REGION

Exclusions	Area	Cumulative Area	
	(hectares)	(hectares)*	(%)
Preferred Management Priority	22 914	22 914	11.56
Rainforest and buffers	5 061	26 731	13.49
Rocky areas and buffers	2 122	27 711	13.99

Exclusions	Area	Cumulative Area	
	(hectares)	(hectares)*	(%)
Swamp (wetlands) and buffers	754	28 320	14.29
Heath and buffers	2 166	29 590	14.93
Slope>30°	3 456	31 746	16.02
Fauna stream buffers	14 350	40 987	20.69
Pollution control stream buffers	16 804	44 416	22.42
High erosion risk	5 236	45 493	22.96

* Due to overlap of areas these figures are not simply a sum of exclusion areas.

A table of net harvestable area was generated from the GIS layers. The net harvestable area information was entered into the Eden FRAMES database (see Section 5.1).

The net harvestable area model used to derive the net harvestable area layer can be used to recalculate net harvestable area under alternative area based prescriptive exclusions.

3.4 SITE PRODUCTIVITY INDEX

Development of a Site Productivity Index for Eden

Project No. NE/13 FRA

3.4.1 Project objectives

The site productivity index for Eden aimed to develop a quantitative and repeatable site productivity index that would identify the potential productivity of the regrowth forest for growth modelling.

It sought to provide a mechanism to quantify variability in relation to productivity within compartments in order to more accurately assess the impacts current or future prescriptions may have on potential yields.

3.4.2 Methods

The project was based around the mapping of environmental factors that contribute to forest growth. These factors were broadly: nutrients, moisture, temperature and light.

The project was split into three components:

- The development of the generalised site productivity index (GSPI) which incorporated monthly radiation, rainfall, evaporation, minimum temperature, and topographic position.
- The re-classification of forest types into yield associations.
- The development of a low, average and high mean annual increment for each yield association. These were qualitative estimates based on limited plot data.

Within each yield association, the GSPI was then normalised to assign a low, average or high mean annual increment (MAI) by reclassifying the frequency distribution into three equal interval classes. This generally resulted in exposed northerly aspects and ridges being assigned a lower MAI and sheltered southern aspects and gullies being assigned a higher MAI. A weighted average MAI was calculated for each coupe, based on the area of each MAI class within the coupe.

MAIs ranged from $2m^3$/ha/yr to $12m^3$/ha/yr. These MAIs were converted to an index between 0 and 1.2, with an index of 1 equivalent to $12m^3$/ha/yr. Based on a combination of inventory and research data providing MAI and site productivity estimates at known locations, the index was split into classes as follows:

- for fire regrowth, two site productivity strata were identified, comprising ≤0.6 and >0.6 index values;
- for logging regrowth, three site productivity strata were identified, comprising <0.5, 0.5-0.7 and >0.7 index values.

These site productivity indices (SPI) are used in the stratification set out in Table 4a.

3.4.3 Results

The project produced a SPI for each coupe and regrowth forests were stratified using this SPI value, whether the regrowth was derived from harvesting or fire and whether the coupe was located within the coastal or tablelands part of the management area..

Different STANDSIM yield tables applied to each stratum. The stratum for each coupe was included in the Eden FRAMES database (Section 5.1). Yield information was passed to the yield estimating and scheduling toolbox (see Section 5.2)

This dataset has not been validated through field checking and is only an interim dataset.

3.5 SAWLOG SPECIES MIX

Sawlog Species Mix
Project No: NE 20/FRA

3.5.1 Project objectives

The objective of the project was to determine, for the multi-aged forest, proportions of species and size class within each compartment and coupe.

3.5.2 Methods

The method used in this project was as follows:

- Sawlog volumes since 1979 were extracted from State Forests' sales systems (FORSALE and FORPRAC) by compartment, species and diameter classes. Some data prior to this date was available from paper records.
- For compartments with the alternate coupe harvested, the percentage of species of the total coupe volume was calculated. These percentages were included in the Eden FRAMES database (refer Section 5.1) and applied to the predicted total volumes (refer Section 3.1).
- For compartments with the alternate coupes not harvested (approximately 15% of compartments), the percentage of species of the management section's total volume was calculated. These percentages were included in the Eden FRAMES database (refer Section 5.1) and applied to the predicted total volumes (refer Section 3.1).
- For diameter classes, the percentage diameter classes were calculated for each management section. These percentages were included in the Eden FRAMES database (refer Section 5.1) and applied to the predicted total volumes (refer Section 3.1).

3.5.3 Results

The expected species and size class sawlog percentages for each coupe were included in the Eden FRAMES database (refer Section 5.1). This data enables volume information to be subdivided into species and indicates the volume of the species and size class of sawlogs that have value-adding potential (refer to Table 6b).

4. MODEL DEVELOPMENT AND APPLICATION

4.1 GROWTH AND YIELD MODEL

Growth modelling
Project No: NE 14/FRA

4.1.1 Project objectives

The objective of this project was to develop growth and yield models for regrowth stands regenerated from harvesting and/or fire in the Eden CRA Region. The project also aimed to test the model using growth data from permanent or temporary growth plots measured in the Eden CRA Region and modify the model further if necessary.

