Strategic Inventory

Upper North East and Lower North East CRA Regions

A project undertaken as part of the NSW Comprehensive Regional Assessments

August 1999

STRATEGIC INVENTORY

UPPER NORTH EAST AND LOWER NORTH EAST CRA REGIONS

State Forests of New South Wales

A project undertaken for
the Joint Commonwealth NSW Regional Forest Agreement Steering Committee
as part of the
NSW Comprehensive Regional Assessments
project number NA04/FRA

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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.

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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 objective/s

The objectives of the FRAMES Strategic Inventory were to:
1. provide stratum-level statistics for timber volumes by product class;
2. provide data for the prediction of long-term wood flows;
3. assign volumes at the sub-compartment level; and
4. provide spatial linkages between the inventory and attribute data.

Unit total volumes and unit volume of high value wood were to be estimated with a target accuracy of ±30% of the true value, at the 95% confidence level.

Methods

The native forest population to be sampled was defined as the net State forest area within the Upper and Lower North East CRA Regions. The plantation population to be sampled was the category A and B plantations within UNE and LNE. The sample design for both populations was a stratified design. Strata in the native forests were based on a yield association (amalgamations of forest type) by stand structure matrix. In plantations, the strata were based on species, thinning history, stocking density and age class. Sample points were selected with a random-start grid. At each point, a range of standard mensurational parameters were measured. All inventory data were processed with the MARVL software package.

Key results and products

Results for native forests showed that the accuracy target for total volume could be met with a sample of around 20 plots; and that the accuracy target for the volume of high quality log volume could be met with a sample of 40 - 45 plots. In UNE, accuracy targets for total volume were met in 25 out of the 31 strata, which contained 92% of all volume estimated in the inventory; accuracy targets for high value volume were met in 8 out of 31 strata, for 42% of all high value volume measured in the inventory. In LNE, accuracy targets for total volume were met in 25 out of the 31 strata, which contained 95% of all volume estimated in the inventory; accuracy targets for high value volume were met in 11 out of 31 strata, for 69% of all high value volume measured in the inventory. The conclusion to be drawn from these data is that the forests of LNE are more uniform than the forests of UNE. Although the target confidence limits were not met for all strata, the data were considered to be sufficiently close to the confidence limits for the more important strata to effectively underpin long term yield estimates.

Strategic Inventory data is passed to the FRAMES Yield Simulator for calculation of the range of future yields that then underpin the sustainable yield calculations performed by the FRAMES Strategic Yield Scheduler.

All plot locations and associated strata are stored in a GIS database.

1. INTRODUCTION

State Forests has traditionally collected inventory data on a management area basis, in response to prevailing market demands. A variety of inventory techniques have been used to estimate timber resources: broad area inventories using fixed area or point samples, pre-harvesting inventories and desktop assessments. The inventories described in this report used standard methods for both Upper North East (UNE) and Lower North East (LNE) CRA Regions. The use of standard methods and the creation of standard inventory databases will allow monitoring and updating processes to be more easily achieved.

The purpose of this report is to document the procedures used in the strategic inventory of all native and plantation *Eucalyptus* forests within State Forests in the UNE and LNE CRA Regions, and to present results of the inventory in terms of the stated objectives.

This report aims to present, in a single document, an overview of the strategic inventory. Procedures and techniques are described in detail in a series of separate reports, all of which are appended to this report. The individual reports are:

- Field Procedures for Eucalypt Plantation - MARVL Inventory (Appendix A)
- MARVL system analysis (Appendix B)
- Strategic Inventory - Field Manual (Appendix C)
- Strategic Inventory Project Auditing Methodology Outline (Appendix D)
- Strategic Inventory Audit Report (UNE and LNE) (Appendix E)

2. INVENTORY PROCEDURES

2.1 OBJECTIVES OF THE INVENTORY

The objectives of the strategic inventory, as stated in the “Strategic Inventory CRA Project Proposal” were:

1. to provide estimates at stratum level (aggregated forest types by structure class) of total timber volume and timber quality class volume with associated confidence limits; as well as estimates of volume by log product class,
2. to provide data for the prediction of long term wood flows using stand structure information;
3. to assign total and available timber volume by quality class, calculated at stratum level, to stand unit (sub-compartment) level, where stand units comprise strata within a compartment. Other forest attribute data could also be assigned at this level;
4. to provide a spatial link for forest attribute and inventory data.

