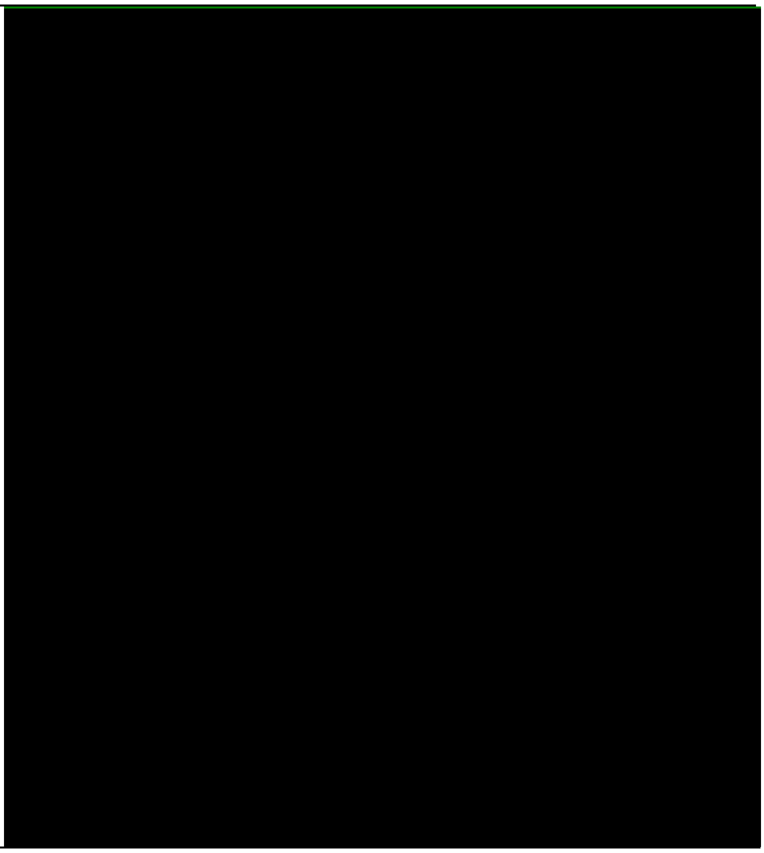
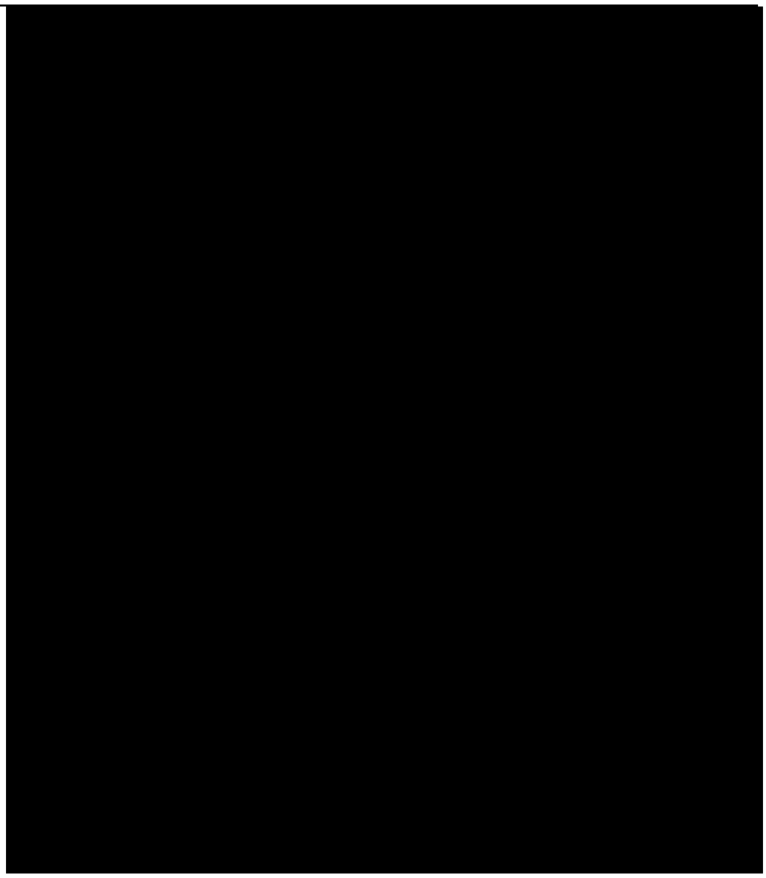


Strategic Yield Scheduler

Upper North East and Lower North East Region

A project undertaken as part of the NSW Comprehensive Regional Assessments

January 2000



STRATEGIC YIELD SCHEDULER

UPPER NORTH EAST AND LOWER NORTH EAST REGIONS

STATE FORESTS OF NSW

A project undertaken for
the Joint Commonwealth NSW Regional Forest Agreement Steering Committee
as part of the
NSW Comprehensive Regional Assessments
project number NA54/FRA

For more information and for information on access to data contact the:

Resource and Conservation Division, Department of Urban Affairs and Planning

GPO Box 3927
SYDNEY NSW 2001

Phone: (02) 9228 3166
Fax: (02) 9228 4967

Forests Taskforce, Department of the Prime Minister and Cabinet

3-5 National Circuit
BARTON ACT 2600

Phone**:** 1800 650 983
Fax: (02) 6271 5511

ISBN 1 74029 055 0

This project has been jointly funded by the New South Wales and Commonwealth Governments and managed through the Resource and Conservation Division, Department of Urban Affairs and Planning, and the Forests Taskforce, Department of the Prime Minister and Cabinet

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

Acknowledgements

The FRAMES Scheduler consists of a large set of interconnected components developed by various parties under the direction of the FRAMES Technical Committee. These components include:

- *Spectrum* software package (developed by USDA FS)
- MPS mathematical programming package
- PERL interpreter
- UNE and LNE *Spectrum* models (developed by BRS and SFNSW)
- external report writers (developed by SFNSW)
- hardwood plantation and native forest yield curve loading systems (developed by SFNSW) and
- net area determination system (developed by SFNSW)

The implementation of the *Spectrum* model component was a joint effort of BRS and SFNSW. The author acknowledges the extensive assistance of Dr Oliver Chikumbo of BRS in building, setting up and testing of the *Spectrum* model for the UNE, and Tom Moore of Spatial Planning Systems contracted to SFNSW. Although the Commonwealth formally withdrew from the process before the model was fully developed, SFNSW greatly appreciated the continued technical assistance and suggestions from Dr Chikumbo on the significant modifications and amendments that were required. During the CRA negotiations SFNSW provided all software installation, stakeholder briefings, training and support related to *Spectrum*, MPS, Perl, and the FRAMES Scheduler.

CONTENTS

PROJECT SUMMARY

This report describes a project undertaken as part of 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 major forest areas of New South Wales. These agreements will determine the future of these forests, providing a balance between conservation and ecologically sustainable use of forest resources.

This project is one of four modules of the Forest Resource and Management Evaluation System (FRAMES), which was the tool used in CRA/RFA negotiations to calculate sustainable wood flows over time.

Project objectives

1. To provide a tool to select from among a range of yields by management strategy (from the FRAMES Yield Simulator) the set of yields that produce sustainable wood flow volumes by quality class, size and species group for a range of management options and a varying resource base. These yields are responsive to the set of environmental protocols applying to the management strategies chosen.
2. To track over time forest values such as proportion by growth stage, to enable assessment of the long term implications of particular silvicultural practices.
3. To develop an effective system that is easy to use, interactive and sufficiently responsive for RFA negotiations.

Methods

A yield scheduling framework was developed to integrate the net harvestable area and predicted yields under alternative management strategies to determine future wood supply forecasts. The framework was built around the linear programming forest yield scheduling model *Spectrum*.

Development of the framework involved 5 broad stages:

1. *Spectrum* model set up and design
2. Development of area and yield input databases
3. Model template construction. This included definition of objectives, management actions and constraints; importing databases, and custom report development.
4. Model testing and validation
5. Development of model input and output linkages and reports. This included the definition, design, formatting, construction of electronic linkages (data flows) between:
    - C-PLAN, ESFM tools, GIS spatial analysis units and net area inputs;
    - Net area and yield simulator models and FRAMES and various outputs;
    - FRAMES and FRAMES reports; and
    - FRAMES and the economic and social model data.

Key results and products

Development of a semi-automated and integrated yield scheduling framework and modelling approach centred on *Spectrum*, which enables the rapid and repeated determination of sustainable wood flows and wood supply capacity under a range of silvicultural options and for varying resource bases.

1. INTRODUCTION

The development of a Regional Forest Agreement for the Upper North East NSW and Lower North East NSW Comprehensive Regional Assessment (CRA) regions was dependent on understanding the currently available wood resources in the regions forests, and the expected yields which can be sustained over time under the proposed conservation reserve designs.

The Forest Resource and Management System (FRAMES) Technical Committee was established to develop the methodology for determining the available wood resource and future yields, and to oversee progress on the work. The objectives of the FRAMES Technical Committee objectives were to:

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

The FRAMES objectives were achieved through 4 primary projects:

- Forest inventory – which provides an assessment of the current resource and data for yield simulation;
- Net harvest area determination – provides an estimate of the productive land area available for utilisation;
- Growth and yield simulation – which provides predicted yields of logs under alternative management strategies; and
- Yield scheduling – the final step in FRAMES which integrates the net harvestable area and predicted yields under alternative management strategies to determine future wood supply forecasts.

The FRAMES Technical Committee recommended the use of a yield scheduling model for determining the long term wood supply from State Forests of NSW' eucalypt native and plantation forests in the Upper North East, Lower North East and Southern CRA regions. The yield scheduling model *Spectrum* was used to determine the sustainable wood flows and wood supply capacity under a range of silvicultural options and for varying resource bases.

The primary focus was to evaluate the impacts of implementing multiple conservation reserve designs on sustainable wood supplies and to converge on management options which maximised conservation targets and satisfied industry wood supply commitments. The wood supply forecasts provided were direct inputs into the socio-economic evaluation models.

This report provides an overview of the yield scheduling approach used for the LNE and UNE CRA.

2. BACKGROUND

Strategic Yield Scheduling is a procedure for determining the long term wood supply and/or cashflow capable of being produced from a forest resource subjected to a wide range of management constraints, and a mechanism for identifying a long term forest management strategy which achieves the desirable wood supply and/or cashflow profile over time. Other non-timber management objectives can also be modelled.

Yield scheduling is normally done using computer based models due to the computational complexity involved in defining the forest characteristics, range of silvicultural options, forest management constraints, the linkages and dependencies between these, together with evaluating and determining the optimal long term forest management strategy.

The objectives of yield scheduling may involve determining one or more of the following:

- strategy which maximise the wood volume (one or more log product volumes) or NPV for a defined period;
- maximum potential wood supply capacity and characteristics independent of wood supply requirements;
- sustainable or non-declining yield;
- capacity to supply at a level necessary to develop or supply existing and proposed market opportunities;
- whether wood supply requirements can be met;
- the way to smooth or regulate the wood supply level and composition at threshold levels to supply markets;
- the most cost-effective way to meet wood supply targets given a range of management constraints and options;
- the impacts of changing constraints on the woodflow or cashflow profile; and
- the impact of changing wood supply requirements on the forest management strategy.

Often during a yield scheduling process, the forest resource is modelled in multiple phases. Initially to determine the wood supply capacity, and then progressively implementing new constraints or modifying constraints, until a satisfactory wood supply target / profile or cashflow is arrived at.

A management strategy determined through yield scheduling typically includes the identification of appropriate silvicultural options for forest areas and the allocation of forest areas to a harvesting sequence in a manner which best meets the management objectives. The management strategy may also involve the formulation of a replanting and/or afforestation schedule in the case of plantations and even-aged natural forests, though typically not for uneven-aged natural forests.

The strategic yield scheduler involves modelling the management of a forest resource base over a long planning horizon (multiple rotations and cutting cycles). Strategic level scheduling involves modelling for a term sufficient to cover multiple rotations or cutting cycles of the forest resource, in order to determine not only that current wood supply targets can be satisfied, but to demonstrate that harvesting is sustainable, or to determine the impacts of low or high levels of cutting in the short to medium term. Much broader and larger forest units and higher levels of forest constraints are used in strategic modelling than an operational level harvest planning model where harvest plans based on small area units and micro-level constraints for the short to medium term are determined.

Management constraints included in strategic level modelling may comprise restrictions on the:

- level and timing of volume harvested;
- log product volume and composition;
- minimum / maximum cashflow levels (revenue and/or expenditure);
- geographical location, spatial distribution and magnitude of the area harvested;
- species or forest type harvested;
- new planting or replanting levels and types;
- permissible silvicultural options;
- rotation or cutting cycle length; and
- non-forest constraints.

The wood volume constraints are typically specified with the requirement to be above a minimum level and not to exceed a maximum level for a defined period(s), or wood production needs to be tightly regulated (smoothed), non-declining or sustainable.

Harvest scheduling computer models are based on mathematical programming techniques due to the computational complexity and size of the modelling problem. Two common techniques are simulation and optimisation.

The simulation approach involves representing the forest resource (characteristics, linkages and dependencies) and modelling the consequences (wood supply level and characteristic, cashflow profile) of a user defined management strategy. Arriving at an acceptable management strategy involves significant trial and error until an acceptable solution is converged on. Simulation has certain advantages over conventional optimisation techniques. The outcomes are more easily understood as the relationships, options and constraints implemented are determined by the modeller; multiple objectives can be monitored; the area units do not need to be highly aggregated so the modelling can be more operationally focussed and spatially presented; soft constraints (permissible degrees of modification of management constraints to represent trade-offs e.g. deviation from budget or production targets, timing of pre-harvest roading construction) can be modelled together with hard constraints (non-modifiable restrictions e.g. permissible silvicultural options, minimum or maximum harvest level); simulation enables the modeller to derive multiple suitable solutions, and to explore practical management options around optimal solutions to derive an appropriate management rather than purely mathematical optimal solution.

Optimisation involves defining the resource, management constraints and the objective. An optimisation based yield scheduler selects the mix of forest management strategies (harvesting timing and intensity, silvicultural alternatives, replant / afforestation levels, timing and characteristics) from among the range of options that best achieves (optimises) the desired objective within the specified constraints. Through various mathematical programming techniques such as linear programming, a strategy can be arrived at which provides an optimal solution i.e. a management strategy which best meets the objective and satisfies the management constraints. This approach enables far more complex interactions, constraints and objectives to be modelled and within a very short turn-around time.

Alternative more sophisticated mathematical programming approaches have been and are being developed. However, for the majority of problems, which exclude detailed spatial interactions and constraints, and are at a strategic rather than operational level of planning, the linear programming approach provides an effective, comparatively inexpensive and easily understood approach.

The scheduling model *Spectrum* used for this process is a linear programming model developed by the USDA Forest Service. This product is designed for strategic level modelling which is compatible with the CRA objectives, and is able to be used to solve different scenarios “turn around” solutions rapidly (say, 30-60 minutes) - the time frame demanded of the process in the CRA negotiations.

3. SPECTRUM MODEL

Spectrum is an LP (linear programming)-based forest planning model used to optimise land allocation and activity and output scheduling for a forest over a specified planning horizon. It includes a data entry system, model manager, matrix generator and report software. A commercial LP package is used to solve the LP matrix generated by *Spectrum*. The matrix generator reads and interprets model data and creates rows and columns for the LP software to solve. The report utilities interprets the LP solution and produces a series of reports and data base files (USDA Forest Service, 1997).

Spectrum capabilities include:

- multiple mathematical programming options to model/simulate management scenarios across landscapes. Capabilities include linear, goal and mixed integer formulations;
- objective functions including MAX/MIN, MIN/MAX, and goal programming. Flexible objective functions for addressing biodiversity issues;
- ability for linear approximation of non-linear relationships (mixed integer formulation);
- temporal resolution for addressing sustainability issues;
- generalised constraint specification capability;
- vegetation mortality and decision tree modelling features; and
- a generalised graphical user interface, relational database entry system, matrix generator and report writer.

Some of the features of the linear programming model *Spectrum* which made it suitable for long term yield scheduling of the SFNSW forest estate include:

- easy to use, interactive and sufficiently responsive for RFA negotiations;

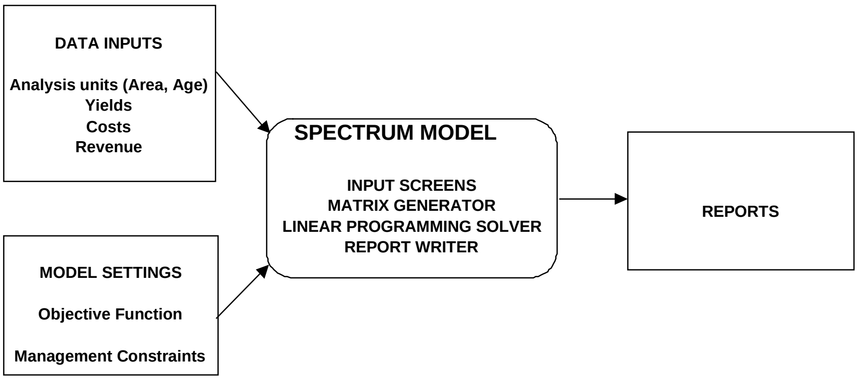
- capacity to model uneven aged native forest and even aged plantation resource;

- ability to determine long term wood supply options from a varying forest resource under a range of silvicultural treatment options and management constraints; and

- low cost. The *Spectrum* model is freely available from the USDA Forest Service (world wide web or direct). The user only needs to purchase a commercial optimisation software package (C-WHIZ was used) required for solving the linear programming matrix generated within *Spectrum*.

Conceptually the yield scheduling process using the *Spectrum* model comprises the components outlined in Figure 3-1. Area and yield data inputs (and financial data if desirable) are imported into the *Spectrum* model via the graphical user interface (GUI). The objective function and constraints are manually selected and defined through the GUI. Spectrum creates a matrix containing the yield data by analysis unit (area units), objective function to be optimised and any associated constraints. The *Spectrum* LP matrix is then processed with a commercial linear programming (LP) solution package (C-WHIZ) and if a feasible solution can be found, the LP package will continue to process the model problem formulated until it is solved i.e. identifies the optimal solution which best meets the objective function and satisfies all of the specified constraints. The *Spectrum* report writer transforms the LP solver output into user customised or standard reports.

FIGURE 3-1: SCHEMATIC DIAGRAM OF SPECTRUM MODEL COMPONENTS AND LINKAGES



4. OVERVIEW OF MODELLING APPROACH AND METHODOLOGY

The application of the yield scheduling model *Spectrum* in FRAMES for the CRA negotiation involved the development of a range of data bases, data transformation and summary reporting scripts, and the formulation of a model template which characterised the forest resource and management practices in NSW. The relationship between the various components of the yield scheduling framework and process are illustrated in Figure 4-1. This process was semi-automated to enable repeated analyses.

The development of the yield scheduling framework involved five broad stages, details of which are discussed in the following sections of this report.

1. Model set up and design

- Set up hardware and software platform
- Identify model formulation
- Identify data input file requirements and structures
- Area and yield database design

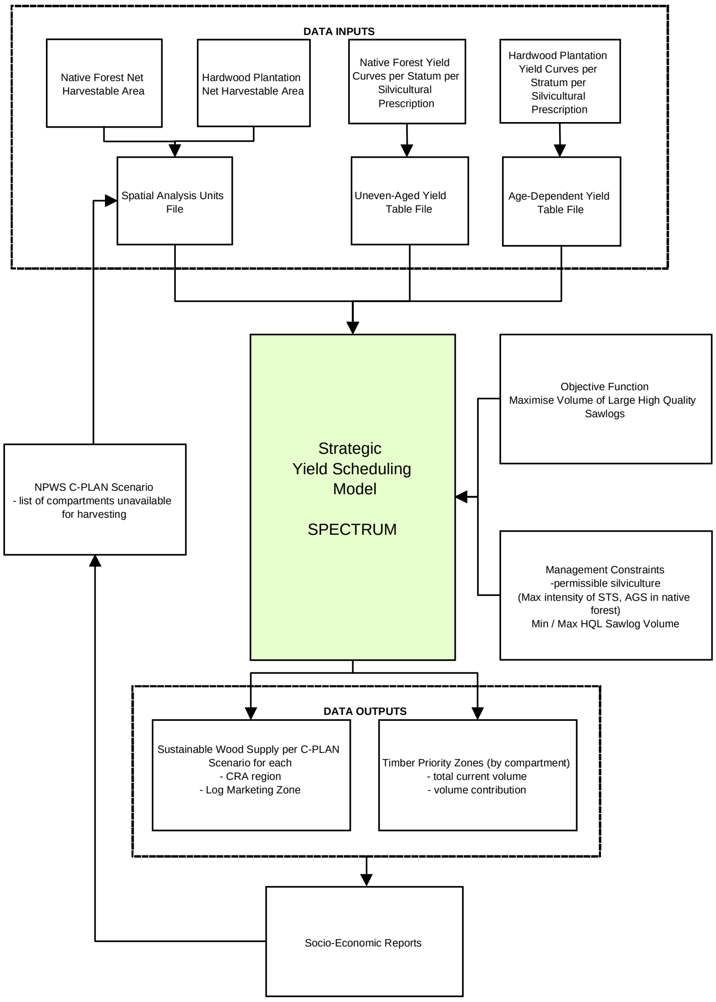
2. Development of input databases

- Land attributes and analysis units
- Yield tables

3. Model construction

- Import of yield tables and net harvestable area data
- Construction of database
- Definition of management actions (activities, outputs, conditions)
- Definition of goals and objective function
- Formulation of matrix
- Solving Problem
- Development of custom reports

FIGURE 4-1: SPECTRUM MODEL FRAMEWORK



4. Model testing and validation

Repeated model runs, changing input variables to test validity of results and sensitivity.