4.1.2 Methods and Results

It was assumed that the multi-aged forest resource has a zero net growth in quota sawlogs, as any growth is offset by decline (this has been verified by a small scale study undertaken by SFNSW (Jurskis and Hudson, 1994; refer Appendix 4).

For the regrowth resource, estimation of growth rates (by developing growth models based on actual forest growth) was required to estimate future yields of wood products from the regrowth component of the forest. STANDSIM, a stand simulator developed for Victorian stands of *Eucalyptus sieberi* (Silvertop Ash), and other species, was modified and adopted for use in the Eden CRA Region.

Data for growth models are drawn from Research Growth Plots (RGPs). RGPs are plots in which all trees are permanently identified and are subject to remeasurement, usually every five years. RGPs (and Permanent Growth Plots elsewhere in the state) are designed to enable prediction of growth rates under normal forest conditions (refer to Bi, Chikumbo and Jurskis, unpublished (Appendix 6) for details of how this data was used).

This other plot data used in Eden was inventory plot data for regrowth stands. This inventory is detailed in Section 3.1.2. The inventory data was classified into strata based on:

- regrowth type (ie fire or logging regrowth);
- site productivity (refer Section 3.4);
- location (ie cost or tablelands); and
- thinning history.

Within each of these strata, inventory data was analysed to derive input parameters for STANDSIM. These parameters were stocking information, basal area, site productivity index and age.

The uses of this RGP and inventory data in model development are noted in the following text in italics which has been extracted from the report “Modification of the STANDSIM model for the Eden Management Area” Forest Essentials Pty Ltd, 1997b report (refer Appendix 5)

4.1.3 Review of the STANDSIM model

STANDSIM is a deterministic FORTRAN coded growth simulation model originally designed (Opie 1972) for evenaged, single species stands (it has since been modified to accommodate two aged stands). It is unnecessary to specify the arrangement of trees, making it possible to use standard inventory information as inputs to the model, although to make this possible, it is assumed that tree spacing is reasonably even (with the exception of response to strip thinning). The FORTRAN program includes a set of fifteen growth and mensurational functions that apply to one species. The program structure is not species specific, thus to modify the model for a new species, it is only necessary to insert the functions necessary for that species. Functions currently in the model apply to Victorian stands of E. regnans, E. delegatensis, E. nitens and E. sieberi.

The model can simulate growth from age zero, requiring specification of stem stocking and site *index (stand height at age 20). To simulate growth from ages greater than 15, it is necessary to specify stem stocking, site index and standing basal area, or instead of basal area, a distribution of stem diameters. The estimation of growth is most accurate if diameter distributions are specified.*

The model can estimate the consequences of thinning from below or thinning in strips, from age fifteen onwards. For E. sieberi, the effects of four intensities of burning on mortality and stand growth can be estimated.

The conversion of gross bole volume to merchantable product volumes can be simulated by relationships between product cutoff points and tree DBHOB, tree height or product small end diameter and the specification of defect percentage. Maximum and minimum dimensions can be specified for product pieces.

A more detailed description of the model and its operation is given by Incoll (1983).

Refer Appendix 5 for Figure 1 - Maximum height vs age curves for E. sieberi, Eden.

Functions used in the SFNSW model

The functions available for use came from work carried out by the South East Regrowth Forest Growth and Yield Modelling Project (Bi 1994) since 1991, listed as follows:

1. *Single tree volume functions for a range of tablelands and coastal species (Bi undated, probably early 1997). This function, with coefficients for E. sieberi, was used unaltered.*

2. *Taper functions predicting stem diameter at any height on the tree stem. The taper functions described (Bi 1997a) are formulated to estimate diameter at any point on the tree stem as a function of relative height at the desired point and total height. For use in STANDSIM, it is also necessary to estimate height for a nominated diameter on the tree stem. Bi's function could be used iteratively to achieve this, but there was not enough time to code this capability in the current work.*

3. *Tree height as a function of tree diameter for a range of species in tablelands and coastal forests. This function is described in Bi 1997b, but because the functions do not include stand variables, it is unclear whether they are suitable for inclusion in STANDSIM. This will need to be clarified with Dr Bi.*

4. *Maximum tree height/age functions for tablelands forests. This function was not included during the current work because E. sieberi forests were of higher priority.*

5. *Maximum tree height/age functions for coastal forests (Bi et al 1997c)* [refer Appendix 6 of this report]. *This function was used in a modified form. When plotted on the same axes as function 4, the maximum height of E. sieberi between age ten and age 33 was expected to be greater than for tablelands forests, thereafter becoming less again. Additionally, the maximum height at age 20 was expected to be about 33m, considerably in excess of this author's experience in high site quality Orbost stands. The function was therefore modified to provide a maximum height at age 20 of 25m and this function was used in the model. A further reason for modifying this function is that the variable required by STANDSIM is mean dominant height, not the maximum tree height provided by Bi's function. The relationship between maximum and mean dominant height is unclear, but mean dominant height would be expected to be less than maximum height, as in the modified function. The functions concerned are shown on Figure 1, including the Victorian function (for a site index of 25m).*

6. *Total stocking as a function of age and overwood stocking for tablelands forests. This function was not included during the current work because E. sieberi forests were of higher priority.*