The accuracy target for the strategic inventory is that the unit volume of all useable wood (that is, all products and species) and unit volume of high value wood, in any given stratum, are to be estimated to an accuracy of ±30% of the true value, 95 times out of 100.

It is emphasised, objective 3 notwithstanding, that the strategic inventory was not designed to be accurate at compartment level or lower. Each stratum has a volume per hectare (the arithmetic mean volume of all plots in that stratum), and the stratum net area in each compartment is known, so it is possible, in a mechanical sense, to estimate total volumes at the compartment level. The sampling design devised for the strategic inventory took into account only variation which occurred within the strata; no provision was made for measuring within-compartment variation. Because there is no information available on within-compartment variation, no definitive statement can be made about the accuracy of compartment-level estimates, but experience has shown that compartments are often highly variable, so it can be reasonable inferred that the accuracy of compartment-level estimates, when calculated as described, would be low.

More accurate estimates at the compartment level would require that the inventory process be redesigned to somehow account for, and measure, within-compartment variation. Given the large number of compartments in each CRA Region, and the observed high variability of these compartments, it is clear that measurement to the compartment level would require the measurement of many, many more sample plots, a proposal that was not thought realistic, given the time and cost constraints that were in force when the inventory design was being considered.

2.2 DETERMINATION OF AREA TO BE SAMPLED

2.2.1 Native forest

The net mapped area for the inventory (the sample population) was determined by State Forests' GIS Branch. In UNE, the gross area of State forest was reduced to net area by excluding the following classifications:

- physically and economically inaccessible forests areas;
- steep land;
- non-commercial forest types;
- eucalypt plantations;
- unavailable Preferred Management Priority (PMP) zones;
- areas excluded because of conservation protocols; and
- drainage buffers (filterstrips).

Steep land was defined as contiguous blocks of land, with an area greater than 1 hectare, and with a slope greater than 30 degrees.

Those plantations which were considered, at the time, to be suitable for accreditation under the *Timber Plantations (Harvest Guarantee) Act 1996* were excluded from the net area and assessed separately as plantation areas. Areas originally tagged as plantation (other than those areas suitable for accreditation) were treated as native forest.

Forest types, as defined in Forestry Commission of NSW (1969), commonly referred to as Research Note 17 or RN17, were used to separate commercial and non-commercial forest types. Additional rainforest areas, in excess of those types identified as RN17 rainforest types, were determined from the results of the CRA API Project (CRAFTI). Additional non-commercial forest areas were determined from the results of the CRAFTI project; those polygons where site height was estimated to be less than 20 m were deemed to be non-commercial.

Unavailable PMP zones were:

PMP 1.2 Undeveloped Native Forest
PMP 1.3 Preserved Natural Forest
PMP 1.1.5 Catchment Protection (where timber harvesting was excluded)
PMP 1.1.6 Visual Resource Protection (where timber harvesting was excluded)
PMP 1.1.7 Flora and Fauna Protection (where timber harvesting was excluded)

Net mapped area for LNE was arrived at by a similar process. The results of the CRAFTI project were not available, so additional rainforest and non-commercial types were delineated using the results of the Broad Old Growth Mapping Project (BOGMP).

Native forest stratum areas are shown in Table 4. These areas are correct as at 15/6/98.

2.2.2 Plantation

Native species plantations were reviewed separately to native forest. The plantation stratum areas shown in Table 6 are correct as at 31/7/98. These areas included both category A and B[1] plantations.

2.3 DATA TO BE COLLECTED

2.3.1 Native forest

The variables measured at each plot are defined in the "Strategic Inventory Field Manual" (refer Appendix C). Measured variables are listed below.

Inventory-level variables:

- inventory name
- Region(s)
- District(s)
- Management Area

Plot-level variables:

- plot number
- State Forest identifier
- compartment number
- measure date
- coordinates (zone, easting, northing)
- site height
- plot area
- distance to filter strip (if <=50 m)
- stratum identifier
- name of measurer(s)
- aspect
- slope

Tree level variables

- tree number
- species code
- DBHOB
- dominance
- crown quality
- tree height
- hollow status
- logging impediment
- MARVL tree description (quality codes and height)

2.3.2 Plantation

[1] Category A plantations are those plantations which are suitable for immediate accreditation under the Timber Plantations (Harvest Guarantee) Act 1996. Category B plantations are plantations for which more intensive field investigation is needed before accreditation can be obtained.