5. Model input and output linkages and reports

Definition, design, formatting, construction of electronic linkages (data flows) between:

- C-PLAN, ESFM tools, GIS spatial analysis units and net area inputs;
- Net area and yield simulator models and FRAMES and various outputs;
- FRAMES and FRAMES reports; and
- FRAMES and the economic and social model data.

5. MODEL INPUT FILE REQUIRMENTS AND STRUCTURE

Two main data inputs are required for the yield scheduler:

- *Area Statements* – the net harvestable area of the forest management units supplied by the ESFM Project 4 and the FRAMES Yield Simulator net harvestable area sub-project; and

- *Yield Tables* – proposed harvest volumes for each stratum supplied by the FRAMES native forest yield simulator project (m^3/ha by 4 products by period for alternative silvicultural options) and from the hardwood plantations growth and yield simulation project (m^3/ha by 4 products by age for existing and subsequent replanting rotations).

The area and yield table file preparation is external to *Spectrum* and is imported as comma delimited files. The following sections outline the structure of the data required, and the methodology used to derive and automate the preparation of these data.

5.1 FORMULATION OF LAND ATTRIBUTES AND AREA STATEMENTS (ANALYSIS UNITS)

5.1.1 Structure of area file

In *Spectrum* the forest land base (area) is defined in terms of analysis units. Layers and attributes are used to define analysis units. The land base was stratified by up to 6 classification variables (“layers”) which describe the land area (location, site capability, forest type, silviculture & management intent). Each classification variable has up to 125 unique values (“attributes”) which break the layer down into meaningful components. Each analysis unit has a unique combination of attributes and is identified with a unique ID number.

The layers used to describe the native forest and plantation estate were:

- Timber Supply Zone (catchment and TSZ combination);
- Uneven-aged forest strata no. (31 forest type / growth stage combinations);
- Forest type (moist or dry native forest; dedicated or undedicated SFNSW plantation);
- Intensity – maximum harvesting intensity permissible in modelling; and
- Hardwood Plantation Strata no. (54 strata reflecting different species, growth and silviculture characteristics. Each strata was subdivided into one or more age classes).

The analysis unit file structure is illustrated in Table 5.a. The file used in *Spectrum* is a comma delimited (csv) file. A single area file was created for the combined uneven aged and native forest resource in each CRA region. Separate files can be created and appended in *Spectrum*.

TABLE 5.A: ANALYSIS UNIT INPUT FILE STRUCTURE

Analysis Unit Unique ID Number	Blank Column	TSZ (Layer 1)	Uneven aged native forest strata number (Layer 2)	Forest type (Layer 3)	Intensity (Layer 4)	Hardwood Plantation Strata No. (Layer 5)	Unused (Layer 6)	Blank Column	Area (ha)
0		TC3-10	5	Dry	heavy				55.77
1		TC3-10	7	Moist	heavy				6.81
2		TC3-10	8	Moist	heavy				4.45
3		TC3-10	9	Moist	heavy				351.75
4		TC3-10	10	Dry	heavy				469.93
5		TC3-10	13	Moist	heavy				5.08
...									
10339		TC3-40		Pur	normal	L51.1			35
10340		TC3-28		Pur	normal	L51.1			64.5
10341		TC3-7		pur	normal	L51.1			23
10342		TC3-2		pur	normal	L54.1			19.3
10343		TC6-NA		pln	normal	P56.0			50
10344		TC6-NA		pln	normal	P57.0			50

Note: In the LNE CRA region uneven aged native forests (Layer 2) and hardwood plantations (Layer 5) were defined in separate layers because collectively the strata number exceeded the capacity limit (125 attributes plus attribute groups per layer). In the UNE the uneven aged native forest and hardwood plantation strata were defined in the same layer 2.

5.1.2 Net Harvest Area Generation

The *Spectrum* area data file was created using the NHAQUERY software which extracts the area data from a Spatial Analysis Units (SAU) database (data files with details on the attributes and area of each planning unit). The SAU comprises details representing the location and area of State Forest land holdings available and accessible for timber production operations and those areas protected through conservation protocols (either defined as forests zones that are entirely excluded from timber production practices, or emphasis zones where restricted practices may be applied). The Net Harvest Area is that component of the land base that is outside the defined timber exclusion areas (refer Moore, 1999 and Section 6.11 for further details).

NHAQUERY determines the net harvest area by deducting the following factors from the total area:

1. C-PLAN Reserve design – planning units nominated for inclusion in a formal or informal reserve.

2. User specified exclusions:
   - agreed management protocols such as the EPA license conditions and NPWS general protocols;
   - terrain factors (e.g. steep slopes);
   - accessibility factors (road access);
   - leasehold conditions (timber availability encumbered by lease conditions);
   - State Forests management priorities (visual quality retention, reserves, PMP's);
   - operability factors (e.g. proximity to buffer zones, rocky or bouldery conditions, traffic impediments);
   - economic factors;
   - merchantability factors; and
   - NPWS species specific management protocols.

3. User specified net area modifiers.

The net harvest area modifier comprises:

(a) a reduction factor to account for the probability that part of the available harvestable area will not be harvested due to factors which are in addition to the general ESFM protocols. There were two base variations of net harvest area modifier made during LNE & UNE CRA negotiations:

- original net harvest area modifier from FRAMES study; and
- new modifier refactored to exclude filter strip effects (i.e. additional informal buffers left around formal buffer zone requirements which are left to avoid felling trees into the filter strips).

(b) estimates of old-growth exclusion zones which were unable to be included in the SAU database.

Three versions of the NHA modifier were created to reflect the type of old growth exclusions which were not included in SAU database. The categories of old growth exclusions were:
- Candidate old growth;
- High quality habitat (HQH) old growth; and
- High conservation value (HCV) old growth.

The range of attributes able to be excluded from the harvestable area to derive the UNE & LNE NHA are outlined in Table 5.b.

TABLE 5.B: STATE FOREST AREA EXCLUSION OPTIONS

Attribute	Code	UNE	LNE
Purchased land (hardwood plantation)	purch	Y	Y
Softwood plantation	swd_pl	Y	Y
Hardwood plantation (SFNSW land)	hwd_pl	Y	Y
Physically and economically inaccessible	pei	Y	Y
Reserved native forest	pmp13	Y	Y
PMP unavailable classes (1.2, 1.1.5, 1.1.6, 1.1.7)	pmpunav	Y	Y
Typed wetlands areas	rn17_wet	Y	Y
Typed rocky outcrops areas	rn17_rock	Y	Y
Typed heath areas	rn17_heath	Y	Y
Erosion EPA inherent hazard class 4	haz4	Y	Y
Typed rainforest areas (RN17 rainforest –including buffers around warm temperate)	rn17_rf	Y	Y
CRAFTI rainforest (all codes starting with R)	CRAFTI_RF	Y	n/a
CRAFTI rainforest (all codes starting with R except RE)	CRAFTI_RF2	Y	n/a
CRAFTI rainforest (all codes starting with R8)	CRAFTI_RF3	Y	n/a
CRAFTI rainforest (all R codes except RE, RB, RM)	CRAFTI_RF4	Y	n/a
BOGM rainforest type 'r'	bogm_rf1	n/a	Y
BOGM rainforest types 'ry' and 'rd'	bogm_rf2	n/a	Y
BOGM rainforest - all types with embedded 'r'	bogm_rf3	n/a	Y
EPA mapped drainage filter strips	epafilter1	Y	Y
EPA modelled drainage system extensions	epafilter0	Y	Y
Rare and non-commercial forest types	rn17_rnc	Y	Y
Identified wilderness areas	idwild	Y	Y
Unmerchantable forest types	unmerch	Y	Y
State capable wilderness areas	wildcap	Y	Y
Buffers on riparian buffers	BOB	Y	Y

The hardwood plantation areas represented in the *Spectrum* area database was calculated separately for the Land purchase and SF dedicated land areas.

The SFNSW hardwood plantation "gross" area was reduced by 10% to derive an estimate of net area. The level of reduction required varies geographically, due to the quality of mapping the gross area and the level to which mappable gaps had been removed. However, as no detailed records were available at the time of the analysis, an estimated 10% was adopted.

The areas of Land Purchase hardwood plantation were not adjusted down, as accurate records of net area based on aerial photographs were available.

5.1.3 Land attributes

Timber Supply Zones

The timber supply zones defined are a composite of the Timber Catchment and the Timber Supply Priority Zone. A total of 109 timber supply zones were defined for the UNE CRA region and 94 in the LNE CRA region (refer Table 5.c).

(a) *Wood Supply Catchments* are broad supply zones - amalgamations of timber price zones and timber supply priority zones. The supply zones reflect:

- large areas which supply current industry because of existing contracts;
- large contiguous areas worked by specific industries;
- physical or economic catchment areas in which the wood flows are similar due to geographical factors which do not favour inter-catchment wood movement, and possibly reflect economic distances to specific ports and/or industrial facilities; and
- forest management and administrative boundaries.

(b) *Timber Supply Priority Zones* are groupings of compartments with similar relative commercial timber values. Compartments with similar measures (within a range of indicator values) were represented as the same Timber Supply Priority Zone. The compartments within each Timber Supply Priority Zone each have a single indicator which was to be used to assist in trade-offs between conservation, wood resource and economic criteria.

TSPZ Index value = f (Log Quality / Harvesting Index, Log Volume, Productivity, High Value Products/ Species)

The Timber Supply Priority Zones also provided a basis for reporting the source of wood for the supply targets which assist in evaluating the wood supply options.

TABLE 5.C: CRA REGION TIMBER SUPPLY ZONES

Region	Wood Supply Catchment	No. of Timber Supply Priority Zones
UNE	1	67
UNE	2	42
LNE	3	40
LNE	4	34
LNE	5	12
LNE	6	8

Uneven –Aged Native Forest Strata

The final stratification used to represent the commercial UNE and LNE native forest resource contained 31 strata. These strata are combinations of Yield Association and Forest Structure Class (Table 5.d). Non-commercial forest areas were not represented in the *Spectrum* area databases as they were excluded from the net harvestable area.

TABLE 5.D: NATIVE FOREST STRATA

Yield Association	Forest Structure Class				
	e1	e2	A	B	C
Moist blackbutt	1	7	11	18	25
Moist coastal eucalypts	2	8	12	19	26
Semi Moist and Tall dry eucalypts	3	9	13	20	27
Dry blackbutt and spotted gum	4	10	14	21	28
Dry sclerophyll	5		15	22	29
Moist tablelands	6		16	23	30
Dry tablelands			17	24	31

<u>Forest Yield Associations</u>

The strata used area combination of yield association and structure class. The yield associations were amalgams of forest types. The following 7 yield associations were used:

- *Moist blackbutt.* This is primarily dominated by blackbutt in Research Note 17 types 36 and 37A.
- *Moist coastal eucalypts.* This includes the forest types found in the RN 17 Sydney blue gum/bangalay league.
- *Semi-moist coastal eucalypts.* This includes the forest types in the grey gum- grey ironbark league, and moist spotted gum.
- *Dry spotted gum and dry blackbutt.* In UNE this YA is primarily dominated by the dry spotted gum forest types, with a smaller distribution of dry blackbutt plots. In LNE, the distribution is primarily dry blackbutt.
- *Dry sclerophyll.* The remainder of productive dry sclerophyll types found in coastal areas.
- *Moist tablelands*. Moist forest types in the messmate/ brown barrell league.
- *Dry tablelands.* Dry tableland and tableland stringybark forest types.

<u>Forest Structure Classes</u>

Forest structure classes were derived from CRAFTI in the UNE and BOGMP in the LNE. The 5 classes were:

- e1 Regrowth dominated forest (i.e. regrowth crown cover percent greater than 30%) with small regrowth less than 30 cm DBHOB.
- e2 Regrowth dominated forest (i.e. regrowth crown cover percent greater than 30%) with large regrowth between 30-50 cm DBHOB
- A Multi aged stands with senescent crown cover percentage greater than 30%.

- B Multi aged stands with senescent crown cover percentage between 10-30%.
- C Multi aged stands with senescent crown cover percentage less than 10%.

In UNE, the CRAFTI regrowth size code was the basis for creating tree size, while in LNE the basis was the Wood Resources Study regrowth size code.

Multi aged stands, although showing substantial similarity in there diameter class distributions, were split for potential management reasons on the basis of senescence percentage.

Hardwood Plantation Strata

The hardwood plantation strata were represented by 54 strata. These strata were based on combinations of species, stand condition (thinned or unthinned), current stocking and age class. Insufficient data were available to stratify on the basis of productivity class.

The hardwood plantation strata attributes code comprises three components with the format OSS.AA

Where:
O = plantation land ownership class (L= land purchase, P = SFNSW dedicated SF)
SS = strata number (1- 54)
AA = age class (1- 12)

<u>Strata</u>

The 54 strata comprise:

(a) Pre-1998 plantations were stratified into 49 types based on combinations of the following criteria (refer Table 5.e):

TABLE 5.E: CRITERIA FOR HARDWOOD PLANTATION STRATIFICATION

Species	Blackbutt
	Flooded Gum
	Other (all remaining *Eucalyptus* and *Corymbia* species)
Stand Condition	Thinned
	Unthinned
Current Stocking	0 – 400 stems/ha
	400 - 800 stems/ha
	800+ stems/ha
Age Class	Year of establishment classes

(b) Post-1998 plantations were classified into 5 strata on the basis of species. The stratification was not done by productivity class and potential silvicultural regime as the resource was too immature to be inventoried and were established on first rotation sites for which limited productivity data were available. The 5 species were:

- Blackbutt (*E. pilularis*);
- Flooded Gum (*E. grandis*);
- Dunn’s White Gum (*E. dunnii*);
- Spotted Gum (*Corymbia variegata* in northern NSW and *C. maculata* in southern NSW); and
- Other species.

Age Class

The plantation age class distribution was amalgamated into 5 year age classes (refer Table 5.f).

TABLE 5.F: ALLOCATION OF AGE CLASSES TO AGE PERIODS

Date of Planting	Age	Period
1993-97	1 – 5	1
1988-92	6 – 10	2
1983-87	11 – 15	3
1978-82	16 – 20	4
1973-77	21 – 25	5
1968-72	26 – 30	6
1963-67	31 – 35	7
1958-62	36 – 40	8
1953-57	41 – 45	9
1948-52	46 – 50	10
1943-47	51 – 55	11
1938-42	56 – 60	12

Note: Land Purchase Areas (1998 plantings (age 0) were classified with Period 1 areas) which were subsequently included in the *Spectrum* model.

The age of the plantation relates to the mid-point of the first period. For example, stands established between 1963 and 1967 are between 31 and 35 years old in 1998 (first year of planning horizon). The mid age for the age class is 33 years. Mid way through the first period (year 3) the stand is aged 35 years or age 7 periods.

Forest Types

Uneven-aged native forest

In the area database, the two broad native forest type groups Dry and Moist forest types were identified. The groups were created to facilitate modelling different silvicultural options. The strata included in the broad categories are shown in Table 5.g and Table 5.h.

TABLE 5.G: UNE AND LNE STRATA NUMBERS WITH MOIST FOREST TYPES

Yield Association	Structure Class				
	e1	e2	A	B	C
Moist blackbutt	1	7	11	18	25
Moist coastal eucalypts	2	8	12	19	26
Semi Moist and Tall dry eucalypts	3	9	13	20	27
Moist tablelands	6		16	23	30

TABLE 5.H: UNE AND LNE STRATA NUMBERS WITH DRY FOREST TYPES

Yield Association	Structure Class				
	e1	e2	A	B	C
Dry blackbutt and spotted gum	4	10	14	21	28
Dry sclerophyll	5		15	22	29
Dry tablelands	classified with moist tablelands		17	24	31

Hardwood plantations

The hardwood plantations were categorised as those on undedicated Purchased Land (pur) or those on dedicated SF (pln). The separation provided the facility to apply alternative management actions (e.g. rotation length, replant strategy etc) to the different land classes, and provided a mechanism for excluding a land base from the resource modelled.

Disturbance Intensity

The Disturbance Intensity field represents the maximum intensity of disturbance (silviculture) possible for the analysis unit.

Uneven-aged native forest

The Australian Group Selection (AGS) and Single Tree Selection (STS) silviculture were modelled at 3 different intensity levels (light, moderate, heavy), and separate yield curves were generated for these (refer Section 5.2.1). The STS intensity refers to the proportion of the standing crop which will be removed per hectare of forest available for harvesting. The AGS intensity refers to the size of gaps, return time, proportion of a given area gapped in a single operation and the proportion of the net harvestable area which is retained and not subject to harvesting. The lower intensity silviculture has a lower impact on the overstorey canopy and creates less disturbance to the site.

In the area database each analysis unit disturbance intensity class was initially set at the maximum class heavy so that light, moderate or heavy intensity operations could be applied. No silvicultural intensity restrictions were applied to specific strata or analysis units. The permissible intensity is regulated in the modelling using the management action definitions and schedules (Section 6.5) though the area database can be changed to lower intensity levels to control the silviculture applied. Some scenarios were tested in which the maximum intensity was set at a lower level (moderate) to evaluate the impacts of less intensive silviculture on future wood supply.

Hardwood Plantation

The disturbance intensity for the plantations was set as “Normal” intensity. No differentiation in silvicultural intensity was applicable to plantations. In a *Spectrum* model 1 formulation only a single yield table (i.e one silvicultural regime) is provided for the existing and regeneration plantation crops, not a range reflecting different silvicultural regimes or intensities.

5.2 YIELD TABLES

The expected per hectare yields of log products arising from native forests and plantations managed under a range of silvicultural scenarios were represented as yield table files. The native forest yields were characterised using uneven-aged yield tables while the plantation yields were represented using age-dependent yield tables in *Spectrum*. Uneven-aged yield tables contain expected yields that are a function of time (period) with a separate yield for each period in the model planning horizon. Age-dependent yield tables contain yields which are a function of stand age with a separate yield for each age. Refer to Tables in Appendix 2.1 and 2.2.

The structure of the yield tables used to represent the native forest and plantation resource in *Spectrum* differs because of the distinct forest structure, silviculture and management differences of the forest resources. The primary differences between the two classes of forest are listed in Table 5.i:

TABLE 5.I: PRIMARY DIFFERENCES BETWEEN NATIVE FOREST & PLANTATION

Native forest	Plantation forest
Uneven aged (primarily multi-aged, some two-tiered)	Even aged
Mixed species	Single species
Cutting cycles, structural modification but retention of stand	Distinct rotation length
Partial stand removal only – commercially mature trees (thinning and reset i.e. gap creation, or single tree removal)	Thinning and clear cutting
Retention of over storey (habitat trees)	100% tree removal
Low volume yield	High volume yield

The purpose of separating the two resource types relates to the structure of the forests and the way they are managed. The following sections provide a brief overview of the rationale used in modelling these resource yields separately, the basis of the range of yield tables modelled and their structure.

Since FRAMES is a strategic tool and the inventory was conducted at the strata level, the yield tables reflect strata level yield predictions. Assignment of yields to compartments was inappropriate and would have implied a level of accuracy that cannot be justified.