7. *Stocking of upper canopy trees as a function of age, overwood stocking and site productivity index for coastal forests (Bi et al 1997c). This function was inserted unchanged in the model, but was subsequently modified as a result of test runs (see later).*

8. *Stand volume of age, site productivity index, overwood stocking, and regrowth*

stocking for tablelands for tablelands forests. This function was not included during the current work because <u>*E. sieberi*</u> *forests were of higher priority.*

9. *Stand volume as a function of age, site productivity index, overwood stocking, and regrowth stocking for coastal forests. This function was not necessary since STANDSIM requires a single tree volume table, provided as function 1 above.*
10. *Stand basal area as a function of age, site productivity index and overwood stocking and mean annual increment of basal area as a function of the same variables. STANDSIM requires a function estimating current annual increment of gross basal area, thus this function was not appropriate.*
11. *Current annual increment of stand volume as a function of age, site productivity index and overwood stocking for tablelands forests. This function was not included during the current work because* <u>*E .sieberi*</u> *forests were of higher priority.*

The functions described above were inserted in the STANDSIM source program, SSIMNU.FOR. Comments have been inserted in the source code where alterations have been made and these can be located by searching on part or whole of the line:

"C <u>*E. sieberi*</u> *SFNSW aug97"*

Testing the Modified program

Inserting functions

Testing of the single tree volume function was carried out externally to the STANDSIM model. A series of DBHOB classes and their estimated tree heights were obtained from a typical fire regrowth STANDSIM run. Volumes were calculated for the sets of diameters and heights using the Victorian and Eden functions. The difference between the estimates was expressed as a percentage of the Eden estimate. Figure 2 [refer Appendix 5 for Table 2 – Comparison of Victoria and Eden volume tables] *shows the results of this comparison, with the percentage difference plotted against $DBHOB^2$*Height. The figure shows that the differences are appreciable for small, short trees, but fall below 5% when D^2H is greater than 10,000 (ie DBHOB about 14 cm) and less than 2% when D^2H is greater than 22,000 (DBHOB about 22 cm). The differences should not be regarded as an error in either function, since the trees may well be different shapes. Whatever the source of the differences, they are regarded as unimportant for the purposes of estimating yields of merchantable material.*

Further testing was carried out following the insertion of each function into the STANDSIM model and the effects evaluated by comparison with runs of an unaltered version of STANDSIM. The model was run using an initial stocking of l0,000 trees/hectare at age 5, with a site index of 20m, equivalent to a stand productivity index of 0.6. Functions were inserted as follows.

1. The height age function. Figure 3 [refer Appendix 5 for Figure 3 – Effect of replacing height age and volume function on gross bole volume prediction] *indicates the gross bole volume (gbv) estimated by the two different STANDSIM models. The figure shows that differences are minor until about age 50, when gbv for the Eden model has fallen about 10% behind. By age 80, the difference is about 20%. These differences approximate the differences in stand height, see Figure l.*

2. The maximum stocking function. Figure 4 [refer Appendix 5 for Figure 4 – Effect of replacing height age, volume and maximum stocking functions on simulation of gross bole volume prediction] *indicates the gross bole volume (gbv) estimated by the two different STANDSIM models. The figure shows that differences now remain minor throughout the age range simulated. However, when the stem stocking predictions are examined (Figure 5)* [refer Appendix 5 for Figure 5 – Effect of replacing maximum stocking functions on stem stocking predictions], *it is apparent that the Eden function results in very heavy mortality up to age 20, followed by very little subsequent mortality. This seems an anomalous situation, since regrowth stands in the real world can be observed to have continuing mortality well past age 20. Various modifications to the Eden model were tried without changing the situation much and eventually a different model form was used, resulting in a function intermediate in shape between the Eden and Victorian models. The model used was:*

$$N = 25000\,(1-e^{(-4.7*spi/age)})$$

where

N = maximum stocking, stems per hectare from inventory data as specified above

spi = site productivity index from Section 3.4

age = stand age in years recorded as starting age for regrowth type

This model resulted in prediction of stem stockings intermediate between the two curves shown in Figure 5.

Testing with temporary plot data

While data from permanent plots were being prepared) the model was tested against the available temporary plot data by running the model from typical initial stem stockings through to ages similar to the temporary plots The simulated volumes were then compared with the volumes on the temporary plots. When this was done simulation of typical fire regrowth stockings (5,000 stems/ha) produced standing gross bole volumes within the top half of the spread of temporary plot standing volumes at age 45. This is considered a sensible result, considering that most real world stands will have been burnt several times severely enough to have retarded their growth rates. Time was not available to investigate the effects of burning in the simulation runs, although the model could have accommodated this. Simulation of the growth of logging regrowth (initial stocking 1,000 stems/ha) resulted in higher standing volumes at age 45, and although there were no temporary plot data of this age resulting from logging, it seems sensible that the lower density (but still fully stocked) logging regrowth stands would produce higher volumes than fire regrowth.

Testing with permanent plot data - stand variables only

The STANDSIM model was initially tested using data from a report describing the response to a range of early thinning for a series of plots in the Mumbulla State Forest. Input data (stem stocking and standing basal area) were obtained from the report for stem stocking at age four. The simulation was then run from age four to age 28, the last age for which data were given in the report. Diameter distributions were not given in the report, making the simulation task less likely to be accurate, and the unthinned plots were of restricted area.