For crop trees the following parameters were measured.

Inventory-level variables:
- Inventory name

Plot-level variables:
- plot number
- measure date
- plot area
- stratum identifier
- name of measurer(s)

Tree-level variables
- tree number
- species code
- DBHOB
- crown quality
- tree height
- MARVL tree description (quality codes and height)
- availability for harvest

Non-crop trees (that is, those trees not deliberately planted or seeded) were counted by 5 cm diameter classes. No additional tree parameters were measured for these trees.

2.4 METHODS OF MEASUREMENT

2.4.1 Native forest

Plot measurement methods are described in the “Strategic Inventory Field Manual” (refer Appendix C).

Plots were fixed area 0.1 ha circular plots. The same size plot was used for all strata so that restratification could be easily accomplished.

A brief summary of the measurement procedure for each plot is as follows. Sample points were predetermined in the office; transect bearings and distances were calculated from identifiable take-off points to each sample point. A hip chain and compass were used to locate the points. A 0.1 ha plot (which has a horizontal radius of 17.84 m) was established at each sample point, using either a tape and clinometer (in conjunction with a conversion table to correct for variation in slope) or a Forestor “Vertex” hypsometer (which automatically corrects for variation in slope). To facilitate possible relocation, the centre point of each plot was marked with a painted peg. Individual tree numbers were sprayed on each sample tree to permit relocation for audit purposes.

All trees with an overbark diameter at breast height (DBHOB) equal to or greater than 100 mm, were measured in the inventory. The State Forest standard for breast height is 1.3 m; this point was marked on each tree.

Other variables recorded for each tree were crown condition, dominance and hollow status and logging impediment. These variables are described in “Strategic Inventory Field Manual” (Appendix C). A MARVL tree description was recorded for each tree. A MARVL tree description is a method for describing the morphology of each tree and the quality of the timber it contains. The method is described more fully in “MARVL system analysis” (Appendix B).

Tree heights were measured as part of the MARVL tree description. All heights were measured with the Forestor "Vertex" hypsometer. Only trees with no evidence of past or present damage to their crowns (that is, those trees which had a "typical" height/DBHOB ratio) were measured. Trees for height measurement were selected from across the DBHOB range of each plot.

All field work was done by State Forests' staff.

2.4.2 Plantation

Plot measurement methods are described in "Field Procedures for Eucalypt Plantation" (refer Appendix A). Plantation inventory plots were 0.03 ha in most strata, and 0.10 ha in strata 2, 14, 29, 30, 31, 40 and 41. The basic approach was similar to the method used in the native forest, except that a contractor was used for all field work.

2.5 SELECTION OF THE SAMPLE

2.5.1 Native forest

Stratification
Strata used in the inventory were a combination of yield association and structure class. A yield association is an amalgam of forest types. Yield associations are described in Table 1.

TABLE 1. YIELD ASSOCIATIONS USED IN UNE AND LNE

Name	Description
Moist blackbutt.	This is primarily dominated by blackbutt in RN 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	This is primarily dominated by the dry spotted gum and dry blackbutt forest types
Dry sclerophyll	The remainder of productive dry sclerophyll types found in coastal areas.
Moist tablelands	Moist forest types in the messmate/brown barrel league.
Dry tablelands	Dry tableland and tableland stringybark forest types

Structure classes were amalgams of polygon codes, initially from BOGMP but subsequently from CRAFTI in UNE and from BOGMP in LNE. No CRAFTI results were available for LNE. Classes and descriptions are shown in Table 2.

TABLE 2. STRUCTURE CLASSES USED IN UNE AND LNE

Name	Description
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 basis of splitting regrowth polygons was the CRAFTI regrowth size code, while in LNE the basis was Wood Resources Study stand structure data. Multi aged stands, although showing substantial similarity in their diameter class distributions, were split for potential management reasons by the percentage of senescent trees. The stratum matrix, with stratum labels, is shown in Table 3.