5.2.1 Native Forest Yields

Regulation of the flow of wood fibre from an extensive native forest resource which is heterogeneous (in structure, species composition, extent, productivity and the management history) requires a wide range of cutting cycle lengths, intensities of harvest, and the need to stagger commencing implementation of a regulated cut in different portions of the resource. Consequently, for the UNE and LNE CRA regions multiple yield tables were provided for each strata to ensure *Spectrum* had the flexibility to apply the appropriate blend of silvicultural options to achieve the wood supply targets and under the constraints imposed.

Yield tables which contain the predicted volume of log product (m^3/ha by 4 products) harvested by 5 year period were generated for each of the 31 native forest. Thirty yield tables per strata were generated, each representing the yield streams expected if managed under different silvicultural regimes, different intensities of management and to reflect different transition periods (delays) before a regulated harvest cycle is applied.

The options included combinations of:

- 2 silvicultural options (STS & AGS);
- 3 intensity levels for silviculture (light, moderate, heavy); and
- 5 delay period (5 year delays before first harvest can commence in area).

Each yield table type constructed reflects the yield stream profile from the stratum when managed under a single silvicultural regime / intensity for the whole planning horizon. The *Spectrum* model formulation used is a Model I formulation (refer Section 6.2) meaning that each analysis unit (smallest subset of a strata) is assigned a single yield table in the first period of the modelling planning horizon and is retained throughout the complete planning horizon. There is no scope for allocating another yield table to the analysis unit midstream in the planning horizon. Consequently the range of yield tables reflect the impact of a single silvicultural prescription for the full term of the planning horizon.

The native forest yields were modelled as Uneven-Aged *Spectrum* Yield Tables which contain a volume coefficients (m^3/ha of each log product) for each time period that volume is removed, and a stream of volume coefficients for the entire planning horizon to track the standing inventory volume before each harvest removal. The generation of the native forest yield tables was automated using the FRAMES yield simulator (refer Appendix 1.1) coupled with the use of a PERL script to transform and format the simulator output data into the appropriate *Spectrum* CSV import file format (refer Section 6.11).

The yield table data developed and imported into *Spectrum* is structured as 2 files (refer Appendix 2.1) which comprise:

(a) File 1 - yield table definition:
- stratum and silvicultural option;
- yield table type (uneven aged);
- management action attributes;
- period of first yield; and
- unique stratum age class ID which links with file 2.

(b) File 2 - Merchantable yields for each stratum age class, by:
- harvest yield or inventory standing volume prior to harvest;
- log product (HQL, HQS,LV, Pulp); and
- period.

Native Forest Strategic vs Operational Level Yields

The native forest yield tables are strategic level yield tables which exhibit two distinct differences from operational level (compartment / management unit) yields:

(a) the yield tables reflect the stratum average yield stream. The strategic level stratum yield tables represent the average flows on a regional basis if each constituent management area is stringently managed according to the silvicultural prescription. At an operational level, the volume harvested and timing of the harvest is a function of management history, productivity, species composition and forest structure of a forest block; and the need for each unit of forest to be harvested as part of a larger harvest block to produce wood on an economic basis. The harvest timing imposed on individual units of forest may be optimal because of the over-riding economic objectives and practical harvesting considerations.

(b) A given management unit will yield larger periodic volumes rather than a steady stream of small volumes each period as implied by the strategic level yield table.

5.2.2 Hardwood Plantation Yields

The plantation yields are represented as age-dependent yield tables in *Spectrum*. The yield tables contain the predicted volume of log product (m^3/ha by 4 products) by 5 year age class from production thinning operation(s) and the clearcutting volume expected at a range of potential rotation ages.

In *Spectrum* the yield table for a stratum is customised for each age class within that stratum. For each stratum age class two yield tables were provided – one to represent the existing stand and another for subsequent replanted stands. At the beginning of the planning horizon all stands are considered *existing* and access *existing* yield tables. Once a stand has been replanted it will access a replanted (*regeneration*) yield table for the rest of the planning horizon. The replanted yield tables have higher yields and an improved log composition compared to existing stand yields, due to better quality tree stock and improved silviculture.

Each yield table developed for importing into *Spectrum* comprises two files (refer Appendix 2.2):

(a) File 1 - yield table definition:
- land theme (stratum, whether SF plantation or purchased land);
- yield table type (existing or regeneration);
- stand age at beginning of planning horizon;
- age of first yield; and
- unique stratum age class ID which links with file 2.

(b) File 2 - Merchantable yields for each stratum age class, by:
- treatment (thin or clearcut operation);
- log product (HQL, HQS,LV, Pulp); and
- age.

Yield tables were developed for each of the 54 plantation strata. Two classes of yield tables were derived based on silvicultural prescriptions and stand quality (refer Turland, 1998).

- The pre - 1998 forest areas which were stratified into 49 based on combinations of species, stand condition, current stocking, age class.
- The 1988 - 1997 plantation resource which was classified as 5 strata on the basis of species. The recent stands were not stratified by productivity class or potential silvicultural regime as the resource was too immature to be inventoried and limited site data were available.

One existing stand yield table can be used in *Spectrum* for each strata, however two sets of yield tables were generated for the existing stand strata:

- yield tables based on no further thinning before clearcutting; and

- yield tables reflecting future thinning. These were derived for each of the recent plantations but only for the pre-1988 plantation strata where future thinning operation would be economic (i.e those which could yield adequate volumes and thinning response, and those strata which were not too old).

The yield table based on a “future thinning” silvicultural regime was used as the yield table for each strata in *Spectrum* in preference to the yield table reflecting no further thinning, as the more intensive silvicultural regime was identified as a more favourable option for supplying large high quality sawlogs and was expected to provide a higher financial return. However, the “no further thinning” yield table option was applied in the Walcha and Styx River Wood Supply Districts, where thinning was considered uneconomic due to distance from market.

Replant Strategy

All 54 strata were assumed to be replanted as improved stands. Ten generic replant yield tables were derived based on 5 species (Blackbutt, Flooded Gum, Dunn’s White Gum, Spotted Gum and other species) (refer Table 5.j) and two silvicultural regimes (no thinning, with thinning). The yield tables based on silvicultural regimes with thinning were used for all strata, except in the Walcha and Styx River Wood Supply Districts where thinning was considered uneconomic due to distance from market.

TABLE 5.J: EXISTING AND REPLANT STAND SPECIES

Existing Stand	Replant Species
Old Plantation	
Blackbutt	Blackbutt
Flooded Gum	Flooded Gum
Other species	Blackbutt
New Plantation	
Blackbutt	Blackbutt
Flooded Gum	Flooded Gum
Dunn's White Gum	Dunn's White Gum
Spotted Gum	Spotted Gum
Other species	Blackbutt

The yields included in the plantation yield tables correspond to the specific volumes expected at the defined age for the period, not the age class averages (refer Table 5.k). Note that the age of a plantation stratum age class at the beginning of the planning horizon corresponds to the mid-point age (e.g. age period 7 = 35 years) which corresponds to the yield table age (e.g. period 7 yield is at age 35).

TABLE 5.K: RELATIONSHIP BETWEEN PERIOD AND PLANTATION AGE

Period	Age class	Yield Age (years)
1	1 - 5	5
2	6 – 10	10
3	11 – 15	15
4	16 – 20	20
5	21 – 25	25
6	26 – 30	30
7	31 – 35	35
8	36 – 40	40
9	41 – 45	45
10	46 – 50	50

5.2.3 Yield Table Log Products

The native forest and hardwood plantation yield tables comprise volumes of 4 generic log grades (refer Table 5.l):

TABLE 5.L: LOG PRODUCT SPECIFICATIONS

Log Product Name	Length (m)		Small end diameter under bark (cm)	
	Min	Max	Min	Max
Large High Quality (LHQ)	3.6	15.4	34	70
Small High Quality (SHQ)	3.6	15.4	20	34
Low value (LV)	3.6	15.4	30	70
Pulp	3.6	15.4	10	70

6. MODEL SET-UP, DESIGN AND CONSTRUCTION

6.1 HARDWARE AND SOFTWARE PLATFORM

The *Spectrum* model and associated LP optimisation package C-WHIZ were set up on IBM compatible personal computers in Windows NT and Windows 95 operating environments. The version of *Spectrum* does NOT run under Windows; it is executed directly from DOS.

The *Spectrum* yield scheduling model is available free from the USDA Forest Service on the worldwide web. The model files are contained in several self extracting ZIP files. The minimum hardware specifications for running *Spectrum* on a microcomputer are:

- an IBM compatible 80386 or better machine;
- an Intel math coprocessor;
- a minimum of 8 Megabytes (MB) of random access memory (RAM) 16 MB is recommended; and
- a hard disk with at least 200 MB free space.

C-WHIZ a commercial LP software package used to solve *Spectrum* generated matrices can be used on personal computers and selected UNIX workstations. The PC version of C-WHIZ requires an i386 or better CPU with at least 2mb RAM, a math coprocessor, and DOS 3.1 or later.

6.2 MODEL FORMULATION

Spectrum can be formulated as a Model 1 or Model 2 formulation which is effectively the way in which the management options (and therefore yield tables) can be assigned to the unit areas.

In a model 1 formulation each forest age class or forest strata forms a management unit whose integrity is retained throughout the planning horizon. Each analysis unit hectare is assigned to one of many possible management schedules for the complete planning horizon. In the case of a plantation the existing and all future rotations are managed by a predetermined schedule.

In a model 2 formulation each age class (or strata) containing hectares in the first period form a management unit until these hectares are regeneration harvested. All hectares that are harvested and regenerated in each period form a new age class (or strata) and management unit until they are harvested again. Over the planning horizon a stand can be assigned one of many different management sequences.

For the CRA strategic yield scheduling a Model I formulation was used. This decision was made because of the characteristics of the uneven aged native forest management and the way the native forest yield tables were developed. Modelling was tailored to reflect the management of native forests as opposed to the hardwood plantations which are better suited to modelling under model 2 formulations, since the native forest is the dominant resource in the CRA regions.

The Yield Simulator was designed to generate a yield table for a stratum over the whole planning horizon according to a particular silvicultural option. For each strata, a yield table was provided for each of a range of silvicultural options are provided (AGS/STS, Light/Medium/Heavy intensity, different delay periods). Changes in management during the planning horizon were not modelled as the aim was to model the yields under consistent silvicultural regimes.

The *Spectrum* Model 1 formulation assigns one of the yield table options to a strata analysis unit in the first period. The yields in all future periods arise from the same yield table assigned in period 1. In the case of plantation strata a single yield table is assigned to the existing rotation. All future rotations are assigned a single nominated replanting yield table. Variation in plantation yields from subsequent rotations can arise because the rotation length is flexible.

Under a model 1 formulation a partially complete range of management options are provided for each management unit. This can result in sub-optimal solutions being derived. The model 2 formulation has the advantage for plantations in that the management option assigned to an area in each rotation is selected from a multiple management options (different silviculture) and can be changed in future rotations. Similarly in the case of native forests the intensity and timing of harvesting events could be modified between cutting cycles.

However, as the CRA modelling is a strategic level modelling whereupon the strata data were collected at a broad level, and resources did not permit high resolution detailed data to be collected and analysed, the model 1 option was adopted. This formulation selected determined the way in which the yield scheduling model templates were constructed.

6.3 CONSTRUCTION OF MODEL TEMPLATE

A separate *Spectrum* model was prepared for each of the LNE and UNE CRA regions.

The initial model template was constructed for each CRA region. The construction of a complete model ready to undertake yield scheduling involved multiple stages:

(a) Enter land attributes:
- Create catchment groups (aggregates of Timber Supply Zones);
- Create strata groups (plantation groups and moist/dry native forest groups);
- Create silvicultural practice attributes;
- Add silvicultural practice land groups;
- Create disturbance intensity attributes; and
- Add disturbance intensity groups.

(b) Define planning horizon and period length
(c) Create management action activity and output variables
(d) Define management action attributes and groups
(e) Create management action definition
(f) Create management action schedules
(g) Develop customised solution report specifications
(h) Set up default objective function
(i) Import area and yield table data files

Once a model was constructed for a CRA region it was used as a template (LNE & UNE) for the subsequent model runs. As yield table variants were limited they were defined as separate models (LNE_1 to LNE_*n*, UNE_1 to UNE_*n*).

As the negotiations centred around variations in the conservation reserve design and the impact of area changes on yields, a given model variant was repeatedly used and the area file was simply modified and imported to override the pre-existing area data file. The summary files of each model run were saved.

6.4 IMPORT OF YIELD TABLES AND NET HARVESTABLE AREA DATA

The yield tables and net harvestable area data files created in preceding components of FRAMES were structured as comma delimited files so they could be imported into *Spectrum* as opposed to being manually entered through the graphical user interface. The analysis unit and yield data are imported through the *Spectrum* Partial Model Imports GUI. The yield data are imported as two files (refer Appendix 2) and the area data is imported as a single data file.

A separate set of yield tables were created for the native forest (files native1.csv and native2.csv) and plantations (files pl_yld1.csv and pl_yld2.csv). Separate sets of yield tables were created for the LNE and UNE CRA regions. A single analysis unit data file was created for the combined plantation and native forest resource in each CRA region.

The comma delimited file creation was semi-automated with the *NHAQUERY.EXE* model and two PERL scripts *NativeYield.pl* and *BuildPlant.pl* (refer Figure 6-1) so that (a) variants of the area and yield data could be repeatedly and promptly processed during the negotiation process, and (b) to eliminate data transcription and formatting errors which could arise from manual data file creation or manual data entry through the GUI.

NHAQUERY was used to create the analysis unit file of the native hardwood forest net harvestable areas and hardwood plantation areas from the spatial analysis files, C-PLAN and user defined exclusions (refer Section 6.11.1). *NativeYield.Pl* was used to read in hardwood yield tables generated from the Native Forest Yield Simulator and reformat these as CSV files for import into *Spectrum*. *BuildPlant.pl* was used to transform hardwood plantation data files into CSV files for import into *Spectrum*.

6.5 DEFINITION OF MANAGEMENT ACTIONS (ACTIVITIES, OUTPUTS, CONDITIONS)

Management Actions (harvesting system options) were defined so that the *Spectrum* model is able to link elements of data together (analysis unit and yield data) and to select and apply appropriate management options to specific analysis units (strata). There were 7 steps used to model the management actions:

1. Planning horizon and modelling period lengths were defined.

2. Activities (plantation or native forest harvesting) and outputs (timber products) were defined.

3. Forest treatments (Treatment Types e.g. clearcutting, selection cutting, and thinning) were defined.

4. Yield composites (groupings of activities and outputs, and relationships) were defined.

5. Management Attributes, which include all possible management emphases and management intensities, were defined. The emphasis describes the general management goal, and the intensity describes the varying levels of management used to achieve the goal.

6. Management Actions were defined. These include a name, management emphasis, management intensity, and a list of activities, outputs, and conditions. Land Themes (groups of analysis units by attributes) to which the management action may be applied were specified.

7. Schedule options for each management action were defined.

6.5.1 Planning horizon

A planning horizon of 100 years was used for the *Spectrum* modelling. The CRA negotiation yield scheduling focused on exploring the wood supply levels for a term of 20 years under various formal reserve designs and modifications to NPWS / EPA protocols, but the modelling process was conducted beyond the 20 year period to ascertain the long term sustainable yield.

The 100 year planning horizon was used because native eucalypt forest growth rate is low and it was important to model the impacts of the harvesting strategy and silvicultural options on the long term sustainable yield. While a planning horizon of 100 years was selected as it is sufficient for reflecting for representing the impact of most of the forest structural change on wood supply, it is recognised that it covers less than a full rotation for some slow growing native forest strata.

The specifications in *Spectrum* were:

Begin Year	=	1998
Periods for planning horizon	=	20
Each period	=	5 years

6.5.2 Activities and Outputs

A forest management plan consists of a set of management actions applied to specific land units. Management actions include activities and outputs. Management activities (plantation or native forest harvesting) and outputs (timber products) were defined in *Spectrum*.

Activities included in the CRA model were:

plt_harvest	=	Harvest hardwood plantation (m^3)
ue_harvest	=	Harvest uneven aged native forest (m^3)

These activities were qualified with settings:

- Acre - sets the spatial units for activity or output coefficients. If the units are "per acre", then a coefficient is the same for each acre on each analysis unit. In contrast, if the units are "per area" then the coefficient applies to the entire analysis unit regardless of size.

- Period - Attributes measured on a periodic basis already have the number of years/period taken into account. In contrast the coefficient of an attribute measured on a yearly basis is multiplied by the number of years in each period to obtain the periodic total.

Outputs are the results of activities. Outputs included in the CRA model were:

HQ_L_Sawlog	=	High quality (large) sawlogs (m^3)
HQ_S_Sawlog	=	High quality (small) sawlogs (m^3)
LQ_Sawlog	=	Low quality sawlogs (m^3)
Pulp	=	Pulp logs (m^3)
Total_Wood	=	Total volume (m^3) of wood from all product types (HQL+HQS+LQ+PULP)
netarea_plt	=	Net area of hardwood plantations harvested (ha)
netarea_ue	=	Net area of uneven aged native forest harvested (ha)
Wood (group)	=	multi-product of wood volume (m^3)

These activities were qualified with Acre and Period settings defined as above.

6.5.3 Treatment types

Treatment types were used to define the yield information within a given yield table.

The following treatments were defined for the plantation yield tables (age–dependent yield tables):

ThnEst	=	Thinning in existing stands
ThnReg	=	Thinning in regenerated stands
CC-Est	=	Clearcutting existing stands
CC-Rgn	=	Clearcutting regenerated stands

In each yield table the volume of each product arising from a thinning or clearfelling operation is defined. The treatment codes are used to qualify which yields relate to which operation type, and to differentiate between existing and replanted stands.

At the beginning of the planning horizon all analysis units are considered "existing" stands. The stands' beginning age comes from the yield table. The age of the stand increments with each period of the planning horizon. The treatment type property "end of the final harvest sequence" is used to end the life of an existing stand. When the model clearcuts an existing stand, replanting occurs in the same period as the harvest. Replanting does not occur with thinnings.

In the uneven-aged native forests (uneven-aged yields) the following treatments were defined:

Sel-F	=	Selection harvest, first entry
Sel-L	=	Selection harvest, later entries
INV	=	Selection harvest, inventory

The uneven age forest yield tables show the yield flow for the whole planning horizon. The Sel-F treatment merely indicates the first period yield and the Sel-L treatment is associated with the yields expected for each subsequent period. The INV is associated with standing yields. This is used for assessing residual stands or the stand condition over time.

6.5.4 Yield Composites

Management Actions included several activities (plantation or native forest harvesting) and produce more than one output (timber products), and the activity and output quantities are dependent on each other. The activities, outputs and relationships were grouped together in a yield composite that is associated with a management action. Yield composites eliminate the need to repetitively list all the activities and outputs involved in each management action.

The yield composites included were:

(a) pl_c = plantation harvesting yield composite, which is linked to the independent variable *wood
(b) ue_c = uneven-aged harvesting yield composite, which is linked to the independent variable *wood

The yield composite dependencies are defined in Table 6.a and Table 6.b.

TABLE 6.A: YIELD COMPOSITE PL_C

Dependent	Units	Independent	Type	Form	Treatment	Factor
Plt_harvest	amount	Wood	Time	Simple	-	1.000
Netarea_plt	acres treated	Wood	Time	Simple	-	1.000
Total_Wood	amount	Wood	Time	Simple	-	1.000

TABLE 6.B: YIELD COMPOSITE UE_C

Dependent	Units	Independent	Type	Form	Treatment	Factor
ue_harvest	amount	Wood	Time	Simple	-	1.000
netarea_ue	acres treated	Wood	Time	Simple	-	1.000
Total_Wood	amount	Wood	Time	Simple	-	1.000

plt_harvest = plantation harvesting (m^3) (activity)
netarea_plt = net area that receives plantation harvesting (ha) (output)
Total_Wood = total amount of wood from all product types (m^3) (output)
ue_harvest = uneven-aged harvesting (m^3) (activity)
netarea_ue = net area that receives uneven-aged treatment (ha) (output)
*Wood = multiproduct of wood volume HQ_L_sawlog + HQ_S_sawlog + LQ_sawlog + Pulp (m^3) (output)
Amount = State the dependent variable is related to the amount of the independent variable
Acres Treated = The dependent variable is related to the acres associated with the independent variable
Time = Time dependent relationship. The dependent activity or output occurs at the same time as the independent activity or output occurs
Simple = Functional form which relates the dependent variable to the independent with only one factor that does not vary over time, age, qualifier or land attribute.
Factor = Dependent variable multiplicative factor

6.5.5 Management Action Attributes

Management action attributes consist of a *Management Emphasis* and *Management Intensity*. Management emphasis describes the general management goal. Management intensity describes various levels of management available to achieve the goal. These are used in management action definitions to define where these attributes can be applied.