The estimates made by the STANDSIM model considerably underestimated growth in the real world, probably because the functions estimating basal area at age 15 and the corresponding diameter distributions are inappropriate for the test material. The (Victorian) function estimating basal area at age fifteen was modified in an attempt to correct this problem, but there was insufficient time available in the present study to complete the modifications.

The model must therefore be regarded as currently unreliable in estimating growth for understocked stands from initial ages before fifteen years.

Testing with permanent plot data - diameter distributions

The model was used to estimate growth between the initial and final measurements of the commercial thinning trial in East Boyd State Forest (trial L374). The trial included six unthinned plots and six plots thinned from below. These two sets of plots were pooled to provide composite thinned and unthinned sample plots, each 0.36 ha in area. The growth of the unthinned plots was simulated from age 25 to 36 and the thinned plots from age 27 to 36. The factor of most interest was how accurately the model would simulate the final diameter distributions and this is illustrated in Figures 6 and 7 [refer Appendix 5 for Figure 6 – Simulation of growth on unthinned plots trial L374 and Figure 7 – Simulation of growth on thinned plots, trial L374] *for the unthinned and thinned plots respectively.*

Figure 6 indicates that the simulation of growth on unthinned plots has been reasonably successful. However, for thinned plots, the growth of small trees appears to have been underestimated in that the simulated distribution has more small trees than the actual stand. The simulated stand also has more live trees than the real stand, so it may also be that mortality has been underestimated. While the accuracy of the model in this area can be improved by further work, the conservative nature of the inaccuracy means that the model can still be effectively used in its current state for the current planning exercise.

Future modifications

Further work is necessary on the model to refine the simulation of growth and mortality to better reflect real world observations. This work was not possible in the current study because of time restrictions. Testing also needs to be extended to include the other permanent plot data available.

Further modifications, when carried out, need to be inserted into the source program, compiled and the object code renamed SSIMCORE.EXE. This file should be used to replace the current file of the same name in the STANDSIM directory. The program STANDSIM.EXE calls SSIMCORE.EXE as necessary to carry out simulations designed by the user.

The database (refer Section 5.1) classifies all regrowth into strata by:

- regrowth type (ie fire or harvesting regrowth);
- site productivity (refer Section 3.4); and
- location (ie coast or tablelands).

The STANDSIM growth model uses site index as an input parameter. This site index relates to the stand height at age 20. Analysis of research plots in coastal regrowth had shown that a medium to high site productivity index had a STANDSIM site index of 17. Thus, the site productivity index values were converted to STANDSIM site indices ranging from 13 to 22. The upper index of 22 was applied to high site productivity index tablelands areas following discussions with Bill Incoll (Forest Essentials Pty, Ltd).

The results of the stratification of regrowth areas are shown in Table 4a.

TABLE 4A: STRATIFICATION OF REGROWTH AREAS

Strata	Regrowth Type	Site Product-ivity Index	STANDSIM Site Index**	Location
1	Fire	≤0.6	13	Coast
2*	Fire	>0.6	17	Coast
3*	Fire	>0.6	17	Coast
4	Logging	0.5-0.7	16	Coast
5	Logging	>0.7	18	Coast
6	Fire	Thinned	17	Coast
7	Fire	≤0.6	13	Coast
8	Fire	>0.6	17	Coast
9	Logging	<0.5	13	Coast
10	Logging	<0.5	15	Tablelands
11	Logging	0.5-0.7	18	Tablelands
12	Logging	>0.7	22	Tablelands
13	Fire	Thinned	18	Tablelands

* These strata are separated because inventory information shows a significant difference between these strata and they are related to two different fire events.

For each stratum, a yield table is generated by STANDSIM which predicts the volume by product by predicted year of harvest for each regrowth coupe. The yield tables are provided in Table 4b.

TABLE 4B: STANDSIM PREDICTED YIELD TABLES

Stratum	Operation	Age	Sawlogs (m^3/ha)	Pulpwood (t/ha)
1	t1	35	0	100
1	t2	50	5	80
1	rh2	70	50	120
2	t1	30	0	100
2	t2	45	5	80
2	rh2	70	60	100
3	t1	32	0	120
3	t2	45	10	80
3	rh2	65	60	100
4	t1	35	0	100
4	t2	45	10	70
4	rh2	70	50	100
5	t1	30	0	100
5	t2	40	15	65
5	rh2	60	60	100
6	rh2	67	50	100
7	t1	47	2	90
7	rh2	68	50	100
8	t1	46	5	105
8	rh2	68	60	100
9	t1	40	0	100
9	rh2	70	50	100
10	t1	35	0	120
10	t2	50	10	70
10	rh2	70	60	130
11	t1	30	0	110
11	t2	45	12	70
11	rh2	70	70	160
12	t1	25	0	100
12	t2	40	15	80
12	rh2	60	70	170
13	rh2	66	75	150

Note: t1 means first thinning, t2 means second thinning, rh2 means regeneration harvest.

4.1.4 Conclusion

The independent expert (Forest Essentials 1997b) recognised that STANDSIM, as modified, was most suitable for the *E. sieberi* dominated stands in the Eden CRA Region and would produce less accurate, but estimated as conservative outputs (particularly when yield tables were varied by site productivity class) for other forest types.