TABLE 3. NATIVE FOREST STRATUM DEFINITION AND LABELS, UNE AND LNE

	Structure class				
Yield association	e1	e2	A	B	C
Moist blackbutt	1	7	11	18	25
Moist costal 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

Stratum area statistics as at 15/6/98 are shown in Table 4.

TABLE 4. NATIVE FOREST STRATA IN UNE AND LNE AS AT 15/6/98

Stratum	UNE Total Net Area (ha)	LNE Total Net Area (ha)
1	5607.1	3941.9
2	4130.6	6441.2
3	2032.7	6133.0
4	9186.2	5667.9
5	9083.7	17166.1
6	2437.6	9236.4
7	11518.7	16373.2
8	12776.9	18260.9
9	7768.4	15452.8
10	9959.8	11660.8
11	3536.7	1433.2
12	10101.4	10109.1
13	1844.0	4163.1
14	8873.7	306.1
15	10905.2	2546.5
16	15887.7	10932.0
17	8906.2	3482.4
18	10423.8	13096.0
19	26145.9	46742.4
20	19432.7	34560.0
21	46897.1	7322.7
22	50921.7	25306.0
23	18008.6	44727.4
24	16162.4	11350.8
25	3845.1	19733.3
26	5491.1	38901.6
27	3756.3	33671.1
28	22602.3	15225.4
29	11478.7	30173.3
30	6980.3	32386.4
31	5188.4	6710.3
Total	381890.9	503213.1

Plot selection

Within the native eucalypt forest net mapped area, plots were allocated to the strata described above. In the early stages of the inventory, plots were allocated to strata in proportion to net area, that is, each plot represented the same number of hectares. Proportional allocation was adopted to facilitate restratification. In later stages, plots were added to under-represented strata, which altered the proportionality somewhat.

ARC/INFO software was used to generate a random-start grid, which was used to select sample points. The grid size was adjusted so that the number of points selected was about 20% more than required by the net area. The extra plots, termed reserve plots, were used to replace main plots, or as additional plots in some strata (see above).

2.5.2 Plantation

Stratification

The stratification for hardwood plantations was based on species group, stand condition and age class variables. Forty nine strata were defined for the hardwood plantations. Stratification factors are shown in Table 5.

TABLE 5. EUCALYPT PLANTATION STRATIFICATION FACTORS

Factor	Code	Description
Species	BBT	Blackbutt and Blackbutt/Flooded Gum Mix
	FLG	Flooded Gum only
	OTH	Other (all remaining species)
Thinning Class	T	At least one thinning operation
	UT	No recorded thinning event
Stocking Class	1	0 - 400 stems/ha
	2	400 - 800 stems/ha
	3	800+ stems/ha
Age Class	A to F	Year of establishment classes (specific intervals for each stratum)

Stratum area statistics at 31/7/98 are shown in Table 6.

TABLE 6. EUCALYPT PLANTATION STRATA IN UNE AND LNE AS AT 31/7/98

Stratum label	Description	First / Last Yr	Net Area (ha)		
			Category A	Category B	Total
1	BBT_T_1A	1960-1967	167	0	167
2	BBT_T_1B	1968-1970	319	2	321
3	BBT_T_1C	1971-1973	802	0	802
4	BBT_T_1D	1974-1978	216	7	223
40	BBT_T_2A	1960-1967	432	69	501
5	BBT_T_2B	1968-1971	1040	0	1040
41	BBT_T_2C	1972-1974	1780	21	1801
42	BBT_T_2D	1975-1982	424	30	454
6	BBT_UT_2A	1961-1966	445	32	477
7	BBT_UT_2B	1967-1969	704	7	711
8	BBT_UT_2C	1970-1972	933	45	978
9	BBT_UT_2D	1973-1976	630	133	763
10	BBT_UT_2E	1977-1980	521	78	599
11	BBT_UT_2F	1981-1987	293	4	297
43	BBT_UT_3A	1961-1969	473	31	504
44	BBT_UT_3B	1970-1972	836	0	836
12	BBT_UT_3C	1973-1976	637	14	651
13	BBT_UT_3D	1977-1986	302	8	310