The Emphasis classes used include:

gtimb = group selection timber
ptimb = plantation timber
stimb = single timber selection
sgtim = stimb and gtimb group

These are the classes of silviculture modelled - AGS and STS silviculture in uneven aged native forests, and standard silviculture in plantations.

The Intensity Classes used include:

light	=	light intensity management
medium	=	moderate intensity management
heavy	=	heavy intensity management
normal	=	class defining standard silvicultural management in plantations

6.5.6 Management Action Definition

The management actions comprise the silvicultural regime options which will be used to achieve the modelling objectives. These management actions are defined in two levels:

(a) The management emphasis, management intensity, schedule type, and yield composite associated with the management action is specified.

The management emphasis and management intensity defines "what" the action is trying to accomplish and "why" the action was developed. The schedule type defines "how" and "when" the action will be implemented, and the yield composite contains the set of activities, outputs, and conditions that occur as a result of the action being implemented.

The management action options defined in the CRA model are outlined in Table 6.c.

TABLE 6.C: MANAGEMENT ACTION DEFINITIONS

Management Action	Management Emphasis	Management Intensity	Yield Composite	Schedule Type
Australian Group Selection Heavy	gtimb	heavy	ue_c	uneven_aged
Australian Group Selection Medium	gtimb	medium	ue_c	uneven_aged
Australian Group Selection Light	gtimb	light	ue_c	uneven_aged
Single Tree Selection Heavy	stimb	heavy	ue_c	uneven_aged
Single Tree Selection Medium	stimb	medium	ue_c	uneven_aged
Single Tree Selection Light	stimb	light	ue_c	uneven_aged
Plantation silviculture	ptimb	normal	pl_c	age_based general

gtimb	=	group selection silviculture
stimb	=	single tree selection silviculture
ptimb	=	plantation silviculture

(b) The analysis unit(s) to which a management action may be applied were specified. The LP Solver in the *Spectrum* model only selects one action for a given unit of land.

The AGS and STS potential management actions were themed to each land unit. The management actions were themed to analysis units via land attributes (Table 6.d)

TABLE 6.D: MANAGEMENT ACTION DEFINITION LAND THEMES

Management Action	Analysis Unit	TSZ	Strata	Prac	Distub
Australian Group Selection Heavy	All	All	All	Any*	IGNORE
Australian Group Selection Medium	All	All	All	Any*	grp_mh
Australian Group Selection Light	All	All	All	Any*	grp_lmh
Single Tree Selection Heavy	All	All	All	Any*	grp_h
Single Tree Selection Medium	All	All	All	Any*	grp_mh
Single Tree Selection Light	All	All	All	Any*	grp_lmh
Plantation silviculture	All	All	All	pln, pur	All

TSZ = Timber Supply Zone
Prac = Silvicultural practice
Distub = Disturbance intensity
grp_h = The management action can only be used on sites where heavy intensity silviculture is permitted
grp_mh = The management action can only be used on sites where medium and heavy intensity silviculture are permitted
grp_lmh = The management action can be used on all sites in which light, medium, and heavy intensity silviculture is permissible.
Ignore = option non-applicable viz. AGS heavy was negotiated to be a non-permitted practice.
Any* = All dry and most uneven aged forest types (all native forest)
pln = plantations on dedicated SFNSW land
pur = plantations on recently purchased but not yet dedicated State Forest.

6.5.7 Management Action Schedules

Each management action has a schedule and schedule timing options. Schedule timing options are the stand ages or time periods in which a management action may take place. The LP solver selects the timing option that best satisfies the objective function and constraint set associated with the model. Each management action was themed to one or more analysis units (strata).

<u>Schedule</u>

TABLE 6.E: MANAGEMENT ACTION SCHEDULE

Management Action	Schedule Type
Australian Group Selection Heavy	Uneven-aged
Australian Group Selection Medium	Uneven-aged
Australian Group Selection Light	Uneven-aged
Single Tree Selection Heavy	Uneven-aged
Single Tree Selection Medium	Uneven-aged
Single Tree Selection Light	Uneven-aged
Plantation silviculture	General age

All of the analysis units associated with an uneven-aged forest management action have the same schedule. The even-aged analysis units (plantation strata) each have a unique schedule.

TABLE 6.F: MANAGEMENT ACTION SCHEDULE LAND THEMES – UNEVEN AGE NATIVE FOREST

Management Action	Analysis Unit	TSZ	Strata	Prac	Distub	Emphasis	Intensity
Australian Group Selection Heavy	All	All	All	Any*	ignore	gtimb	heavy
Australian Group Selection Medium	All	All	All	Any*	grp_mh	gtimb	medium
Australian Group Selection Light	All	All	All	Any*	grp_lmh	gtimb	light
Single Tree Selection Heavy	All	All	All	Any*	grp_h	stimb	heavy
Single Tree Selection Medium	All	All	All	Any*	grp_mh	stimb	medium
Single Tree Selection Light	All	All	All	Any*	grp_lmh	stimb	light

TABLE 6.G: MANAGEMENT ACTION SCHEDULE LAND THEMES – HARDWOOD PLANTATION FOREST

Management Action	Analysis Unit	TSZ	Strata	Prac	Distub	Emphasis	Intensity	Type
Plantation silviculture	All	All	*	pln, pur	All	ptimb	normal	both

* Each plantation strata group was entered as a separate land theme as the Schedule Information linked to the management action is specific to groups of plantation strata.

Schedule timing

(a) Uneven aged schedule

TABLE 6.H: UNEVEN AGED FOREST SCHEDULE

Management Action	Periods to begin removal sequence
Australian Group Selection Heavy	1 – 5
Australian Group Selection Medium	1 – 5
Australian Group Selection Light	1 – 5
Single Tree Selection Heavy	1 – 5
Single Tree Selection Medium	1 – 5
Single Tree Selection Light	1 – 5

The uneven-aged schedules vary by time period. The “begin removal sequence” time periods specified correspond to the range of yield table delay options (period 1 corresponds to 0 period delay, period 2 corresponds to 1 period delay etc). The begin removal dates are specified in the yield table data file

(b) Even-aged schedule

The even-aged general schedule type is based on stand age and these schedules have both commercial thinning and clearcut timing. A commercial thinning is the removal of part of the merchantable material from a stand. A clearcut is the removal of all merchantable material from a stand.

TABLE 6.I: EVEN-AGED (PLANTATION) FOREST SCHEDULE - EXAMPLE FOR STRATUM PLN46

Management Action	Stratum	Exist		Regen	
		Entry	Harvest	Entry	Harvest

Plantation silviculture	PLN46	4	6 – 12	5	7 - 10

An existing stand (EXIST) is one which existed at the beginning of the planning horizon.
A regenerated stand (REGEN) is the result of harvesting and replanting some time during the planning horizon.

The thinning and harvest ages for the existing and replanted stands are in periods. The existing plantation thinning ages (ENTRY) is 4 periods i.e. will occur at age 20 years. The existing plantation clearcut ages (HARVEST) are 6 – 12 periods i.e. can occur between ages 30 and 60 years.

It is possible to have more than one commercial thinning per rotation. The thinning age specified here, in the management action schedules, is the age for the FIRST thinning. Any subsequent thinnings are specified in the yield tables.

6.6 DEFINITION OF GOALS AND OBJECTIVE FUNCTION

Wood supply modelling was aimed at ascertaining a management strategy which achieved State Forests' base levels of volume commitments and allocations for all native forest products in the Upper and Lower North East CRA regions for a given proposed new formal reserve design, while satisfying the ESFM protocols, and achieving a future sustainable wood supply.

Achieving the 20 year Term and Wood Supply Agreement Contract volumes (refer Table 6.j) for high quality logs was the critical objective in CRA negotiations. However, the large High Quality Log volume alone was used as the product to maximise in *Spectrum* because it was identified as the limiting factor. Other forest products are either by-products of quota quality harvesting and/or have always been considerably less than maximum volumes capable of being produced.

The objective function specified in *Spectrum* was to maximise the volume of large high quality sawlog (>40cm cdub) volumes within the defined constraints.

TABLE 6.J: SUMMARY OF TOTAL VOLUME COMMITMENTS AND ALLOCATIONS PER TIMBER CATCHMENT ZONE IN UPPER & LOWER NORTH EAST CRA REGIONS

Timber Catchment Zone	**Term & Wood Supply Agreements**	
	Allocation in Term and Wood Supply Agreements - Large High Quality Sawlogs	Allocation in Term and Wood Supply Agreements - Small High Quality Sawlogs
TCZ 1	42,940	429
TCZ 2	86,275	1,448
UNE Total	129,215	1,877
TCZ 3	89,239	7,003
TCZ4	23,794	1,343
TCZ5	5,470	-
TCZ6	21,357	-
LNE Total	139,860	8,346
Total UNE & LNE	269,075	10,223

6.7 CONSTRAINTS

The constraints pertaining to the harvesting of UNE and LNE forest resources on State forest included:

(a) Restrictions on area available for harvesting due to:

- EPA licence conditions;
- NPWS conservation protocols;
- Protected forest types - rainforest and rare forest types; and
- Non-commercial forest, physically and economically inaccessible areas, and PMP exclusions identified by SFNSW.

(b) Permissible silvicultural options due to EPA / NPWS protocols:

- Australian Group Selection silviculture restrictions on gap size and return time; and
- Single Tree Selection silviculture restrictions on maximum proportion of basal area removed.

(c) Forest management requirements:

- Current contractual wood supply levels and proposal to extend these to 20 years;
- Minimise log cartage between wood supply catchments when meeting supply; commitments to industry as these would not occur in practice due to prohibitive transportation costs;
- Achieve appropriate species mix of required product;
- Achieve a future sustainable wood supply;
- Achieving and maintaining suitable native forest composition, structure and distribution to achieve a sustainable wood supply;
- Implementing silvicultural prescriptions in plantations – initial stocking, thinning regime and clearfell ages; and
- Implementing silvicultural prescriptions in native forest – minimum harvesting triggers for economic volume and composition of log products, achieving adequate site disturbance and canopy removal for regeneration, retaining adequate regeneration and habitat trees.

The constraints were modelled using three mechanisms. The constraints on the area available for harvesting and the restrictions on silvicultural prescriptions were largely accounted for in the preparation of data imported into model from the yield simulator, while the constraints on the wood supply, permissible silvicultural options and plantation clearfell ages were addressed in the yield scheduling process. The inter-wood supply catchment, species composition and fauna strike rate issues were addressed post modelling.

6.7.1 Constraints external to model

The constraints accounted for in the preparation of data imported into model included the derivation of the net harvestable area and the yield tables. As the harvest area constraints (exclusion areas) were subject to variation, the database was structured to permit recalculation of the area data files imported (refer Moore, 1999). Similarly the yield constraints (silvicultural prescriptions and log specifications) were subject to variation. The yield simulator model was designed to permit recalculation of yield tables resulting from different silvicultural conditions and log specifications.

Net Harvestable Area

The Net Harvestable Area of native forest used in the *Spectrum* model was calculated using NHAQUERY (refer Section 5.1). This NHA model enables the area datafiles for *Spectrum* to be recalculated after identifying different area exclusion factors and conservation (C-PLAN) reserve designs (refer Moore, 1999).

The FRAMES Net Harvest Area was varied during the "options development phase" of the CRA negotiations.

The modifications included:

(a) C-Plan scenario conservation reserve exclusions (i.e. list of unavailable compartments / planning units were generated with each NPWS C-Plan conservation reserve scenario. A list of unavailable compartments/planning units each time a planning unit is excluded the total stratum net area is reduced by the amount contained in the planning unit); and

(b) Modifying proposed NPWS protocols:

- in/exclusion of buffers on buffers along waterways, identified wilderness, State capable wilderness areas; and
- old growth definitions -candidate old growth, high quality habitat old growth and high conservation value old growth.

Yield Table

Native Forests

The strata yields per hectare (from net harvestable area) were generated for the range of silvicultural systems and prescriptions, log specifications and management options (delay periods before commencing cutting cycle). Any restrictions on silviculture were accounted for in the design of the yield tables.

It should be noted that these yields per hectare are average strata yields per hectare. For a given stratum the yield arising from individual plots are summed and then divided by the total number of plots in the stratum. As the maturity of plots within a stratum varies, the number of plots contributing to yield (i.e. those harvested) varies each year. So the stratum average yield per hectare does not resemble the yield from a specific hectare within the stratum, rather the average yield expected from a conceptual stratum hectare. When the yield is multiplied by the stratum area, the correct total yield is calculated.

The silvicultural systems only included Single Tree Selection (STS) and Australian Group Selection (AGS). Clear cutting was not permitted.

The constraints on silvicultural prescriptions included:

- maximum basal area removal in STS (40% basal area in heavy intensity operation);
- maximum gap size in AGS (The maximum modelled was 100 m gap for heavy operation, but in the more accepted medium intensity operation – the maximum permissible gap was 70m;
- minimum return time between harvesting operations in AGS working circle (10 years in initial silvicultural strategy);
- minimum log length 3.6m for HQL; and
- habitat retention (minimum no. trees required were monitored. No explicit mechanism was modelled).

Hardwood Plantations

The yields per hectare generated for each strata (current and replant) were based on the fixed silvicultural prescriptions, but yields were provide for the full range of potential clearfell ages.

While the clearfell age could be constrained by the use of a single age clearfell volume, the flexibility for harvesting at a range of ages was maintained to provide full flexibility for the yield scheduler.

6.7.2 Modelling constraints

The *Spectrum* model template formulated for modelling the future management of the UNE and LNE NSW forests was structured to enable a range of management constraints to be represented.

The constraint options available included:

<u>Wood supply constraints</u>

1. General Constraints were set up to enable the representation of minimum or maximum target volumes of high quality log (wood supply term agreements or maximum achievable volume, which ever was the lesser).

To apply a general constraint, constraint variables were defined which identified which product (e.g. large high quality logs) and the areas from which the product can be sourced (e.g. whole area, catchment, strata etc).

The analysis units were structured with attributes which enable the constraints to be applied to multiple themes or geographical areas. The classes include:
- Wood Supply Catchment (groups of timber supply zones);
- Timber Supply Zone;
- Strata or groups of strata;
- Forest type / "silvicultural practice" (moist, dry forest types); and
- Disturbance Intensity – maximum harvesting intensity permissible.

While the constraints can be applied to areas ranging from individual analysis units to the whole resource, constraint variables were only defined for the whole modelling region and for wood supply catchments as the wood supply modelling was being conducted at a strategic level. The variable names defined were:

ALQ = volume of large high quality sawlogs that can be sourced from all areas
TC_*n* = volume of large high quality sawlogs that can be sourced from Timber catchment *n*

Constraining the level of harvest / wood production within timber catchments within bounds was seen as necessary to ensure changes in harvesting at an operational level were realistic and to ensure production for nearby industry is maintained within economical transport distances. Without constraints on the source of wood, the LP model will maximise the overall wood supply, which may result in substantially erratic changes in the source of wood over time. The spatial and temporal volatility would result in inter-wood supply catchment log cartage to meet supply commitments to industry. This would not occur or be unfavourable in practice due to prohibitive transportation costs.

The range of outputs and activities (log product volumes, areas harvested, forest type volumes) available for defining a constraint variable were:

Outputs:
- large HQ sawlog volume (HQ_L_sawlog);
- small HQ sawlog volume (HQ_S_sawlog);
- low value sawlog volume (LQ_sawlog);
- pulp volume (PULP);

- net area of plantations harvested (netarea_plt); and
- net area of uneven-aged forest harvested (netarea_ue).

Activities:
- plantation harvest volume (pl_harvest); and
- uneven-aged forest harvest (ue_harvest).

For each General Constraint applied to a variable, the details specified:
- period(s) applicable;
- operator (minimum, maximum or exact value); and
- quantity of product defined for 5 year period (volume of HQL).

2. Harvest Policy Sequential Constraints were set up to enable the wood supply (aggregation of one or more log product volumes) from the whole resource of a nominated log product to be restricted. Note – this constraint can be applied to other defined outputs and not just wood supply of one or more log products.

Options include:
- Non-declining yield. The constraint is used to ensure wood production does not diminish but continues to be maintained or increase. The minimum and maximum increase in the wood supply is specified for a defined period(s) so that the rate of increase can be regulated;
- Sequential yield. The constraint is used to smooth the yield flow. The maximum decrease and maximum increase are specified for a defined period(s) to regulate the maximum level of change in harvest levels between periods. A zero decrease and increase is equivalent sustainable yield; and
- Absolute yield. The constraint is used to limit the total wood supply to within defined bounds. The minimum and maximum levels of harvest are specified for a defined period(s).

<u>Native Forest Silvicultural prescription restrictions</u>

The two primary silvicultural constraints considered in *Spectrum* were to:
- restrict the permissible silvicultural intensity e.g. no heavy intensity AGS; and
- restrict silviculture systems to specific forest types e.g. AGS only applicable in moist forest types and STS applicable in dry forest types.

The Management Action Definitions and Management Action Schedules were collectively used to identify which silvicultural options could be applied (were permissible) to different areas of native forest (land themes). For each management action (e.g. AGS heavy intensity) the land themes (analysis units grouped by specific combinations of attributes) on which the management action can be applied were defined.

The land themes used for constraining silviculture included:
- native forest analysis unit Silvicultural practice (Moist or Dry – surrogates for AGS and STS silviculture);
- native forest analysis unit Disturbance Intensity (maximum harvesting intensity permissible in modelling); and
- native forest strata land themes (specific combinations of strata).

To restrict a given intensity of silviculture (e.g. AGS heavy intensity) the Disturbance Intensity field was set as IGNORE, so that none of these analysis units will be assigned AGS heavy silviculture. IGNORE was pre-set as a Disturbance Intensity Attribute.

The following table (refer Table 6.k) indicates:
- heavy intensity silviculture (STS) can be applied only to sites where heavy intensity is permissible;
- medium intensity silviculture can be applied to sites where medium and heavy intensity is permissible; and

- light intensity silviculture can be applied to sites where light, medium and heavy intensity is permissible.

TABLE 6.K: MANAGEMENT ACTION DEFINITIONS – RESTRICTING SILVICULTURAL INTENSITY

Management Action	Analysis Unit	TSZ	Strata	Prac	Distub	Emphasis	Intensity
Australian Group Selection Heavy	All	All	All	Any	ignore	gtimb	heavy
Australian Group Selection Medium	All	All	All	Any	grp_mh	gtimb	medium
Australian Group Selection Light	All	All	All	Any	grp_lmh	gtimb	light
Single Tree Selection Heavy	All	All	All	Any	grp_h	stimb	heavy
Single Tree Selection Medium	All	All	All	Any	grp_mh	stimb	medium
Single Tree Selection Light	All	All	All	Any	grp_lmh	stimb	light

To restrict the AGS and STS silvicultural system to moist and dry forest types respectively the Silvicultural Practice attributes MOIST and DRY were filtered out as criteria (refer Table 6.l).

TABLE 6.L: MANAGEMENT ACTION DEFINITIONS – RESTRICTING SILVICULTURAL PRACTICE

Management Action	Analysis Unit	TSZ	Strata	Prac	Distub	Emphasis	Intensity
Australian Group Selection Heavy	All	All	All	Moist	grp_h	gtimb	heavy
Australian Group Selection Medium	All	All	All	Moist	grp_mh	gtimb	medium
Australian Group Selection Light	All	All	All	Moist	grp_lmh	gtimb	light
Single Tree Selection Heavy	All	All	All	Dry	grp_h	stimb	heavy
Single Tree Selection Medium	All	All	All	Dry	grp_mh	stimb	medium
Single Tree Selection Light	All	All	All	Dry	grp_lmh	stimb	light

The moist and dry classifications are fixed in the area database. While the imported database Silvicultural Practice attributes can be changed, to apply the silvicultural systems to other classifications, new themes were created by grouping strata.

<u>Plantation Harvest Ages</u>

The plantation yield tables imported into *Spectrum* for each strata contain the yields for thinning at prescribed ages, and clearfelling volumes expected at a range of clearfell ages. Clearfelling yields were provided at a wide range of rotation ages (7 – 12 periods) for modelling flexibility. The clearfell ages could be constrained through two mechanisms:

- The yield table clearfell age range could be reduced in the imported yield table; and
- In the Management Action Schedules for plantation silviculture, the range of stand ages to clearfell the stand could be reduced.