The available plot data gives a reasonable coverage of age and thinning response in fire regrowth stands and of age in harvesting regrowth stands.

The limited time available for work meant that:

- functions for tablelands species have not been included;
- taper functions have not been included;
- the model underestimates growth for understocked stands younger than fifteen years of age; and
- estimation of growth in stands thinned after age fifteen is conservative.

Despite these shortcomings, the project has produced a growth model that can be used to provide conservatively based yield tables for use in the yield scheduler (see Section 5.2) for the period up to around 2040. This will allow an estimation of sustained yield for the CRA/RFA process.

Further work is recommended to improve the accuracy of the model and to fully utilise the SFNSW research programs in progress in the Eden CRA Region.

4.2 MODIFIER MODELS

Development of Modifier Models

Project No: NE 15/FRA

4.2.1 Project objectives

This project aimed to develop a suite of modifier models that would take into account the effects of thinning of the regrowth forest, and other forest management practices that could affect growth and future yields in all forest types.

4.2.2 Methods

The development of a range of modifier models as outlined in the project objectives is dependent on the availability of a range of data from trials covering the proposed modifications. For regrowth forest in Eden (and elsewhere) this data is limited. As a result a conservative approach was used, which included testing against available data.

STANDSIM (which included growth models as adopted for Eden) has the ability to evaluate yields from various thinning regimes for the stands. The input parameters for STANDSIM as described in Section 4.1.2 were used for the strata described in Table 4a. The input parameters were derived by analysis of inventory plot data and estimation based on experience and a stocking prediction function (Bi, 1994 and 1997).

STANDSIM was then run and yield tables determined for commercial thinning(s) from below of each of the strata.

The data limitations outlined above precluded consideration of management intensification practices such as fertilising and the impacts of fire regimes on sawlog yields.

4.2.3 Results

The input parameters to STANDSIM were varied to investigate the possible effects of different initial stockings and fire regimes. STANDSIM does not provide for this easily; the model does estimate the effects of fire on growth, but fires cannot be included in runs that also include production thinnings.

STANDSIM simulated sawlog production in the range of 150 to 200m^3/ha at final harvest at age 70, based on the scheduled commercial thinning regimes for each stratum. Experience at Eden and elsewhere led to the conclusion that these results were unrealistic.

Further, increasing the initial stocking or simulating a wildfire could also reduce sawlog prediction at final harvest at age 70. Given the above, the output yields from STANDSIM were modified to adopt sawlog volumes of 50 to 75 m^3/ha at final rotation that were conservative. It is felt that these estimates are acceptable for the current process that requires estimation of sawlog production in a defensibly conservative manner (B. Incoll pers comm.).

5. DATA COMPILATION AND ANALYSIS

5.1 COMPILE AND DOCUMENT DATABASE

Compilation and Documentation of the Database
Project No: NE 10/FRA

5.1.1 Project objectives

The aim of this project was to collate the spatial and tabular data on the resource so that it could be utilised by growth and yield models and integration projects.

5.1.2 Methods

This project collated the outputs from other projects; resource data (Section 3.1), retained tree information (Section 3.2), net harvestable area (Section 3.3), site productivity (Section 3.4) and available volumes by species (Section 3.5).

The collected data was compiled into a Microsoft Access © database.

5.1.3 Results

Multi-aged forest

The database stores:

- the sawlog and pulpwood volume per hectare for each coupe (refer Section 3.1);
- the net harvestable area for each coupe (refer Section 3.3).

This information is then multiplied together to determine the total volume of sawlogs and pulpwood for each coupe. This occurs as part of the yield estimating procedure (refer Section 5.2).

A separate analysis further breaks down the total volume into diameter and species class (refer Section 3.5). Coupes can be amalgamated into management sections for modelling of supply zones.

Regrowth forest

The database classifies all regrowth into strata as described in Section 4.1.3).

Each regrowth coupe was assigned to a stratum. In instances where multi-aged forest coupes had been partially affected by fire, these fire-affected portions of the coupe were assigned to a regrowth stratum.

For each stratum a yield table was generated from STANDSIM (refer Section 4.1.3, Table 4b for the yield tables). The yield tables predict the volume by product for predicted years of harvest.

For example, a coupe that falls within stratum 1 is a 1980 fire regrowth coupe that has lower site productivity and is located on the coast. According to the yield table, this coupe would receive its first thinning at age 35 (ie in 2015) producing a predicted 100 t/ha of pulpwood. The second thinning at age 50 (ie in 2030) is predicted to produce 5 m^3/ha of sawlogs and 80 t/ha of pulpwood. The regeneration harvest at age 70 (ie in 2050) is predicted to produce 50m^3/ha of sawlogs and 120 t/ha of pulpwood.

Net harvestable area and net thinnable area were also derived for each regrowth coupe (refer Section 3.3).

The volume by product by predicted year of harvest for each regrowth coupe was calculated by multiplying the volume per hectare at the predicted time of the operation from the yield table by the net thinnable area of regrowth. This occurs in the yield estimating toolbox (see Section 5.2).