Stratum label	Description	First / Last Yr	Net Area (ha)		
			Category A	Category B	Total
14	BBT40	1939-1959	122	0	122
15	FLG_T_1A	1960-1963	379	34	413
16	FLG_T_1B	1964-1966	539	102	641
17	FLG_T_1C	1967-1969	771	15	786
18	FLG_T_1D	1971-1978	406	9	415
19	FLG_UT_1A	1960-1963	8	22	30
20	FLG_UT_1B	1964-1967	12	0	12
21	FLG_UT_1C	1968-1970	0	0	0
22	FLG_UT_2A	1960-1968	550	9	559
23	FLG_UT_2B	1969-1971	1169	1	1170
24	FLG_UT_2C	1972-1974	904	166	1070
25	FLG_UT_2D	1975-1977	468	2	470
26	FLG_UT_2E	1978-1979	362	3	365
27	FLG_UT_2F	1980-1987	316	14	330
28	FLG40	1941-1949	86	2	88
29	FLG50	1950-1959	358	10	368
30	OTH_T_1A	1960-1967	9	0	9
31	OTH_T_1B	1968-1971	100	0	100
45	OTH_T_2A	1964-1969	666	29	695
46	OTH_T_2B	1970-1973	190	0	190
47	OTH_T_2C	1974-1977	792	0	792
48	OTH_T_2D	1978-1982	435	0	435
32	OTH_UT_2A	1963-1968	83	0	83
33	OTH_UT_2B	1971-1976	57	7	64
34	OTH_UT_2C	1981-1986	356	2	358
35	OTH_UT_3A	1960-1968	219	45	264
36	OTH_UT_3B	1969-1973	468	0	468
37	OTH_UT_3C	1974-1977	431	24	455
49	OTH_UT_3D	1978-1981	531	134	665
38	OTH_UT_3E	1982-1987	352	40	392
39	OTH_40	1939-1959	196	4	200
	TOTAL		22289	1155	23444

Plot selection
In the plantation inventory plot locations were selected within strata using an ARCVIEW systematic sampling tool.

2.6 FIELD WORK

Plot measurement was conducted in accordance with the guidelines set in the “Strategic Inventory Field Manual” (Appendix C) and “Field Procedures for Eucalypt Plantation” (Appendix A). Each native forest inventory crew had three people, including one experienced in marketing to assist with tree classification. All crews received training prior to commencement and were regularly monitored by supervisory staff.

A percentage of all plots established by each measuring crew was checked by the audit team. The audit process and the results of the audit are the subject of a separate report (refer Appendix D and E).

2.7 DATA AUDIT

A percentage of all plots established by each measuring crew (in both native forest and plantation) was checked by the audit team. The main objectives of the audit process were:

1. In the native forest inventory, to provide a quantitative measure of the accuracy of data collected by field crews and to ensure that data was of a satisfactory standard.
2. In the hardwood plantation inventory, to ensure compliance with "standard of measurement" conditions of the contract between State Forest and the contractor.

The audit process is described in "Strategic Inventory Project Auditing Methodology Outline" (refer Appendix D).

2.8 DATA INPUT

Data collected using the methods described above were entered into the computer using the software package MARVLDE3. Data entered using this program are stored in a standard form, ready for import into the MARVL database.

A full description of MARVLDE3 can be found in NZFRI (1995a). An important point to note here is that data are validated on entry. This validation occurs at several levels; MARVL default variables, user-defined variables and tree descriptions.

Continuous MARVL default variables are checked against limits set in the MARVLDE3 configuration file. The relevant section of this file is shown in Table 7. Four figures are quoted for each variable. Values within the range of the inner pair (100.0 - 1500.0 for diameter, for example) are accepted without question. If a value falls in the range of either of the outer pairs (60.0 – 100.0 and 1500.0 – 4000.0 for diameter) the operator is asked to confirm the value. Values outside the extremes are not accepted.

TABLE 7. MARVLDE3 CONFIGURATION FILE

DiamRange=	60.0000	100.0000	1500.0000	4000.0000
HeightRange=	0.0000	0.0000	50.0000	70.0000
AgeRange=	2.0000	10.0000	50.0000	100.0000
PlotAreaRange=	0.0100	0.0200	0.1000	1.0000
BAFRange=	1.0000	2.0000	4.0000	25.0000
SlopeRange=	-40.0000	-30.0000	30.0000	40.0000
TallyRange=	0.0000	2.0000	25.0000	50.0000
LengthRange=	1.0000	5.0000	60.0000	200.0000
StratumAreaRange=	0.0100	0.0200	10000.0000	99999.0000

User-defined variables, which may be either continuous or categorical, are checked against ranges stored in the input file. Values for dominance code, for example, can only be 1, 2, 3, or 4. No other values are accepted.