<u>Plantation regeneration crop types</u>

As noted in Section 6.2, the model 1 formulation of *Spectrum* was used. So for each plantation strata a single existing crop yield table and regeneration yield table were nominated prior to modelling. Each strata was assigned the relevant existing and regeneration yield table by creating a set of yield tables for each strata, and within Yield Table File 1 specifying the strata code.

6.7.3 Post-Modelling Constraint Allowances

Not all of the constraints were integrated into the data sets or the modelling process but were accounted for through post-modelling adjustments to outputs.

1. ESFM Type "C" protocols describe resource values that cannot be located in advance but must be protected as they are encountered during field operations. Typically the protective measure is a 100% harvest exclusion zone around the feature of interest. The impacts of these measures were modelled using the species specific protocol "Strike Rate".

The net harvest area reduction, which is due to fauna strikes, was estimated to be 6.7%. On average the area reduction correlates to volume reduction, so a volume reduction of 6.7 % was applied to the wood supply level generated.

2. Timber supply catchment woodflows.

In the UNE the TC1 and TC2 wood flows were seen as manageable (based on local knowledge and outcomes of preliminary modelling) and no adjustment to account for any transportation constraints was applied.

In the LNE where 4 timber catchments are present, a volume reduction of 3.5% was applied to account for the impact of transportation constraints on the theoretical maximum achievable wood supply level.

3. Achieve appropriate species mix of required product.

No explicit constraints were applied to model the market requirements. The predicted composition of species was calculated by applying 3 year historical trends to the model forecasts of volume by strata. The consequential species composition reported was evaluated and considered acceptable.

6.8 FORMULATION OF LP MATRIX AND OBTAINING PROBLEM SOLUTION

The linear programming (LP) matrix generation and problem solving are automated stages of the *Spectrum* modelling. Once a model has been constructed, the *Spectrum* model is run to generate an LP matrix and is solved with the optimisation package C-WHIZ.

The matrix default report MAT.FIL is automatically generated and contains a summary of the model data; list of all activities and outputs that occur on each analysis unit for each management action and schedule; and a list of all the model data errors encountered during matrix generation which require correction before solving the matrix. The majority of the data format and data relationship errors were corrected in the initial templates formulated. The matrix generation time varied with the size of the model and the speed of the computer used.

Once an LP matrix was generated without errors, it was solved using the solution software LP package C-WHIZ. Each time an LP matrix is solved the LP report (LP.FIL) and LP solution files (LP.SOL) are created. The LP report contains model summary statistics, timing information on problem input and solution phases, matrix reduction information, abbreviated iteration log and complete solution results. The LP solution files contains the optimal objective function value and information associated with each row and column in the solution. The file is written in the standard LP mathematical programming solution format.

When the LP solver is executed it will converge on an optimal solution and reports either (a) a feasible solution - the most favourable option which maximises / minimises the objective function subject to the constraints imposed, or (b) an infeasible solution where two or more constraints cannot be simultaneously satisfied.

Where an infeasible solution occurred the constraints were relaxed or modified (e.g. minimum HQL volume, % change in volume between periods). While the reasons for the infeasible solutions can be derived from the LP report, experience gained from repeated analyses plus the quick processing time of *Spectrum* runs, enabled yield scheduling staff to identify constraint levels which would provide feasible solutions through limited trial and error.

Feasible solutions were evaluated and improved where possible by imposing tighter or additional constraints and modifying the objective function until the best feasible solution that could be arrived at. The process of deriving an acceptable LP problem solution for a given conservation reserve design was typically multi-staged (refer Section 7.3) where part of the planning horizon was optimised (20 year RFA period) according to one objective function and constraints, and then the outcomes from this were translated into constraints so the sustainable yield for the remaining 80 years of the 100 year planning horizon could be ascertained.

6.9 DEVELOPMENT OF CUSTOM SOLUTION REPORTS

Once the LP matrix has been solved and a feasible solution obtained, solution reports can be generated. Reports include the following types, the information in which can be summarised by analysis unit and forest wide:

- All activities and outputs;
- Customised activity and outputs;
- Complete financial summary;
- All treatment types;
- Customised treatment types;
- All inventory, harvest, and growth;
- Customised inventory, harvest, and growth;
- Customised acres by age class;
- Database reports;
- Goal objective report; and
- Allocation summary.

Spectrum generates reports in two formats:

- Report format - a DOS file for printing (RPT.FIL); and
- Export format - a comma delimited file for export to spreadsheets, ArcView, or other programs (COMADEL.TXT).

Spectrum run solution reports were required during model runs to evaluate solutions and to present summaries of the wood supply forecasts. A customised solution report was constructed in *Spectrum* to provide output details of the wood supply forecasts. A separate model SUMMARY.XLS was developed to translate the export report COMADEL.TXT into summary tables and histograms (refer Section 6.11).

The Customised Solution Report was structured to provide details for each analysis unit and the whole forest resource on the wood volume and area harvested (plantation, uneven-aged native forest) by log product (large and small high quality sawlog, low quality sawlog, pulp) and 5 year time interval over the 100 year planning horizon (refer Table 6m). The forest level summary information provides the volume and area data by prescribed silvicultural system and disturbance intensity. The full range of report types specified in the custom report is listed in Appendix 3.

TABLE 6.M: EXCERPT OF ANALYSIS UNIT DETAILS IN RPT.FIL REPORT

```
ANALYSIS UNIT:   1           46.    ACRES


    MANAGEMENT ACTION:   Single tree sel medium                              46.         ACRES
           TC3-1  8      Moist  heavy     .      .    stimb  medium
           Yield Composite(s):   ue_c
         PROPORTION         OUTPUT NAME
              1.000    (!!      )!!      *!!      +!!

           Column Name:          1yH!'! 2
           Existing Schedule:    ENTRY:   2   HARV:  25
           Regen Schedule:       ENTRY:   0   HARV:   1
           Beginning Age:         1
     - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

A10.2  MULTI-PERIOD OPTIONAL REPORT FOR ANALYSIS UNIT         yH!   yH!
       ACTIVITIES, OUTPUTS AND THEIR FINANCIAL EFFECTS

ACTIVITY/OUTPUT          UNITS
COD  AU /  TSZ    NatStr PRAC   DISTUB PlnStr Layer6 Emphas Intens
    ZONE

    TREATMENT TYPE     - QUALIFIER --  - QUALIFIER --
                       SY   MIN   MAX  SY   MIN   MAX
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
                                                                        PERIOD
                                                         1       2       3       4       5
                                                         6       7       8       9      10
                                                        11      12      13      14      15
                                                        16      17      18      19      20

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
    HQ_L_sawlog             cum
HSM           .      .      .      .      .      .    stimb  medium

                                  OUTPUT/PERIOD                 648             143     121
( 6-10)                                                145     129      77     100     155
(11-15)                                                116      32     104     107
(16-20)                                                175      74      19      84      62
    HQ_S_sawlog             cum
SSM           .      .      .      .      .      .    stimb  medium

                                  OUTPUT/PERIOD                 153              31      43
( 6-10)                                                 41      42      27      35      30
(11-15)                                                 23      12      23      33
(16-20)                                                 33      13       2      11       6
    LQ_sawlog               cum
LSM           .      .      .      .      .      .    stimb  medium

                                  OUTPUT/PERIOD                 329              55      78
( 6-10)                                                 44      85      51      54      99
(11-15)                                                 58      18     109      59
(16-20)                                                151      23      34      99      37
    Pulp                    cum
PSM           .      .      .      .      .      .    stimb  medium

                                  OUTPUT/PERIOD                 481              91     106
( 6-10)                                                100     117      90      74     128
(11-15)                                                 84      28     118      86
(16-20)                                                173      39      19      78      44
    netarea_ue              hectares
ASM           .      .      .      .      .      .    stimb  medium

                                  OUTPUT/PERIOD                  46              46      46
( 6-10)                                                 46      46      46      46      46
(11-15)                                                 46      46      46      46
(16-20)                                                 46      46      46      46      46
    HQ_L_sawlog             cum
FWL           .      .      .      .      .      .      .      .

                                  OUTPUT/PERIOD                 648             143     121
( 6-10)                                                145     129      77     100     155
(11-15)                                                116      32     104     107
(16-20)                                                175      74      19      84      62
    HQ_S_sawlog             cum
FWS           .      .      .      .      .      .      .      .

                                  OUTPUT/PERIOD                 153              31      43
( 6-10)                                                 41      42      27      35      30
(11-15)                                                 23      12      23      33
(16-20)                                                 33      13       2      11       6
```

6.10 MODEL TESTING AND VALIDATION

The model templates created for the LNE and UNE were subjected to acceptance testing and validation.

1. Verification of model template:

- all analysis unit and yield data was imported and interpreted correctly by *Spectrum*;
- all land attributes were valid and the correct groups created;
- planning horizon and period length was valid;
- all management action activities & output variables and attributes & groups were present and valid;
- all management action definitions and schedules were complete and valid;
- the custom report specifications generated correct report format and content; and
- full suite of objective functions and constraints were correctly set up and functional.

2. Testing of *Spectrum* model:

- the *Spectrum* model would work under Windows 95 and Windows NT operating system; and
- the C-WHIZ LP solver settings were made and functioned correctly.

3. Reasonability testing of *Spectrum* model:

- High level wholesale checks of model runs were made to verify that the magnitudes of harvest (volume and area) were realistic and the database was being correctly interpreted.
- The model templates were run repeatedly changing input variables to test validity of results and sensitivity. Checks included evaluating whether the magnitude and trends of solutions were logical and realistic.
- Repeated runs included different net harvestable area, permissible management action definitions & schedules, and different harvest level constraints.

4. Distribution Quality Control Procedure

The model templates were set-up and cut onto on compact disks so these models could be readily installed on computers of all stakeholders in the CRA negotiations. Necessary installation instructions were prepared to ensure all computer settings and the file directory structures were correctly established.

5. Reconciliation of forecasted Timber Priority Index measures from *Spectrum* versus independently assessed measures.

6.11 MODEL INPUT AND OUTPUT LINKAGES AND REPORTS

The strategic yield scheduling framework developed for using *Spectrum* comprises a set of routines which provide the following functions and outputs:

- semi-automated construction and formatting of net harvest area yield table input files for *Spectrum*;
- an interface with C-PLAN to make updated analyses in response to nominated CAR reserve scenarios;
- automated analysis of varying ESFM protocols on net harvest area;
- summary report of net harvest area and area exclusions;
- summary report of the forecasted long term wood supply by management area, log product, species and silvicultural strategies;
- output file (GIS link) which serves as input to spatial display of harvesting patterns over time; and

- data in formats appropriate for the economic and social models.

The purposes of the routines are:

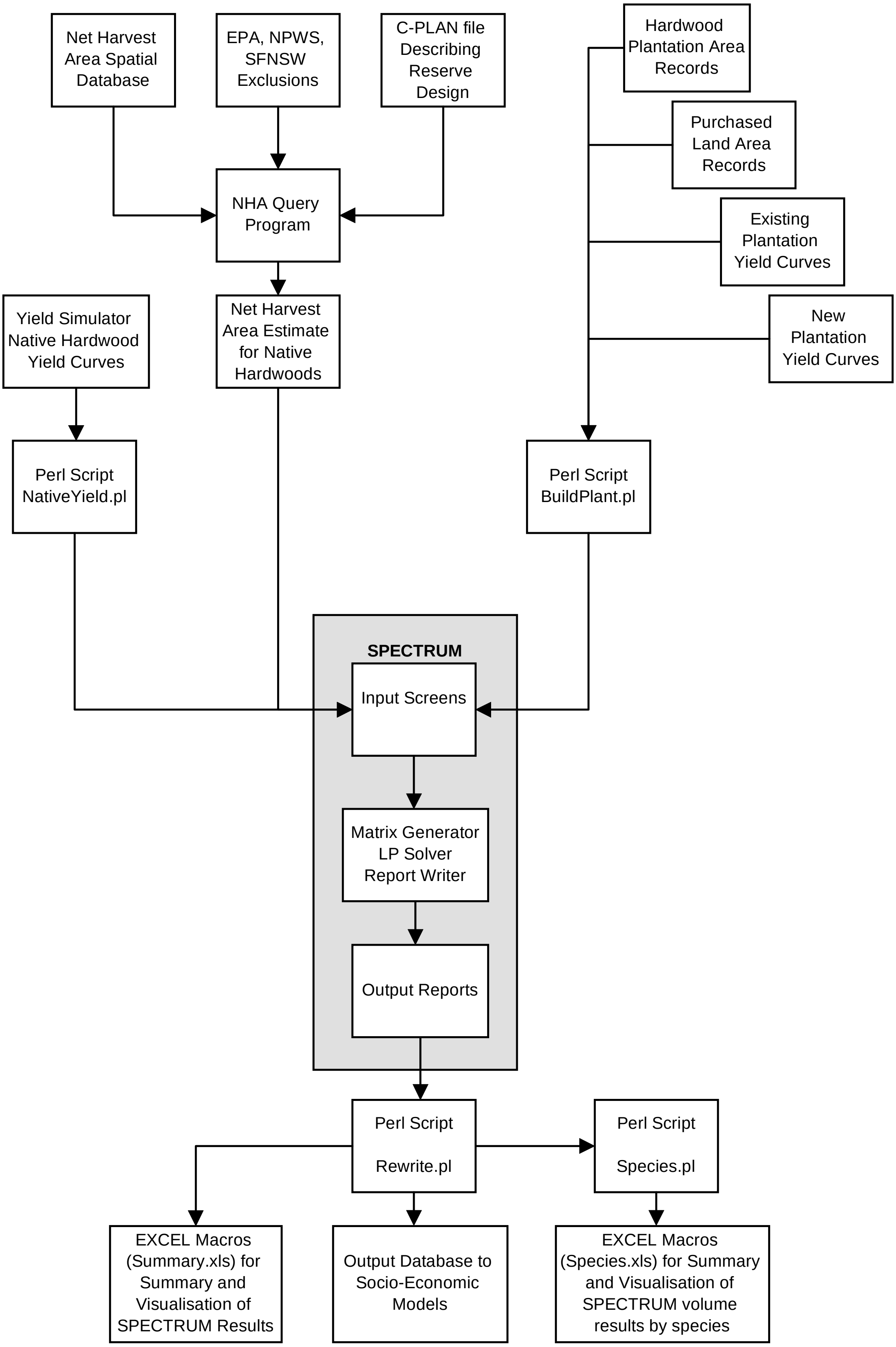
- to provide electronic linkages / interfaces between the various input data sources (GIS analysis units, C-PLAN, yield table files), *Spectrum* and the various required outputs. This process enables prompt and repeated construction of files in a consistent format and eliminates transcription and formatting errors and data compatibility issues;
- to transform input and output files into more useful customised summary reports for reporting the status of scenarios and to facilitate evaluation of inputs and results; and
- to provide supplementary files for linkages with other applications (GIS) and models.

The models and routines developed include:

NHAQUERY.exe	=	net harvest area determination
Native yield.pl	=	transforms native forest yield simulator output files into *Spectrum* yield table input files
BuildPlant.pl	=	transforms hardwood plantation yield files into *Spectrum* yield table input files
Rewrite.pl	=	transforms *Spectrum* output file into Summary.xls input file rewrite.csv
Summary.xls	=	summarises of wood supply results report
Species.pl	=	calculates future volume of species by timber catchment
Species.xls	=	summarises of wood supply by species projection

A range of scripts were written in PERL language (file *.pl) to assist in converting and formatting data into appropriate input and output files for *Spectrum* and summary Excel spreadsheet models.

FIGURE 6-1: SCHEMATIC DIAGRAM OF YIELD SCHEDULING MODELLING FRAMEWORK



6.11.1 NHAQUERY Model

The NHAQUERY model determines the net harvest area by deducting from the total forest area the

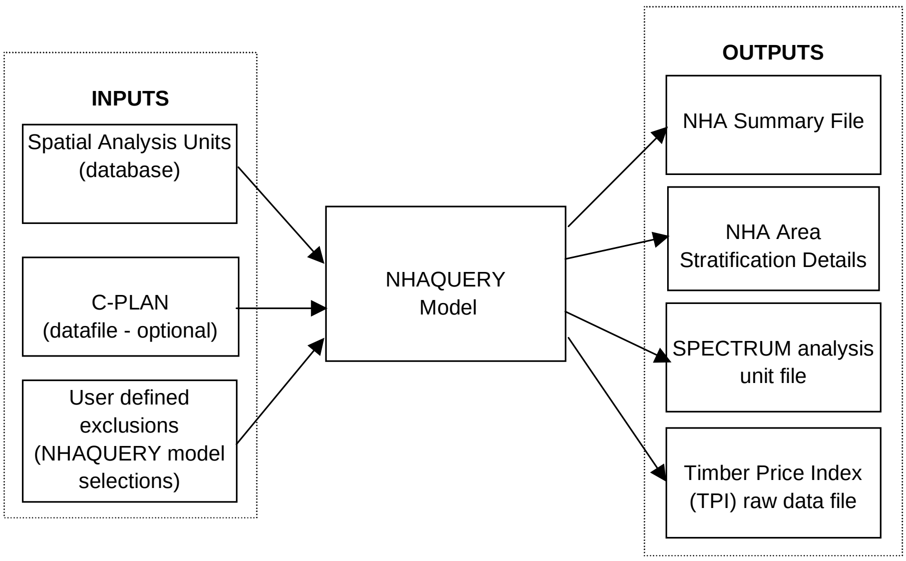
(a) C-PLAN proposed conservation reserve design file – planning units nominated for inclusion in a formal or informal reserve;

(b) User defined exclusions such as agreed EPA licence conditions and NPWS management protocols, SFNSW exclusions (adverse terrain and accessibility factors, leasehold conditions, State Forests management priorities, physical operability factors and economically inaccessible area, unmerchantable areas); and

(c) Net area planned vs actual harvest modifier which accounts for the probability of non-harvest and old growth NHA modifier.

The NHAQUERY model extracts the reserve design, exclusions, and modifiers from the Spatial Analysis Units database which has details on the attributes and area of each planning unit in the total forest area. The Net Harvest Area is that component of the forested land base that is outside the defined timber exclusion areas.

FIGURE 6-2: DIAGRAMMATIC REPRESENTATION OF NHAQUERY FUNCTIONALITY



Note: User defined exclusions include EPA licence conditions, NPWS protocols, SFNSW exclusions, NHA planned vs actual harvest modifier, old growth NHA modifier.

The C-PLAN file contains a description of the proposed conservation reserve design.

NHAQUERY was designed to be repeatedly and quickly run to generate the net harvest area analysis unit file from the spatial analysis unit database by specifying the C-PLAN file, version of NHA modifier and exclusions.

The NHA query program (NHAQUERY.exe) is activated by a batch file (QUERY.bat) where the user specifies the following parameters:

- input spatial analysis unit coverage;
- input C-PLAN reserve design file;
- input name of NHA modifier;
- output NHA summary file (csv format);
- output *Spectrum* analysis unit (AU) file (csv format);
- output TPI raw data file (csv format); and
- list of themes to remove from NHA estimate.