Sampling of the regrowth resource is an ongoing process and plot measurement is continuing so that more detailed information will be available for post RFA reviews.

In summary, sawlog and pulpwood volumes are calculated for all multi-aged coupes and predicted for all regrowth forest coupes. The yield estimating and scheduling toolbox (refer Section 5.2) analyses this data though a set of queries in order to calculate a pattern of harvesting to produce a non-declining annual volume of sawlogs.

Metadata sheets have been prepared for all data.

5.2 YIELD ESTIMATOR AND SCHEDULING TOOLBOX

Development of a yield estimating and scheduling toolbox

Project No: NE 22/FRA

5.2.1 Objectives

The objective of the project was to integrate the forest resource data and growth models into a package which estimated yields from each coupe in the forest and enabled a program of future harvesting to be simulated, with volumes scheduled during each year to ensure a predictable resource supply to wood-based industries during the RFA period.

5.2.2 Methods

Yield estimator

The yield estimation procedure is described in Section 5.1.

As the multi-aged forest is assumed to have zero net sawlog growth, the estimated volumes only require scheduling (ie they are assumed to produce the same volume if harvested now as if harvested in the future).

The regrowth forest uses STANDSIM to estimate yields at various ages and types of operations. This is described in detail in Chapters 4 and 5.

Yield scheduler

The yield scheduler combines the wood flow from the multi-aged forest and regrowth forests (including thinnings) into a nominal annual wood flow.

Multi-aged forest

The multi-aged forest was scheduled to meet requirements until sufficient sawlog volumes become available from the regrowth forests. Initially multi-aged forest coupes were scheduled up to 2019. Each of the uncut multi-aged forest coupes were given a nominal year of harvest following these principles.

1. Dispersion geographically. The number of coupes required for a particular year was proportioned for each Management Section.
2. Dispersion through time. The uncut multi-aged forests coupe were scheduled so the time since logging of the alternate coupes was kept as great as possible, generally greater than 15 years.

Regrowth forest

The regrowth sawlog wood flow for the period 2016 to 2040 is drawn primarily from harvesting of 1952 and 1960s fire regrowth and second thinning of later fire or logging regrowth. These areas are scheduled according to the year wood becomes available from thinning or regeneration harvest according to the yield tables derived from STANDSIM as described in Chapters 4 and 5.

5.2.3 Results

A series of tables were built into the Eden FRAMES Microsoft Access © database. This comprises a set of base data tables and a range of queries to generate the various components of wood flow and to join them together. A description of the sets of queries is provided below:

Multi-aged forest - This query predicts the total sawlog volumes (m^3) and total pulp volumes (t), disaggregated by species and size class, for each unlogged coupe.

Fire regrowth - This query calculates the predicted future sawlog and pulp volumes from areas of regrowth resulting from past wildfire events.

Harvesting regrowth - This query calculates the predicted future sawlog and pulp volumes from areas of regrowth resulting from harvesting events.

Regrowth summary - This query compiles the fire and harvesting regrowth volumes into one table.

Eden CRA Region summary - This query compiles the regrowth and multi-aged forest volumes into one table.

Scenarios - This query excludes coupes and compartments for different scenarios/options and calculates the remaining volumes for each year scheduled by operation type.

A detailed outline of the Eden FRAMES Microsoft Access © database and queries is contained in Appendix 7.

The outputs of the yield scheduling for Eden show:

- when coupes should be/are best harvested in future years;
- expected yield by species, volume and size class for the multi-aged forest;
- volume by products available from the regrowth forest; and

Analysis of the annual flows from the scheduler indicated that wood flows were not even. This uneveness reflects the wildfire and logging history, but particularly of large fires in the years 1952, 1968, 1972 and 1980 that caused significant areas of forest to be converted to regrowth. In particular a large volume of 1952 fire regrowth final sawlog harvest was scheduled in 2020. Peaks of woodflow from both thinning and regeneration harvesting of fire and logging regrowth are not operationally practical as physically harvesting this much volume in any one year is not possible.

An investigation was undertaken to determine the feasibility of bringing forward harvest of the 1952 regrowth. The STANDSIM outputs indicate that at the nominal rotation age of 70, sawlog volume per hectare is increasing rapidly and cutting the stands early will reduce long term sawlog yields. Reducing the rotation age from 70 years would reduce sawlog volume by 5% per year and harvesting earlier than 65 years greatly accelerates this rate of reduction (B.Incoll pers comm.).

For this reason, the minimum rotation age for 1952 regrowth was set at 64 years for those stands that have already received a first thinning and 65 years for stands that will be thinned before the year 2000. This assumption means that there is some guarantee the sawlogs demonstrably exist, rather than needing to develop from a thinning operation has not yet been conducted. These limits mean that the earliest harvest years for 1952 fire regrowth is 2016 for thinned and 2017 for stands currently unthinned.

A smoother has been developed for the purpose of informing FORUM (refer Section 6.1.2), to allocate harvesting years to individual multi-aged forest coupes to provide an indicative “order of working”. This produces a pattern of harvesting each year, which facilitates assessment of how well harvesting has been dispersed geographically and through time within the intent of the alternate coupe harvesting system.