Tree descriptions are checked for internal logic by MARVLDE3. Such things as minimum/maximum heights and diameters, heights decreasing up the stem, or diameters increasing up the stem are trapped at this stage.

The end result of the data entry process is a file called a MARVL Data Interchange file, an MDI file, which is the method by which data are imported into the MARVL database.

2.8.1 Native forest

Most data collected in native forest were first recorded on paper plot sheets and then entered into the computer later. A small proportion of the data were collected were entered in the field using a portable data recorder (PDR). In both cases, the software used for data entry was the same, MARVLDE3, which may be configured for either a desktop PC or a number of types of PDR.

2.8.2 Plantation

All data collected in the inventory of native species plantations were entered in the field using a PDR.

2.9 DATA PROCESSING

2.9.1 The MARVL system

All data were processed using the MARVL software package. This method is described in detail in "MARVL system analysis" (Appendix B); a brief overview of the method is given below.

MARVL differs from other inventory systems in that it separates the field assessment of size and quality of stems from the actual cross-cutting. When the stand is cruised, no attempt is made to divide the stem into logs or estimate merchantable limits at any point on the tree. (Lawrence, 1986).

Use of MARVL involves three basic steps (NZFRI, 1995b):
1. inventory design;
2. sampling of stand(s) to assess tree size, structure and quality; and
3. analysis of the sample data to determine potential product yield.

At step 1, MARVL supports the use of fixed area plots ("bounded" plots in MARVL literature), horizontal point and horizontal line samples, which may be used in simple or stratified designs.

Step 2 is referred to in MARVL literature as "cruising". Standard tree size indices (such as DBHOB, height) are measured in this step. There is the facility for the inclusion of user-defined variables. In addition, each tree is described by structural and quality codes.

Step 3 is accomplished with the Analyse module of MARVL. This module enables the user to produce one or more reports, using one or more views as input, with one or more cutting strategies, to one or more projection dates.

2.9.2 Native forest

Aspects of MARVL relevant to the processing of the native forests data are discussed in this section.

Cutting strategy

The cutting strategy used for the conversion of quality codes to products is summarised in Table 8. This strategy was defined after a study of the size mix of logs sold in 1997.

TABLE 8. CUTTING STRATEGY USED FOR STRATEGIC INVENTORY

Product Type	Allowable qualities	Price ($/m^3)	Min SED (mm)	Max SED (mm)	Max LED (mm)	Min length (m)	Max length (m)
Large high value	A	50	340	700	2999	3.6	15.4
Small high value	A	30	200	360	500	3.6	15.4
Low value	A, B	10	300	700	2999	3.6	15.4
Pulp	A, B, P	5	100	700	2999	3.6	15.4

Taper and volume functions

Two forms of volume and taper functions were used in estimating volumes and upper-stem diameters, those of Gordon (1983) and Muhairwe (1999). The Gordon form was used for New England Blackbutt (*Eucalyptus andrewsii*) and Spotted gum (*Corymbia maculata*), and the Muhairwe form was used for Blackbutt (*E. pilularis*), Flooded gum (*E. grandis*) and all other species. During the course of the work, more functions became available, but the original function set was retained so that any changes in tree, plot or stratum statistics could be attributed to external factors, rather than different estimating functions.

Height/diameter functions

The MARVL processing method requires that all trees have a total height, either measured or estimated, which is used as an independent variable in taper and/or volume functions (see “MARVL system analysis” (Appendix B) for more details). Heights may be estimated with either a height/age or height/DBHOB function. Because age is not known in native forests, height/DBHOB functions were used. Two functions forms are available for height estimation, the Petterson and the logarithmic. NZFRI (1995b) notes that little practical difference results from changing the method. The Petterson form was used for initial runs.