Examples of NHAQUERY outputs

TABLE 6.N: OUT1.CSV NHA AREA STRATIFICATION DETAIL FILE EXCERPT

gross area	net area	strata	tc	purch	swd_pl	hwd_pl	pei	pmp13	pmpunav	rn17 wet	rn17 rock	rn17 heath	haz4
7.07	5.35	12	TC1-1	0	0	0	1	0	0	0	0	0	0
0.14	0.12	13	TC1-1	0	0	0	1	0	0	0	0	0	0
0.38	0.34	15	TC1-1	0	0	0	1	0	0	0	0	0	0
66.11	41.29	19	TC1-1	0	0	0	1	0	0	0	0	0	0
35.84	26.13	20	TC1-1	0	0	0	1	0	0	0	0	0	0
		strata	**tc**	**rn17 rf**	**crafti rf**	**epafilter 1**	**Epafilter 0**	**rn17 rnc**	**idwild**	**Un-merch**	**cplan**	**priority**	
		12	TC1-1	0	0	0	0	0	0	0	0	4	
		13	TC1-1	0	0	0	0	0	0	0	0	4	
		15	TC1-1	0	0	0	0	0	0	0	0	4	
		19	TC1-1	0	0	0	0	0	0	0	0	4	
		20	TC1-1	0	0	0	0	0	0	0	0	4	

TABLE 6.O: OUT2.CSV SPECTRUM ANALYSIS UNIT FILE EXCERPT

Analysis Unit ID	TSZ	Strata Number	Forest Type	Intensity	Blank	Blank	Area (ha)
0	TC1-1	12	Moist	medium			17.49
1	TC1-1	13	Moist	medium			50.51
2	TC1-1	15	Dry	medium			37.11
3	TC1-1	19	Moist	medium			36.97
4	TC1-1	20	Moist	medium			117.2
10000	TC1-17	P22.7	pln	normal			8.47
10001	TC1-17	P23.6	pln	normal			128.69
10002	TC1-17	P24.6	pln	normal			57.58
10003	TC1-17	P25.5	pln	normal			71.22
10004	TC1-17	P39.10	pln	normal			0.58

TABLE 6.P: OUT3.CSV TIMBER PRIORITY INDEX RAW DATA FILE EXCERPT

pluid	compartment	tsz	gross area	net area	net2gr	domYa	HQ_L_ current	HQ_S_ current	LQ_ current	Pulp_ current
10063	500002		190.6	0	0	0	0	0	0	0
10083	500003		692.77	0	0	0	0	0	0	0
10106	500004		491.89	0	0	0	0	0	0	0
10107	500005		599.13	0	0	0	0	0	0	0
10409	500007		36.42	0	0	0	0	0	0	0

			HQ_L_20	HQ_S_20	LQ_20	Pulp_20	HQ_L_100	HQ_S_100	LQ_100	Pulp_100
10063	500002		0	0	0	0	0	0	0	0
10083	500003		0	0	0	0	0	0	0	0
10106	500004		0	0	0	0	0	0	0	0
10107	500005		0	0	0	0	0	0	0	0
10409	500007		0	0	0	0	0	0	0	0

TABLE 6.Q: QUERY.OUT NET HARVEST AREA SUMMARY FILE

```
Coverage:           f:/frames/une/un_sau
CPlan file:         SP_del_101198_I.CSV
NHA modifier:       NHAM2_HCV
NHA summary output: out1.csv
SPECTRUM AU output: out2.csv
exclusion region:   purch
exclusion region:   swd_pl
exclusion region:   hwd_pl
exclusion region:   pei
exclusion region:   pmp13
exclusion region:   pmpunav
exclusion region:   rn17_wet
exclusion region:   rn17_rock
exclusion region:   rn17_heath
exclusion region:   haz4
exclusion region:   rn17_rf
exclusion region:   rn17_rnc
exclusion region:   crafti_rf
exclusion region:   epafilter1
exclusion region:   epafilter0
exclusion region:   unmerch

Using CPlan reserve design:
   Tuesday November 10 1998    04:19 PM - No Description Specified
```

Total area of each exclusion zone

```
This estimate presents the impact of individual exclusions
without incremental effects.  Gross area represent the total
area of this exclusion.  Net area shows the reduction for the
net harvest area modifier.
Exclusion                     Gross Area           Net Area
purch                              22315              17109
swd_pl                             13999              13242
hwd_pl                              6727               5531
pei                               137043              89757
pmp13                              10591               7824
pmpunav                            33443              21853
rn17_wet                            2805               1802
rn17_rock                          10624               5752
rn17_heath                           102                 61
haz4                               28723              15133
rn17_rf                            39286              32201
rn17_rnc                            2627               2095
crafti_rf                          50283              40406
epafilter1                         71883              54341
epafilter0                         19191              14183
unmerch                           140372             105004
cplan                             156873              96798
```

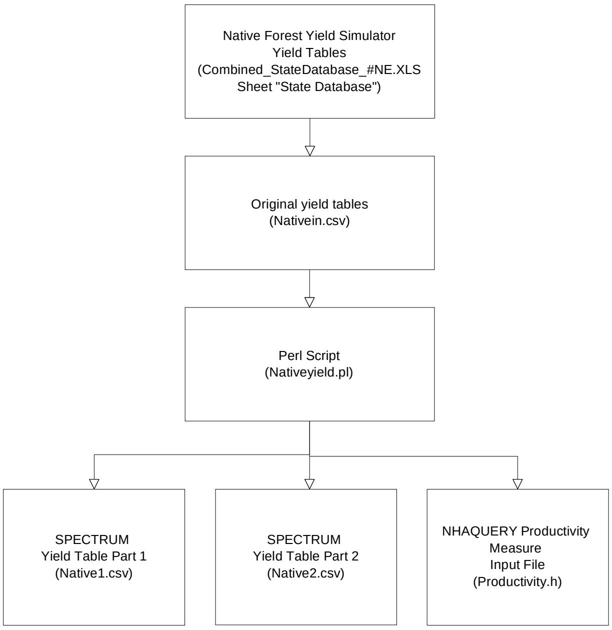
```
Net Harvest Area Estimate
This estimates the incremental impact of adding exclusions
one at a time.  Gross area represents the total area remaining
after the cumulative effect of all previous exclusions.
Net area includes reductions for the net harvest area modifier.

Exclusion                           Area
Gross Area                        624032
purch                             -22315
swd_pl                            -13999
hwd_pl                             -6727
pei                              -137041
pmp13                               -190
pmpunav                             -201
rn17_wet                           -1314
rn17_rock                          -3858
rn17_heath                           -46
haz4                               -8084
rn17_rf                           -13892
rn17_rnc                           -1777
crafti_rf                         -13881
epafilter1                        -39401
epafilter0                        -11783
unmerch                           -37036
cplan                             -62222
Net Mapped Area                   250264
Net Area Modifier                 -59625
Net Harvestable Area              190639


Marginal impact of each exclusion zone
This estimates the marginal impact of individual exclusions.
The estimate shows the increase in area from removing a single
exclusion from the total set.  Gross area represent the total
harvestable area including all other exclusions.  Net area shows
the reduction for the net harvest area modifier.

Exclusion                     Gross Area           Net Area
purch                              22312              17106
swd_pl                               195                178
hwd_pl                               748                519
pei                                28908              17417
pmp13                                  0                  0
pmpunav                                9                  5
rn17_wet                             122                 68
rn17_rock                           1063                649
rn17_heath                             2                  0
haz4                                5292               2627
rn17_rf                              125                 77
rn17_rnc                             192                162
crafti_rf                           4356               3172
epafilter1                         28258              22499
epafilter0                          8018               6302
unmerch                            23699              17255
cplan                              62222              34776
```

6.11.2 Native yield.pl

A PERL script that reads in the FRAMES yield simulator native forest yield table data and reformats them into the appropriate *Spectrum* CSV import file format.

The script also summarises productivity information into a “C” structure for inclusion into the NHAQUERY program.

FIGURE 6-3: DIAGRAMMATIC REPRESENTATION OF NATIVEYIELD.PL FUNCTIONALITY



6.11.3 BuildPlant.Pl

A PERL script that reformats the hardwood plantation yield table data into the appropriate *Spectrum* CSV import file format.

6.11.4 Rewrite .pl

The program reformats *Spectrum* output (wood supply volume and harvested area by land attribute for each log product and period) into files which have a format suitable for use in the EXCEL application.

Rewrite.dbf reads in data from the *Spectrum* Commadel.txt file, and translates the file into a meaningful data file. The conversion uses *Spectrum* Attr.dbf and AU.dbf record files which correspond to data fields in Commadel.txt.

The two files created with the Rewrite Perl script are:

(a) the file Rewrite.csv which summarise the harvesting records by land attributes for use in the Summary.xls program, and

(b) the file Productivity.csv which keeps a track of the 20 year and 100 year volumes of high quality logs by stratum. This is used in computing the Timber Priority Index,

FIGURE 6-4: DIAGRAMMATIC REPRESENTATION OF REWRITE.PL FUNCTIONALITY

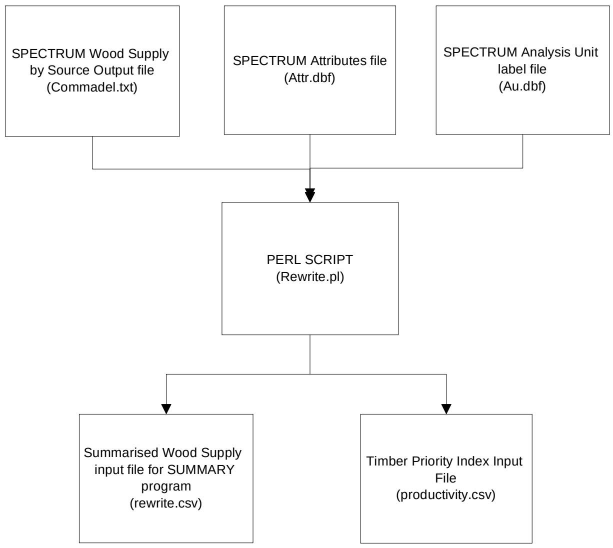


TABLE 6.R: REWRITE.CSV EXCERPT

TC	STRATA	PRACTICE	INTENSITY	PERIOD	AREA	HQ_L	HQ_S	LQ	PULP	Total	Catchment
TC2-19	10	STS	Heavy	1	9.6	74.8	18.8	84.8	95.2	273.6	TC2
TC2-19	10	STS	Heavy	2	0	0	0	0	0	0	TC2
TC2-19	10	STS	Heavy	3	9.6	29.4	7.4	27.4	41.8	106	TC2
TC2-19	10	STS	Heavy	4	9.6	17.4	9.4	22.2	28.2	77.2	TC2
TC2-19	10	STS	Heavy	5	9.6	7	0.4	2.8	5	15.2	TC2
TC2-19	10	STS	Heavy	6	9.6	30.8	20	36.4	64.8	152	TC2

6.11.5 Summary.pl

The summary program is a post-*Spectrum* modelling report writer. Summary.xls activates the rewrite, pl Perl script to transform and format the *Spectrum* model output file comadel.txt into a file compatible with EXCEL (Rewrite.csv). The summary file then produces summary tables and histograms of the long term forecast by period summarise by silvicultural practice, log product and timber catchment (refer Figure 6-6).

FIGURE 6-5: DIAGRAMMATIC REPRESENTATION OF SUMMARY REPORT FUNCTIONALITY

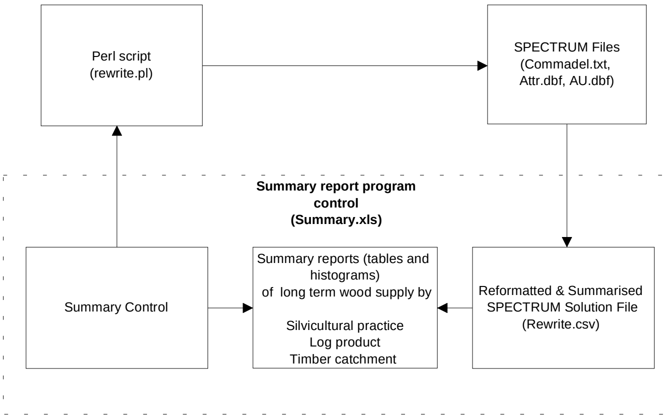
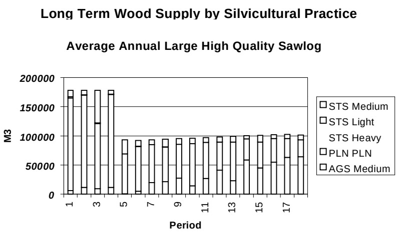
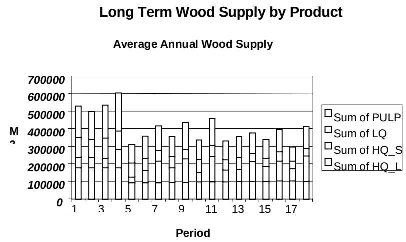
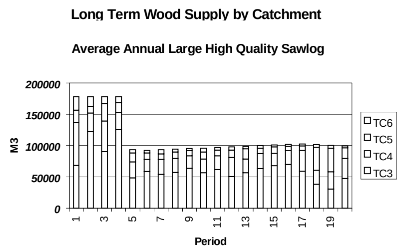


FIGURE 6-6: EXAMPLES OF SUMMARY REPORTS







Catchment	(All)

Sum of HQ_L	PRACTICE	INTENSITY				
	AGS	PLN	STS			Grand Total
PERIOD	Medium	PLN	Heavy	Light	Medium	
1	230	6082	158741	2187	10760	178000
2	0	11729	158195	393	7684	178001
3	234	9594	111103	1160	55912	178003
4	0	11481	159223	493	6808	178006
5	219	695	68331	0	24074	93319
6	88	5348	76480	251	10219	92385
7	211	19623	65006	0	8468	93308
8	93	21436	59248	185	13284	94246
9	0	27351	58176	0	9656	95183
10	99	14433	72172	0	9435	96139
11	0	27153	61861	0	8083	97097
12	106	41346	47730	206	8682	98070
13	0	23182	66062	0	9807	99052
14	0	58754	36087	0	5199	100040
15	0	45159	44334	0	11548	101040
16	0	54851	40296	0	6903	102050
17	0	62918	32506	0	6974	102398
18	0	64343	28669	0	8368	101380
19	0	49608	44169	0	6585	100362
20	0	64659	30300	0	4402	99361

Catchment	(All)

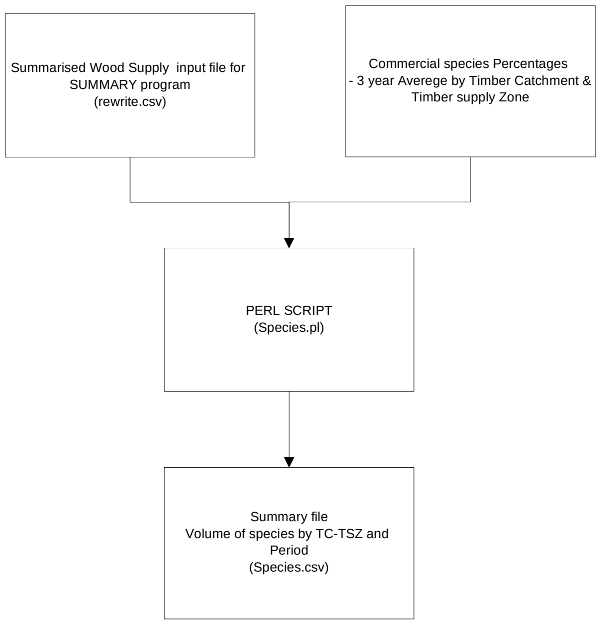
	Data				
PERIOD	Sum of HQ_L	Sum of HQ_S	Sum of LQ	Sum of PULP	Sum of Total
1	178000	59930	113125	176939	527995
2	178001	60942	100838	157459	497240
3	178003	54326	115823	187435	535586
4	178006	104381	105286	215440	603114
5	93319	30709	81148	103753	308929
6	92385	68026	72303	125656	358370
7	93308	122266	61555	139161	416290
8	94246	85163	63047	114388	356843
9	95183	133822	51906	154953	435863
10	96139	55753	73077	107922	332892
11	97097	146385	61447	153285	458214
12	98070	65897	59322	107185	330474
13	99052	68823	70573	117312	355759
14	100040	112481	46856	114297	373674
15	101040	82955	49974	101331	335300
16	102050	113224	53885	124662	393821
17	102398	70814	42195	79877	295284
18	101380	143546	42231	125257	412413
19	100362	46732	53688	92681	293463
20	99361	93366	41696	89596	324020

Sum of HQ_L	Catchment				
PERIOD	TC3	TC4	TC5	TC6	Grand Total
1	68275	68447	19633	21645	178000
2	122593	29322	11035	15051	178001
3	90160	48846	28614	10382	178003
4	125769	27421	15755	9060	178006
5	48383	25449	14363	5123	93319
6	58796	19272	10263	4055	92385
7	54290	24131	8507	6380	93308
8	57231	22435	10133	4447	94246
9	63575	19840	8395	3373	95183
10	56637	21882	11268	6352	96139
11	61869	21480	9407	4341	97097
12	50290	30628	12013	5139	98070
13	56435	22028	16594	3995	99052
14	63074	24113	8887	3966	100040
15	67673	20085	10128	3154	101040
16	69763	21991	7490	2806	102050
17	59493	32812	7436	2657	102398
18	38352	22142	36938	3947	101380
19	30777	27223	37788	4574	100362
20	47616	31908	16729	3108	99361

6.11.6 Species.pl

The species perl program is designed to read in the reformatted *Spectrum* file wood supply forecast Rewrite.csv and compute the percentages of commercial species by timber catchment and timber supply zone. The Rewrite program has the expected area harvested by stratum, timber catchment and timber supply zone by period. The Perl script Species.pl contains the percentages of commercial species based on 3 year historical log production data. The program calculates the weighted average species composition and total volume (high quality large sawlogs) expected by Timber Catchment and Species by period.

FIGURE 6-7: DIAGRAMMATIC REPRESENTATION OF SPECIES.PL FUNCTIONALITY



6.11.7 Species.xls

The Species.xls program provides summary tables and histograms of the forecast species composition by SFNSW management area and CRA Timber Catchment.

FIGURE 6-8: DIAGRAMMATIC REPRESENTATION OF SPECIES.XLS FUNCTIONALITY

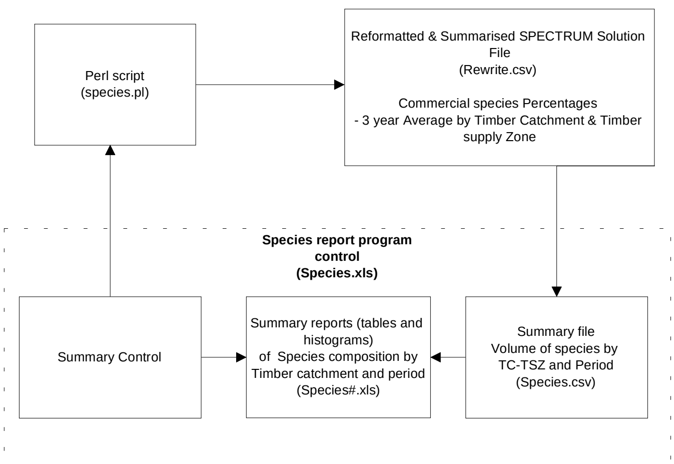
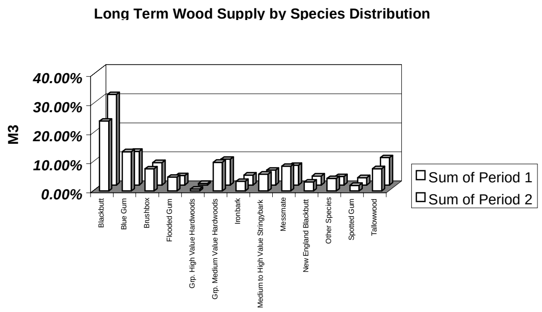
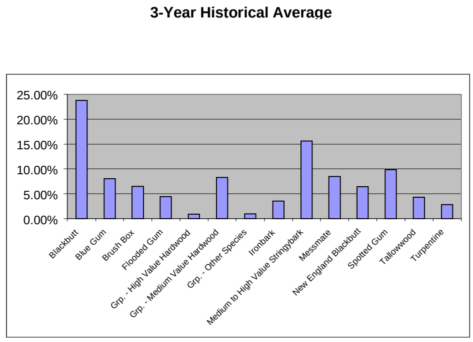


TABLE 6.S: SPECIES.XLS EXCERPT

'TC	Species	Period 1 Volume	Period 2 Volume	Period 3 Volume	Period 4 Volume
TC3	Blackbutt	181,949	252,188	404,490	233,371
TC3	Blue Gum	35,100	26,849	34,097	26,809
TC3	Brushbox	39,832	37,756	39,692	35,120

FIGURE 6-9: EXAMPLES OF SPECIES.XLS OUTPUTS





'TC	(All)

	Data			
Species	Sum of Period 1	Sum of Period 2	Sum of Period 3	Sum of Period 4
Blackbutt	24.11%	31.17%	46.91%	32.12%
Blue Gum	13.53%	11.62%	8.39%	10.75%
Brushbox	7.64%	7.76%	6.24%	6.41%
Flooded Gum	4.77%	3.26%	4.09%	3.80%
Grp. High Value Hardwoods	0.65%	0.58%	0.33%	0.60%
Grp. Medium Value Hardwoods	9.89%	8.92%	7.66%	9.01%
Ironbark	3.31%	3.46%	3.00%	5.44%
Medium to High Value Stringybark	5.81%	5.15%	2.95%	5.25%
Messmate	8.46%	6.84%	5.07%	3.20%
New England Blackbutt	3.17%	3.13%	1.83%	1.89%
Other Species	4.34%	2.93%	1.77%	3.99%
Spotted Gum	1.99%	2.58%	1.49%	3.77%
Tallowwood	7.65%	9.42%	7.97%	7.43%
Turpentine	4.68%	3.17%	2.31%	6.33%
Grand Total	100.00%	100.00%	100.00%	100.00%

TC	(All)

Average of percent	
Species	Total
Blackbutt	23.78%
Blue Gum	8.04%
Brush Box	6.46%
Flooded Gum	4.44%
Grp. - High Value Hardwood	0.90%
Grp. - Medium Value Hardwood	8.26%
Grp. - Other Species	1.00%
Ironbark	3.56%
Medium to High Value Stringybark	15.64%
Messmate	8.50%
New England Blackbutt	6.42%
Spotted Gum	9.85%
Tallowwood	4.34%
Turpentine	2.84%

7. WOOD SUPPLY MODELLING PROCESS

7.1 OVERVIEW

During the CRA negotiations multiple wood supply scenarios were modelled with *Spectrum* to ascertain the impacts of changing variables on future wood volumes, composition and location of harvesting. The process culminated in the formulation of a Final State Position for the LNE and UNE CRA regions.