6. OUTPUTS

6.1 KEY OUTPUTS OF EDEN FRAMES

Key outputs of Eden FRAMES are:

- resource data in terms of standing volume and value (the latter via current log price);
- prediction of future yields for multi-aged and regrowth forest; and
- gross and net harvestable areas of forest under specified prescriptions.

6.1.1 Projected volumes

The timber currently available for harvesting is shown in Table 6a. The volumes have been calculated using the current land tenure, and applying current management prescriptions but do not take account of fauna moratorium areas which will be considered as part of the RFA.

There is potential impact from wildfire which was not taken into account in Tables 6a and 6b and applying current management prescriptions. Table 6b shows total harvestable volume for the multi-aged forest by species group and diameter class. This data has been extracted from the Eden FRAMES database.

The FRAMES Technical Committee recognised that the certainty of these estimates varies with time period. The relevant time periods are:

- From 1997 to 2019 estimated yields are drawn primarily from the multi-aged forest;
- From 2020 to 2040 estimated yields are largely drawn from fire regrowth and thinning of logging regrowth.

There are many uncertainties in estimating timber yields from forests with high inherent variability, such as the Eden forests. In considering the scenarios, FRAMES estimates of mean sawlog yields per hectare from the multi-aged forest for the period 1997-2020 have confidence limits of +/- 30%. Although some of this variability cancels out as compartments are aggregated to produce an annual yield, that annual yield may still have reasonably wide confidence limits. There is some uncertainty regarding areas and growth rates for regrowth stands harvested up to 2040 and no confidence limits can be assigned.

Beyond 2040 estimated yields are drawn primarily from logging regrowth which has not been well sampled. Estimates are indicative only.

Based on this information allowable cut calculations can be estimated for the current planning horizon (Forest Essentials Pty Ltd 1997b).

6.1.2 Integration and development of scenarios for Eden

As various scenarios were developed during the integration phase of the CRA process, Eden FRAMES was used to predict the sawlog and pulpwood yields during the periods 1997 - 2019 and 2020 - 2040, for the areas of forest available for harvesting and for the then current prescriptions. These outcomes are provided in relation to each of the scenarios.

Further analysis was applied to the FRAMES data by the ESFM Technical Committee to simulate changes to forest management practices for particular scenarios. These are reported for each scenario in the reports “Towards an RFA for Eden” and in ESFM project reports (Project Area 5: Management Options and Scenarios to Generate ESFM Targets for the Eden RFA).

For each scenario developed in the integration phase of the CRA process, the breakdown of volume shown in Table 6b was generated, by location within the Eden CRA Region and for each year of supply, and was supplemented by volume of regrowth sawlogs and pulpwood. This data was then provided to the Economic and Social Technical Committee for use in the Forest Resource Use Model (FORUM), to allow economic modelling of wood based production to be carried out.

Alternative conservation protocols were considered after integration for various scenarios. These will impact on available volumes and are discussed in the report “Towards an RFA for Eden”.

TABLE 6a ANNUAL WOOD RESOURCE VOLUMES FROM NATIVE STATE FORESTS IN THE EDEN CRA REGION

Period	Current land tenure including any areas from which harvesting has been deferred	
	Sawlog[1] (m^3) per annum	Pulp[1] (t) per annum
1997-2019	28 300	403 000
2020-2040	28 300	444 000
2040+	>30 000	~500 000

[1] From the multi-aged forest and regrowth, including thinning

TABLE 6b: TOTAL PREDICTED HARVESTABLE VOLUME (m^3) FROM THE MULTI-AGED FOREST BY SPECIES AND DIAMETER CLASS

	Sawlog diameter class (centre diameter under bark)	
Species Group	**<40 cm (m^3)**	**≥40 cm (m^3)**
Silvertop Ash	10 000	134 000
Stringybarks	15 000	149 000
Messmate	3 000	56 000
Spotted Gum	3 000	12 000
Monkey Gum	5 000	68 000
Tablelands spp[1]	3 000	64 000
Specials[2]	1 000	3 000
Other	3 000	26 000

[1] Mountain gum, brown barrel, shining gum, manna gum
[2] Grey box, grey gum, ironbark, white box

6.2 AFTER THE REGIONAL FOREST AGREEMENT

A number of issues are not likely to be addressed before the Eden RFA will be signed. The issues mainly affect parts of the resource which would only become available for sawlog harvesting beyond around 2040 and include:

- large parts of the regrowth resource (mainly logging regrowth) have not had adequate plot data collected to enable estimation of current stand variables;
- an objective statistical basis for growth predictions for logging regrowth needs to be developed;
- information on the growth of non-silvertop ash dominated State forests is very limited.
- the level of defect in regrowth sawlogs from fire and logging regrowth needs to be better understood;
- thinning and regrowth models need further refinement.

The FRAMES Technical Committee therefore considers that the data available beyond around 2040 is not adequate to define the progressive levels of sawlog yield that are available beyond 2040.

Further, the Technical Committee highlights the need for improved inventory and growth information on multi-aged and regrowth forest resources that become available before 2040.

In summary, Eden FRAMES identified a need for more inventory data for future evaluations of the multi-aged and regrowth resource. The FRAMES Technical Committee considers an inventory system is necessary to more accurately predict when fire and logging regrowth will become available as sawlogs. An inventory of multi-aged and regrowth forest needs to be completed by 2001. Initial results of the inventory should be reviewed two years after signing the RFA and the five yearly RFA review should include a detailed review of sustained yield calculations using that inventory.