The multiple scenarios were aimed at exploring the trade-off between conservation reserve design area including JANIS targets and wood supply, particularly of large high quality sawlogs.

Spectrum results and area zoned for production (net harvest area outside proposed reserves and exclusion areas associated with EPA / NPWS protocols and ESFM restrictions) were evaluated in terms of:

- ability to meet the Term & Wood Supply Agreement level of large high quality log production in the first 20 years and achieve the maximum future sustainable wood supply;
- ensuring the commercial species composition produced in the next 20 years would be satisfactory for industry;
- harvestable area was located in the more productive forest strata and geographical areas;
- harvestable area was concentrated in economic blocks (large blocks and closer to industrial processing plants);
- industry requirements with minimal inter-timber catchment log haulage;
- volatility of timber catchment production levels; and
- smaller, landlocked and remote blocks were excluded from the of production estate.

7.2 MODELLING SCENARIOS

CRA negotiations focussed on identifying a forest reserve design which best met the conservation criteria and attempted to meet the large high quality log (quota) contractual commitments.

The wood supply modelling scenarios included modelling the effects of changes to one or more of the following variables (refer Section 6.7 on constraints and Appendix 5 for example of scenario worksheet):

1. Net forest area available for harvesting.

Factors affecting the net harvestable area (NHA) which were evaluated included:

- conservation reserve designs from C-PLAN. A wide range of options were evaluated. Conservation reserves are a direct reduction in the State Forest gross forest area, not the area available for harvesting;
- modifications to EPA & NPWS protocols (in/exclusion of buffers on filter-strip buffers, identified wilderness and state capable wilderness, EPA filter strip extensions and mapped drainage filter strips);
- in/exclusions of alternative rainforest forest type definitions; and
- definitions of Old Growth areas (Candidate, High Quality Habitat, High Conservation Value).

2. Native forest yield tables applied

Factors evaluated which affect the type of yield tables applied included:

- restrictions on the intensity of harvesting operations (light, moderate, heavy) permissible in native forest;
- definition of harvesting operation intensity - maximum gap size and other specifications for AGS silviculture;
- restrictions on type of silviculture applied in different forest types (STS in dry forest types, AGS in moist forest types); and
- definition of large high quality sawlog specification for minimum length and diameter.

7.3 MODELLING APPROACH

The procedure used for obtaining a model solution for each scenario involved modifying the data inputs, objectives and constraints in the base model template and rerunning *Spectrum*. The modelling process depends on the `nature of constraints and resource characteristics, but the approach involved in the CRA negotiation for the UNE and LNE regions involved the following steps:

1. Importation of data files

The analysis unit file (net harvest area of native forest and plantation strata) was imported and where applicable the plantation and native forest yield tables were imported.

Separate templates were created for the different yield tables. This was done to minimise the time involved in data importing and record sorting, and to minimise erroneous use of model templates. A change to the net harvestable area of native forest was the primary factor evaluated in new scenarios.

2. Define management objectives and constraints

Objectives and constraints defined were:

- to attempt to meet the minimum volume of large high quality logs for a 20 year term, followed by a constraint identifying the maximum long term sustainable yield of large high quality logs; and
- the maximum permissible intensity of silvicultural regimes (AGS, STS) able to be assigned to native forest strata was constrained.

3. Run *Spectrum* model

The yield scheduling model was then run to generate a solution. The LP solver selects the best mix of stratum treatments to maximise the high quality timber volume from the whole forest over the modelling timeframe, and nominates the proportions of the stratum to be harvested at various points in the range of timing possibilities provided.

4. Evaluate results and re-define area inputs, silvicultural options, wood supply targets & constraints

The wood supply results from each *Spectrum* run and socio-economic impacts were evaluated to ascertain the need for further modifications in order to arrive at a scenario which maximises the conservation benefits and maintaining sufficient resource to meet industry objectives. Modifications include change to the areas available for harvesting (via forest reserve design based on NPWS C-PLAN model), NHA exclusions, yield table determinants (log specifications, silvicultural assumptions), the silvicultural options available and the wood supply constraints.

The precise modelling approach varied between scenarios as the area and location of formal reserves and the permissible silvicultural intensity varied.

The process of determining an optimal solution for a given scenario typically involved multiple runs for a given area statement and set of yield tables, due to the resource characteristics and level and profile of the wood supply target levels sought. For a given conservation reserve design the initial target for the northern NSW CRA Regions was to meet the Term and Wood Supply Agreement Contract volumes of high quality logs for 20 years, and to ascertain the sustainable wood supply level thereafter. The wood supply was modelled in two phases changing the Objective Function, General Constraints and Harvest Policy Sequential Constraints in *Spectrum*. While the objective function was always maintained at maximising the volume of high quality large logs, the constraints were modified to achieve the desirable wood supply profile.

First phase:
Aim: To ascertain if the Term and Wood Supply Agreement Contract target could be achieved for 20 years, or the maximum achievable level of production.

Objective function: set to maximise the volume of large high quality logs harvested in Periods 1 to 4 and to permit nil variation in production level over this period

Harvest Policy Constraints: Set sequential constraint so that no increase or decrease in large high quality logs production level between periods is permitted. Set the maximum permissible decrease to 0.000 and the maximum permissible increase to 0.000.

General constraints: No general wood supply constraints were applied to periods 5 – 20.

Second Phase:
Aim: Determine the maximum sustainable level of HQL production for periods 5 – 20.

Redefinition of targets and constraints based on the first phase outcomes. Define 20 year volume as constraint then determine maximum sustainable yield (smoothed) for balance of planning horizon.

Objective function: set to maximise the volume of large high quality logs harvested in Periods 5 to 20 and to permit nil variation in production level over this period

Harvest Policy Constraints: Set sequential constraint so that no increase or decrease in large high quality logs production level between periods is permitted. Set the maximum permissible decrease to 0.000 and the maximum permissible increase to 0.000.

General constraints: Set the general wood supply constraint for the UNE and LNE at the Term and Wood Supply Agreement Contract levels or maximum HQL production level achievable for periods 1 – 4, whichever is the lesser.

APPENDIX 1: SILVICULTURE AND YIELD TABLES

Appendix 1.1: Native Forest Yields

Silvicultural Options

The UNE and LNE NSW native uneven aged forests are managed according to two primary silvicultural systems – Single Tree Selection (STS) and Australian Group Selection (AGS). The yield tables simulated are based on the following silvicultural prescriptions.

Single Tree Selection

The management of uneven aged forest involving periodic selective harvesting of individual or small clusters of commercially mature trees. The level of tree removal is limited by a maximum level of basal area that can be removed.

A harvesting event can occur when the merchantability conditions (stand end-point) are reached – a condition of stand where it is sufficiently mature for the extraction of a minimum economic volume of high quality logs while ensuring an adequate basal area is retained for future wood production and habitat. Only high and low composite quality trees will be removed (i.e. quota, salvage logs, poles, posts, girders). No pulp or waste composite quality trees are removed. The proportion of eligible trees removed in a harvest event is constrained to ensure there is adequate recruitment into larger diameter classes, and to preserve adequate seed and habitat trees in the residual stand. The maximum proportion of the basal area removed varies with the operation intensity. Three intensity levels (light, moderate, heavy) of STS were modelled.

SINGLE TREE SELECTION (STS) BASAL AREA REMOVAL

Specification	Silvicultural Regime		
	STS Light	STS Medium	STS Heavy
Maximum % BA removal	20%	30%	40%

SPECIFICATIONS FOR STS REGIME HARVEST OPERATION IN NATIVE FOREST

Variable	Yield Association				
	Moist Blackbutt	Moist Coastal Eucalypts	Semi Moist & Taller Dry Eucalypts	Moist Tablelands	All Dry Types
Min HQ large volume for harvest (m^3/ha)	7	7	7	7	7
Min diameter for HQ large volume for harvest (cm)	65	55	50	50	50
Min. retained BA (m^2/ha)	12	12	12	12	12
Min. harvest return time (years)	10	10	10	10	10

MAXIMUM PROPORTIONS OF DIAMETER CLASS REMOVED IN DRY FOREST TYPES

Dry Yield Associations				
Tree Quality Type	**Maximum Percentages Removed by Diameter Class**			
	10-30cm	**30-50cm**	**50-70cm**	**70cm+**
High Quality	0%	20%	80%	80%
Low Quality	0%	80%	80%	80%
Pulpwood	0%	0%	0%	0%
Waste	0%	0%	0%	0%

MAXIMUM PROPORTIONS OF DIAMETER CLASS REMOVED IN MOIST FOREST TYPES

Moist Yield Associations				
Tree Quality Type	**Maximum Percentages Removed by Diameter Class**			
	10-30cm	**30-50cm**	**50-70cm**	**70cm+**
High Quality	0%	20%	80%	95%
Low Quality	0%	80%	80%	80%
Pulpwood	0%	0%	0%	0%
Waste	0%	0%	0%	0%

<u>Australian Group Selection (AGS) Management</u>

AGS is a harvesting system where a management unit (working circle) is progressively harvested as small groups of trees in a staggered sequence over time. A large number of small areas (gaps) are simultaneously harvested within a compartment. The total area harvested within a working circle is determined by the allowable gap size, maximum proportion of the working circle which can be harvested in a given harvest event, the proportion of the working circle which will be retained and the minimum return time before the working circle can be revisited to create subsequent gaps, thinning or re-resets. As the sequence of gaps is established, the gaps will be harvested according to the thinning / gap. Two sets of silvicultural specifications were modelled in the CRA negotiations – an Initial Silvicultural Strategy and a Revised Achievable Silviculture. The Initial Silvicultural Strategy was adopted in the Final State Position.

An initial harvesting event (reset) involves the complete clearance in a gap of all trees in all age classes. After the first proportion of gaps are created, at the subsequent return time adjacent gaps (not necessarily immediately adjacent, but within the same area) will be formed. At each return time for the working circle, the previously formed gaps (older regenerated trees) are evaluated in terms of their suitability for thinning to promote growth on the larger better form trees and remove smaller less desirable trees. Eventually once the sequence of gaps has been established across the whole area, the initial gaps will be harvested (re-reset) as they mature and the whole cutting cycle repeated. Three intensity levels (light, moderate, heavy) of AGS were modelled.

SPECIFICATIONS FOR THE AGS SILVICULTURE GAP CREATION IN NATIVE FOREST

Specification (All yield associations)	Initial Silvicultural Strategy			Revised Achievable Silvicultural Strategy		
	AGS Light	AGS Moderate	AGS Heavy	AGS Light	AGS Moderate	AGS Heavy
Gap Size (m)	40	70	100	40	50	70
Proportion of net area gapped in harvesting event	10%	20.0%	30.0%	15%	22.5%	22.5%
Proportion of net area reserved from harvesting	20%	20%	10%	10%	10%	10%
Number of gapping event cycles undertaken	8	4	3	6	4	4
Return time (years)	10	10	10	10	7	5

SPECIFICATIONS FOR AGS REGIME THINNING NATIVE FOREST

Thinning Specifications	Yield Association				
	Moist Blackbutt	Moist Coastal Eucalypts	Semi Moist & Taller Dry Eucalypts	Moist Tablelands	All Dry Types
Thinning in gapped forest					
T1 Retained BA (m^2/ha)	12	12	12	12	10
T1 Min. Volume Required (m^3/ha)	35	35	35	35	35

SPECIFICATIONS FOR AGS REGIME RESET OPERATION IN NATIVE FOREST

Variable	Yield Association				
	Moist Blackbutt	Moist Coastal Eucalypts	Semi Moist & Taller Dry Eucalypts	Moist Tablelands	All Dry Types
Min HQ large volume for reset (m^3/ha)	7	7	7	7	7
Min Diameter for HQ large volume for reset (cm)	65	55	50	50	50

In addition to the differences in silvicultural specifications, the recruitment models had to be calibrated with different proportions of tree vigour classes to reflect the different gap sizes. The proportion of co-dominant trees were increased by the adjustment factors, while the dominant, sub-dominant and suppressed tree vigour classes were reduced by the equivalent proportion on a pro-rata basis.

CO-DOMINANT TREE VIGOUR CLASS RECRUITMENT ADJUSTMENT FACTORS

Specification (All yield associations)	Initial Silvicultural Strategy			Revised Achievable Silvicultural Strategy		
	AGS Light	AGS Moderate	AGS Heavy	AGS Light	AGS Moderate	AGS Heavy
Co-dominant tree vigour class increase	20%	40%	60%	20%	25%	40%
Gap Size (m)	40	70	100	40	50	70

Native Forest Yield simulator

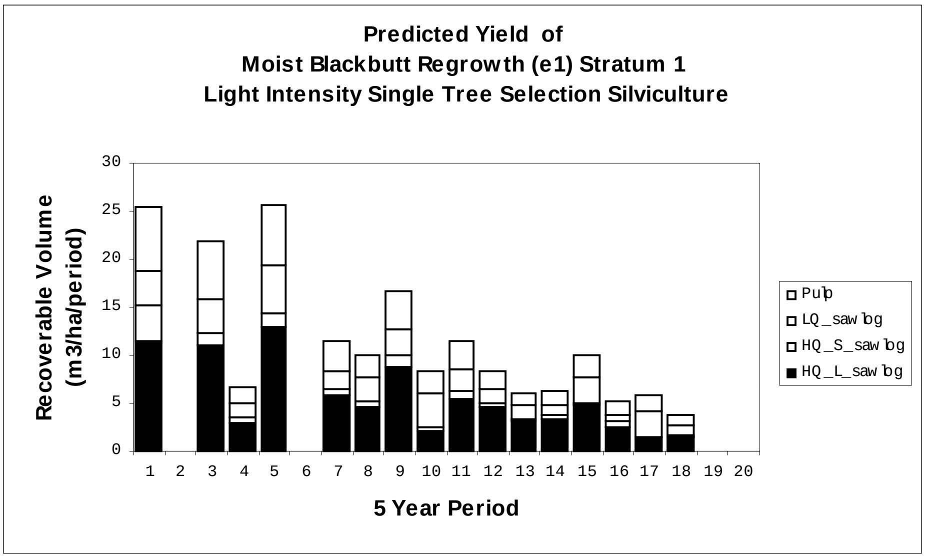
The FRAMES yield simulator is a model designed to simulate the future growth and silvicultural management of the native eucalypt forest, and generates the expected per hectare log yields when managed according to defined silvicultural prescriptions.

The yield simulator uses strategic inventory plot and tree level data. The growth of each tree in each plot is simulated using a range of tree and stand level growth, mortality and recruitment models. Each plot is modelled according to the range of silvicultural regimes (light, moderate, heavy intensity AGS and STS) and for a range of transition (5 year delay) periods before a regulated harvest cycle commences defined by the user. The natural dynamics and forest management of each plot are simulated independently.

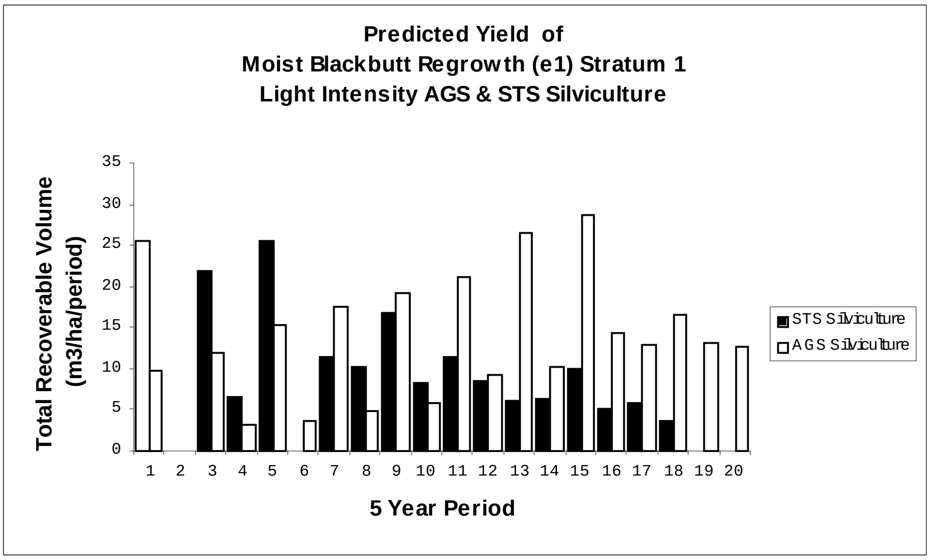
Each plot is independently evaluated as to its suitability for harvesting each year, by comparing the plot parameters (volume of different log grades, basal area, and stocking) against predefined sets of threshold harvesting criteria for each year of the simulation period. If these harvest criteria are met the simulator will remove those trees in the plots according to the harvesting prescriptions (single tree removal, thinning from below or group selection; and light, moderate and intensive operations). Following the harvesting, the model simulates tree recruitment, incremental growth and mortality of the retained trees in a plot. This sequence of events is repeated each year for the simulation period defined by the user.

The annual yields arising from the simulated harvesting of plots within each stratum are combined and divided by the number of plots within the strata to provide average strata yields per year. The yields from each stratum are reported on a m^3 / hectare per 5 year period basis for the 100 year simulation period.

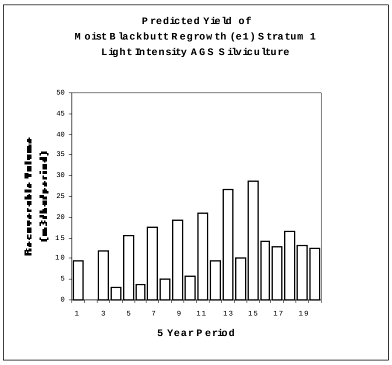
EXAMPLE OF NATIVE FOREST PERIODIC "YIELD CURVE"

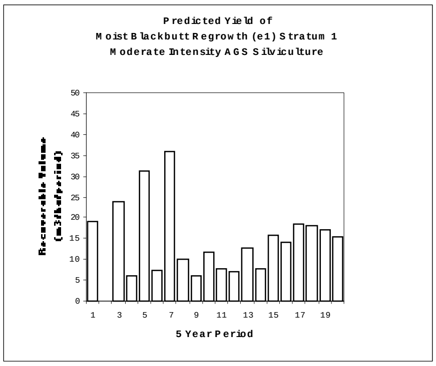


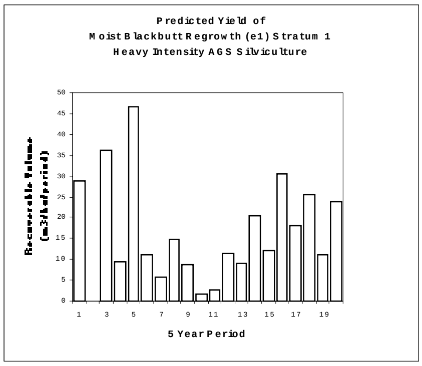
EXAMPLE OF NATIVE FOREST AGS AND STS PER HECTARE YIELD FLOW PROFILE



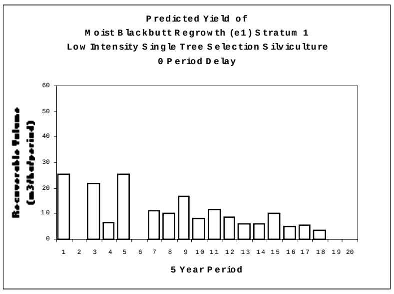
EXAMPLE OF EFFECTS OF SILVICULTURAL INTENSITY ON YIELD PROFILE

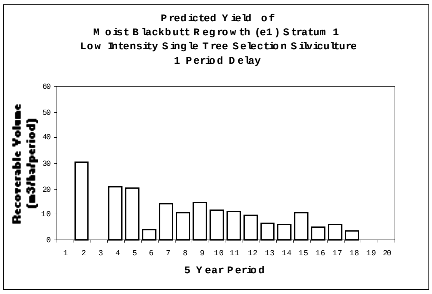


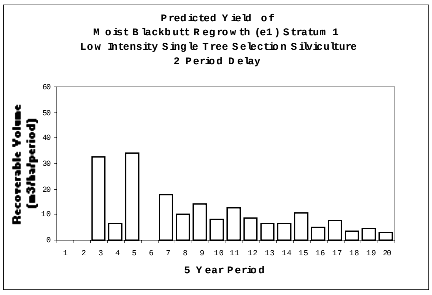


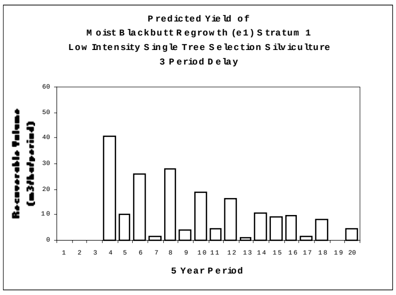


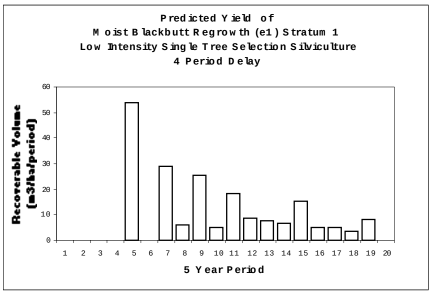
EXAMPLE OF INITIAL HARVEST DELAY OPTIONS ON NATIVE FOREST YIELD PROFILE











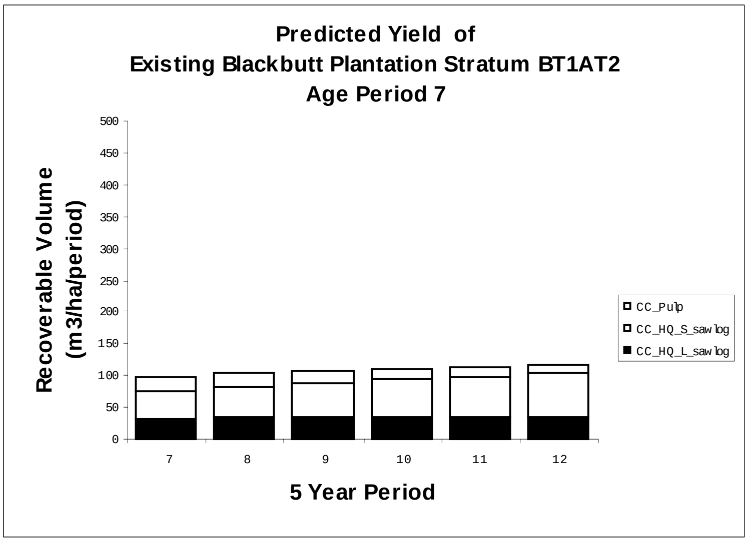
Appendix 1.2: Plantation Yields

Hardwood Plantation Growth and Yield Forecasting

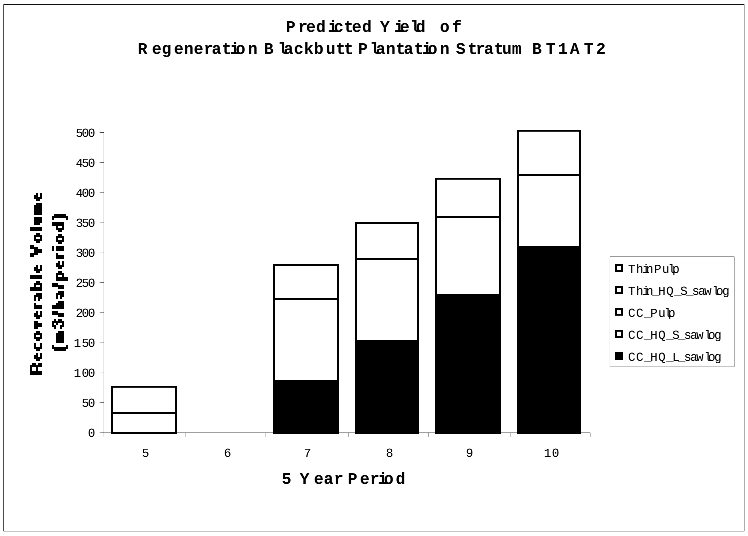
The generation of the plantation yield tables was automated using two predictive growth models coupled with the use of a PERL script to format the data into the appropriate *Spectrum* CSV import file format.

The pre-1988 plantation strata yield tables were generated using a growth and yield model SFPLTN (West, June 1998) which was commissioned and developed for the CRA process. The younger plantation yields were generated using the PYP model (West, April 1998) which was independently commissioned for commercial purposes within State Forests. Details on the models, model parameters, formulation of silvicultural regimes used, forecasted volume adjustments and modelling assumptions are outlined in the NSW Hardwood Plantation Yield Table Formulation report (Turland, 1998).

EXAMPLE OF EXISTING PLANTATION "YIELD CURVE"



EXAMPLE OF REPLANT PLANTATION "YIELD CURVE"



Appendix 1.3: Yield Table Log Products

The native forest and hardwood plantation yield tables comprise volumes of 4 generic log grades defined in the following table:

Native forests

The software package MARVL used to provide the proportions of product uses the log specifications defined in terms of small end diameter under bark (sedub), while in practice the current industry transactions are based on logs defined in terms of centre diameter under bark (cdub). For the native forests the actual log cutting strategy used in MARVL for determining the volume of each log product in a yield table is a composite of numerous log length sed combinations. For example, a 3.6m log had 38 cm sed (2 cm allowance for taper over half log length from 40 cm cdub).

Plantations

The plantation yield tables were based on the specifications. The plantation growth and yield models are not designed to accommodate multiple length:sed combinations.

LOG PRODUCT SPECIFICATIONS

Log Product Name	Allowable qualities	Length (m)		Small end diameter under bark (cm)	
		Min	Max	Min	Max
Large High Quality (LHQ)	A	3.6	15.4	34	70
Small High Quality (SHQ)	A	3.6	15.4	20	34
Low value (LV)	A, B	3.6	15.4	30	70
Pulp	A, B, P	3.6	15.4	10	70

LOG QUALITY CODE DESCRIPTIONS

MARVL Inventory Quality Codes	Product	General Log Grades
A	High value product	quota sawlogs, small graded sawlogs, sleeper logs, veneer logs, larger poles, piles and girders
B	Low value product	salvage sawlogs, non-compulsory logs, small sawlogs
P	Pulp	pulp
W	Waste	stump, long butts, dockings

The yield table log product volumes are realisable volumes - the volume which will be harvested and removed from the site. The native forest realisable volume is the merchantable sawlog volumes adjusted downwards to account for internal defects and utilisation standards (sub-optimal cross-cutting, breakages, mis-grading) based on SFNSW defect and utilisation study. The hardwood plantation volume adjustments were based on evaluation of inventory data and consultation with forestry operation managers.

APPENDIX 2: YIELD TABLES

Appendix 2.1: Uneven-Aged Yield Tables

UNEVEN-AGED YIELD TABLE FILE 1

Yield Table Name	Output Name (Group)	Layer 1 Attribute Unused	Layer 2 Attribute Unused	Layer 3 Attribute Stratum No.	Layer 4 Attribute Silvicultural Practice	Layer 5 Attribute Management Intensity Group	Layer 6 Attribute Unused	Blank	Management Emphasis Attribute	Management Intensity Attribute	Yield Table Type	Regulated Period	Entry Period	Unique ID No. which links to Yield Table File 2	Regulated Cycle Length (in periods)	Contributes to LTSY (T or F)
Uneven STS S1.1, 0 delay	wood			1	Any	gp_lmn			stimb	light	uneven	1	1	S1.1	1	T
Uneven STS S1.2, 0 delay	wood			1	Any	grp_mn			stimb	medium	uneven	1	1	S1.2	1	T
Uneven STS S1.3, 0 delay	wood			1	Any	heavy			stimb	heavy	uneven	1	1	S1.3	1	T
Uneven AGS S1.4, 0 delay	wood			1	Any	gp_lmn			gtimb	light	uneven	1	1	S1.4	1	T
Uneven AGS S1.5, 0 delay	wood			1	Any	grp_mn			gtimb	medium	uneven	1	1	S1.5	1	T
Uneven AGS S1.6, 0 delay	wood			1	Any	ignore			gtimb	heavy	uneven	1	1	S1.6	1	T
Uneven STS S1.7, 1 delay	wood			1	Any	gp_lmn			stimb	light	uneven	2	2	S1.7	1	T
Uneven STS S1.8, 1 delay	wood			1	Any	grp_mn			stimb	medium	uneven	2	2	S1.8	1	T
Uneven STS S1.9, 1 delay	wood			1	Any	heavy			stimb	heavy	uneven	2	2	S1.9	1	T
Uneven AGS S1.10, 1 delay	wood			1	Any	gp_lmn			gtimb	light	uneven	2	2	S1.10	1	T

Treatment Types:
Sel-F: For first harvest volume
Sel-L: For all later or subsequent harvest volumes
Selinv: To track the standing inventory volume, before harvest in each time period.

UNEVEN-AGED YIELD TABLE FILE 2

Unique ID Number Which Links to Yield Table File 1	Activity / Output	Treatment Type	Qualifier	Period of first coefficient	Merchantable Yield (m^3/ha) (coefficient)																			
S1.1	HQ_L_sawlog	Sel-F	Amount	1	5.93																			
S1.1	HQ_L_sawlog	Sel-L	Amount	2	0	0	2.45	2.94	0	3.12	0	13.26	4.06	5.98	6.61	5.13	9.49	3.93	0	3.26	0	4.83	1.83	
S1.1	HQ_L_sawlog	Selinv	Amount	1	6.58	10.75	13.69	16.11	18.64	25.25	30.04	35.77	29.83	31.18	31.31	30.88	30.88	24.79	23.76	26.18	26.59	28.73	26.22	27.81
S1.1	HQ_S_sawlog	Sel-F	Amount	1	1.26																			
S1.1	HQ_S_sawlog	Sel-L	Amount	2	0	0	1.22	0.45	0	0.3	0	1.56	0.7	0.9	1.51	1.15	1.47	0.54	0	0.55	0	0.63	0.42	
S1.1	HQ_S_sawlog	Selinv	Amount	1	20.61	25.56	31.96	34.81	36.29	39.33	37.35	37.08	31.37	29.02	26.21	21.81	19.18	16.73	16.04	16.09	14.17	13.27	12.07	10.71
S1.1	LQ_sawlog	Sel-F	Amount	1	2.22																			
S1.1	LQ_sawlog	Sel-L	Amount	2	0	0	0.99	1.19	0	1.09	0	4.94	1.51	3.19	2.59	4.37	3.78	1.32	0	1.06	0	2.01	3.87	
S1.1	LQ_sawlog	Selinv	Amount	1	8	9.94	12	13.09	14.56	17.47	19.81	23.51	23.17	26.62	27	27.12	25.15	23.98	24.59	27.19	28.56	31.67	31.31	30.46
S1.1	Pulp	Sel-F	Amount	1	3.11																			
S1.1	Pulp	Sel-L	Amount	2	0	0	2.11	1.53	0	1.47	0	6.25	2.07	3.46	3.65	2.67	4.93	1.76	0	1.59	0	2.6	2.62	
S1.1	Pulp	Selinv	Amount	1	45.72	52.87	57.72	56.96	57.57	61.65	62.15	65.09	59.14	58.91	58.41	56.28	56.28	53.41	55.46	58.31	61.07	61.71	60.44	61.21

Appendix 2.2: Even-Aged (Plantation) Yield Tables

EVEN-AGED (PLANTATION) YIELD TABLE FILE 1:

Yield Table Name	**Output Name (Group)**	**Layer 1 Attribute Unused**	**Layer 2 Attribute Unused**	**Layer 3 Attribute Unused**	**Layer 4 Attribute Silvicultural Practice**	**Layer 5 Attribute Unused**	**Layer 6 Attribute Stratum**	**Blank**	**Management Emphasis Attribute**	**Management Intensity Attribute**	**Yield Table Type**	**Beginning Stand Age**	**Entry Age**	**Unique ID No. which links to Yield Table File 2**
Existing curve for JCF1TP age period 1 (thinned)	wood				pln		P51.1				exist	1	3	P171
Regen curve for JCF1TP (JRF2TP) age period 1	wood				pln		P51.1				regen	0	5	P172
Existing curve for JCF1TP age period 1 (thinned)	wood				pur		L51.1				exist	1	3	P173
Regen curve for JCF1TP (JRF2TP) age period 1	wood				pur		L51.1				regen	0	5	P174

EVEN-AGED (PLANTATION) YIELD TABLE FILE 2:

Unique ID Number Which Links to Yield Table Part 1	**Activity / Output**	**Treatment**	**Qualifier**	**Age (5 year period) of first coefficient**	**Merchantable Yield (m^3/ha) (coefficient) - Thin: at age specified. Clearfell: from earliest clearfell age specified to latest age specified in Age-Based General Schedule . Ages correspond the 5 year periods.**					
10 Character Length	*12 Character Length*	*6 Character Length*	*6 Character Length*							
P189	HQ_L_sawlog	ThnEst	Amount	3	0					
P189	HQ_L_sawlog	CC-EX	Amount	5	3	12	30	54	84	117
P189	HQ_S_sawlog	ThnEst	Amount	3	11					
P189	HQ_S_sawlog	CC-EX	Amount	5	113	152	178	193	199	200
P189	LQ_sawlog	ThnEst	Amount	3	0					
P189	LQ_sawlog	CC-EX	Amount	5	0	0	0	0	0	0
P189	Pulp	ThnEst	Amount	3	68					
P189	Pulp	CC-EX	Amount	5	81	84	85	86	87	87

APPENDIX 3: SOLUTION REPORT CODES

SOLUTION REPORT - CUSTOM ACTIVITIES AND OUTPUTS

Report Name	Activity & Output	Emphasis	Intensity	Report Name	Activity & Output	Emphasis	Intensity
AGH	netarea_ue	gtimb	heavy	SSH	HQS Sawlog	stimb	heavy
AGM	netarea_ue	gtimb	medium	SSM	HQS Sawlog	stimb	medium
AGL	netarea_ue	gtimb	light	SSL	HQS Sawlog	stimb	light
ASH	netarea_ue	stimb	heavy	SP	HQS Sawlog	ptimb	normal
ASM	netarea_ue	stimb	medium	LGH	LQ Sawlog	gtimb	heavy
ASL	netarea_ue	stimb	light	LGM	LQ Sawlog	gtimb	medium
AP	netarea_plt	ptimb	normal	LGL	LQ Sawlog	gtimb	light
FWL	HQL Sawlog	all	all	LSH	LQ Sawlog	stimb	heavy
FWS	HQSSawlog	all	all	LSM	LQ Sawlog	stimb	medium
HGH	HQL Sawlog	gtimb	heavy	LSL	LQ Sawlog	stimb	light
HGM	HQL Sawlog	gtimb	medium	LP	LQ Sawlog	ptimb	normal
HGL	HQL Sawlog	gtimb	light	LGH	LQ Sawlog	gtimb	heavy
HSH	HQL Sawlog	stimb	heavy	LGM	LQ Sawlog	gtimb	medium
HSM	HQL Sawlog	stimb	medium	LGL	LQ Sawlog	gtimb	light
HSL	HQL Sawlog	stimb	light	LSH	LQ Sawlog	stimb	heavy
HP	HQL Sawlog	ptimb	normal	LSM	LQ Sawlog	stimb	medium
HGH	HQL Sawlog	gtimb	heavy	LSL	LQ Sawlog	stimb	light
HGM	HQL Sawlog	gtimb	medium	LP	LQ Sawlog	ptimb	normal
HGL	HQL Sawlog	gtimb	light	PGH	Pulp	gtimb	heavy
HSH	HQL Sawlog	stimb	heavy	PGM	Pulp	gtimb	medium
HSM	HQL Sawlog	stimb	medium	PGL	Pulp	gtimb	light
HSL	HQL Sawlog	stimb	light	PSH	Pulp	stimb	heavy
HP	HQL Sawlog	ptimb	normal	PSM	Pulp	stimb	medium
SGH	HQS Sawlog	gtimb	heavy	PSL	Pulp	stimb	light
SGM	HQS Sawlog	gtimb	medium	PP	Pulp	ptimb	normal
SGL	HQS Sawlog	gtimb	light	PGH	Pulp	gtimb	heavy
SSH	HQS Sawlog	stimb	heavy	PGM	Pulp	gtimb	medium
SSM	HQS Sawlog	stimb	medium	PGL	Pulp	gtimb	light
SSL	HQS Sawlog	stimb	light	PSH	Pulp	stimb	heavy
SP	HQS Sawlog	ptimb	normal	PSM	Pulp	stimb	medium
SGH	HQS Sawlog	gtimb	heavy	PSL	Pulp	stimb	light
SGM	HQS Sawlog	gtimb	medium	PP	Pulp	ptimb	normal
SGL	HQS Sawlog	gtimb	light				

APPENDIX 4: EXAMPLE OF WOOD SUPPLY SCENARIO CRITERIA SELECTION SHEET

Spectrum Scenario

Title

CRA Region, Date, Scenario name
C-PLAN name

☐ UNE ☐ LNE

Standard Native Forest Net Harvest Area (NHA) Exclusions

- ☐ PMP 1.3
- ☐ PMP 1.2, non-harvestable PMP 1.1.5/6/7
- ☐ EPA Hazard Class 4
- ☐ Physically/economically Inaccessible
- ☐ EPA filter 1 (mapped drainage lines)
- ☐ RN17 RF
- ☐ Unmerchable forest types
- ☐ Rare non-commercial forest types
- ☐ Wetlands
- ☐ Heaths
- ☐ Rocky outcrop
- ☐ Base Net Harvest Area Modifier (NHAM) other than "buffers on buffers"

Additional NHA Exclusions for this scenario (IF TICKED THEN NOT AVAILABLE FOR HARVESTING)

- ☐ Identified Wilderness
- ☐ State Capable Wilderness
- ☐ Candidate Old Growth
- ☐ HQ Habitat Old Growth
- ☐ High Conservation Value OG
- ☐ Crafti RE tags (UNE)
- ☐ Crafti RM and RB tags (UNE)
- ☐ All other Crafti R tags (UNE)
- ☐ All BOG R rainforest (LNE)
- ☐ NHAM "Buffers on buffers"
- ☐ EPA filter 0 (unmapped drainage lines)

Objective function

- ☐ Maximum 20 year HQ Large volumes
- ☐ 100 year non-declining HQ Large volumes
- ☐ X,000/yr Periods 1 -4, Period 5 x,000m3/yr, Periods 6-20 smoothed
- ☐ (+/- x %) at minimum x,000 m3/yr

NHA = *x* ha
HQL Vol *x,000* /yr Periods 1-4

Silvicultural Prescriptions

Trigger volumes (HQ large) for harvesting are: STS 7 m3/ha AGS 7 m3/ha
for trees with at least the following diameters (breast height over bark):
Moist BBT: 65cm Moist Coastal: 55cm All Other Moist: 50cm All Dry: 50cm
High Quality large specifications: 40 cm cdub (34 cm sedub) and 3.6 m in length.
High Quality small specifications: 20 cm sedub and 3.6 m in length.

- ☐ STS Light is applied and uses maximum BA removed of 20%
- ☐ STS Medium is applied and uses maximum BA removed of 30%
- ☐ STS Heavy is applied and uses maximum BA removed of 40%
- ☐ AGS Light is applied and uses ~40 m gaps, 20% net area retained, a return time between harvests of 10 years and 10% gapped in each gapping event.
- ☐ AGS Medium is applied and uses ~70 m gaps, 20% net area retained, a return time between harvests of 10 years and 20% gapped in each gapping event.
- ☐ AGS Heavy is applied and uses ~100 m gaps, 10% net area retained, a return time between harvests of 10 years and 30% gapped in each gapping event.

REFERENCES

Moore, T. Forest Resources Branch. SFNSW. March 1999. *Net Harvest Area Calculations* (ESFM PA 4/2/2)

State Forests of New South Wales. Final report August 1999. *Strategic Inventory*. Upper North East and Lower North East Regions. A project undertaken as part of the NSW Comprehensive Regional Assessments.

Turland, J. September 1998. *NSW hardwood plantation yield table formulation*. Forest Resources Branch, State Forests of New South Wales.

USDA Forest Service. April 1997. *Spectrum User Manual*.