The FRAMES Technical Committee is of the view that considerable work on strategic inventory, development of growth models and yield scheduling should be continued by State Forests in the years following the signing of the Eden RFA, and should be a requirement of the RFA. In particular, the over-estimation of clearfall volume reported in Section 4.2.3 needs to be resolved in the first five years of the RFA.

Work should be carried out according to principles to be agreed by the Technical Committee. This should be consistent with the general FRAMES structure used elsewhere in the State which includes optimising timber flows within an ESFM framework. A commitment should be made by State Forests to fund this work.

These issues are addressed in more detail in the FRAMES Technical Committee submission to the CRA/RFA Steering Committee immediately prior to negotiation. This submission is attached as Appendix 8.

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APPENDIX 1 – IFA WOOD RESOURCE STUDY SUMMARY

The Interim Forest Assessment (IFA) was a scientific assessment of public forested areas in New South Wales conducted by the Resource and Conservation Assessment Council (RACAC) for the New South Wales Government. The aim of the IFA was to identify, on a regional basis, those forested areas that may need to be deferred from logging because of their possible inclusion in a Comprehensive Adequate and Representative (CAR) reserve system. It was a precautionary measure to avoid excluding conservation options pending a more detailed assessment process (the CRA), while at the same time considering the needs for wood production.

The IFA Wood Resources Study was used to provide an assessment of the various outcomes for deferred forest areas on the ongoing supply of timber to industry.

The objectives of the Wood Resources Study were to:

- define forest characteristics, particularly those relating to forest type and potential for growth and future yield, at the scale of sub-divisions of forest compartments;
- use forest characteristics to define future growth patterns and the options for future yields;
- provide the capacity to attach measures of forestry importance to compartments and sub-compartments;
- develop the capacity to include (sub-) compartments in a deferred forest area and assess the implications of that inclusion on available yields over time;
- incorporate the mapping of disturbance history (originally a separate IFA project); and
- develop the capability to display forest characteristics (both originally measured and subsequently assessed) on a map (either on a computer or printed) (RACAC 1996).

Wood resources database

To enable the potential timber yields of a defined area of forest to be predicted by a computer model, forestry compartments were subdivided into ‘resource units’. Each resource unit was relatively homogeneous in respect of tree species mix, standing harvestable volume and stand structure.

Growth and yield modelling

Growth and yield models were developed and applied to resource units.

The rate of growth for given yield associations between harvests was derived from analysis of permanent growth plot (PGP) monitoring carried out by SFNSW over many decades.

The growth modelling process provided the volume per hectare of high value, low value and pulpwood grade logs. It did not separately predict volume of high value specialty products such as poles, piles and girders. The volume estimations could also be linked to forest types to estimate volume by tree species.

Harvesting options

To enable an assessment to be made of the best pattern and mix of resource units to harvest over time, a range of harvesting options were generated for each resource unit.

This process produced a set of harvesting options for each resource unit which essentially vary the first year in which harvesting could occur and assess the growth and yield from that point onwards.

Value calculation

To calculate the value in commercial terms of a harvesting option, the net present value (NPV) of the set of yields nominated for a given harvesting option was calculated using a seven percent discount rate of return.

Dollar values were attached to each yield over time, with the resulting total returns from harvesting discounted to current dollars to provide a value for each harvest option.

Yield scheduling

A linear programming (LP) model was used to:

- maximise the value of the set of harvesting options selected; and
- ensure that the volume to be harvested in any given year is sustainable.

For each harvesting option a NPV was calculated. The model maximises the sum of NPVs for the harvesting options and resource units harvested each year.

The model was constrained so that the volume of high value logs harvested in any year could not be less than the volume harvested in the previous year. Hence, the volume of high value logs produced over time cannot decline; in other words, the volume available for sale each year is sustainable.

Because the IFA negotiations focused on quota sawlogs, the sustained yield of quota sawlogs was calculated by filtering out quota sawlogs from the model's predicted sustainable yield of high value logs based on historical sales data.

The LP model was not intended to define an 'order of working', even though harvesting years are assigned to each resource unit as an output of the model. The output identified a group of resource units which contribute most to meeting the sustained yield requirements over a specified period. Once a set of compartments or resource units is included in a deferred forest area calculation, a re-run of the model identified new resource units possibly harvested in different years which contribute most to meeting the sustained yield requirements for the period.

APPENDIX 2 - VALIDATION OF EDEN WOOD RESOURCES DATA

APPENDIX 3 – IFA RETAINED TREE REPORT

APPENDIX 4 – GROWTH OF SAWLOGS IN MULTI-AGED FOREST AT EDEN

APPENDIX 5 - MODIFICATION OF THE STANDSIM MODEL FOR THE EDEN MANAGEMENT AREA

APPENDIX 6 – YIELD EQUATIONS FOR REGROWTH FORESTS REGENERATED FROM FIRE ON THE SOUTHEAST COAST OF NSW

APPENDIX 7 – EDEN FRAMES USER GUIDE

APPENDIX 8 – FRAMES SUBMISSION TO CRA/RFA STEERING COMMITTEE