The default height/DBHOB equations cover all species and productivity classes in an individual stratum. Subsequent work (Muhairwe, unpublished data) showed that better height estimates could be obtained with a Chapman-Richards function which included a site height term. The Chapman-Richards function with a site height term scales tree height in terms of site height, an index of plot productivity. The fixed exponent of the Petterson function (which has a value of -2.5) suppresses this scaling. The decision was made to use the Chapman-Richards form for height estimation rather than the Petterson form.

Because the Chapman-Richards function is absent from the MARVL code, and because of the extreme complexity of the MARVL interchange (MDI) files and difficulty of modifying these files, a roundabout method was used to get heights (estimated with the Chapman-Richards function) into the data, and the data into a suitable form for MARVL processing. Very briefly, this method was;

All data for each CRA Region were accumulated into regional MDI files.

A program was written to convert these files into files of a standard database form.
Using these files as input, heights for all trees with no measured height were estimated with the Chapman-Richards function.

Another program was written to convert these files (with new height estimates) back to MDI file form.

Once this point was reached, the data were processed again with MARVL in the usual way.

Concentric plots

To maximise the efficiency of field work, the decision was made to include some pre-existing plots in the strategic inventory dataset. These pre-existing plots were all of the type known as “concentric” plots. In a concentric plot sample, trees in different size ranges are sampled with sub-plots of different sizes. Concentric plots are a useful measurement technique in stands which have a large number of small trees, and fewer larger (and therefore more valuable) trees. Background information on concentric plots may be found in Turner (1967) who termed them “variable radius plots”.

The MARVL system will not permit plots of different sizes within the same stratum. The approach taken to the processing of concentric plots was to define dummy strata with plots of equal sizes. For example at Tenterfield, the concentric plots had sub-plots of 0.1 ha (sampling the DBHOB range 10.0 - 29.9 cm) and 0.4 ha (sampling the DBHOB range 30.0 cm and larger). The 0.1 ha plots were assigned to strata 1 – 31 and 0.4 ha plots were assigned to strata 32 – 62. After standard MARVL processing, sub-plot totals were summed to recover total plot statistics.

2.9.3 Plantation

In principle, processing of the plantation data followed the same path as did native forest. Differences are discussed below.

Cutting strategy

The plantation analysis was run using the same cutting strategy as the analysis of the native forest.

Taper and volume functions

The plantation analysis for the crop trees of all species was run using the Gordon form function for plantation blackbutt. The Muhairwe generic function was used for non-crop trees.

Height/diameter functions

The plantation analysis was run using height/DBHOB relationships estimated using the Petterson equation.

Crop and non-crop trees

Plantation data were collected as two distinct groups of trees, crop trees and non-crop trees. Minimal information was collected for the non-crop trees, only DBHOB class and frequency were collected; no quality data were collected. Heights for non-crop trees were estimated with a generic height/DBHOB function derived from the height and DBHOB data for all crop trees.
Total stand density was estimated for plantation plots by summing plot totals for crop and non-crop trees.

2.9.4 The MARVL database

All strategic inventory data are stored in the MARVL database. The database is described in "MARVL system analysis" (Appendix B). The main point to emphasise about this database is that it stores only raw data; derived results, such as plot statistics, are not stored.

3. INVENTORY RESULTS

The results of the inventory will be discussed in four sections, which relate to the objectives of the inventory, as stated earlier in this report.

3.1 DATA QUALITY

The quality of the data used in the inventory (both native forest and plantation) was assured by the audit project. The results of this project are presented in detail in "Strategic Inventory Audit Report (UNE and LNE)" (Appendix E).

In summary, it was found that, in native forest, three plots out of 249 audited plots (1.2%) failed audit. In plantation, no plots failed audit. These results are considered to be highly satisfactory, and indicate that field measurement practice was of a high standard.

3.2 STRATUM STATISTICS, NATIVE FORESTS

Objective number 1, is met by the presentation of stratum statistics.

Stratum statistics for the UNE CRA Region are shown in Tables 9 (total standing volume), 10 (total standing merchantable volume), 11 (total standing large high value volume), 12 (total standing high value volume), 13 (total standing low value volume) and 14 (total standing pulp volume).

The project proposal for the strategic inventory specified an accuracy target of ±30% for total standing volume and merchantable volume. Figures 1 and 2 show the relationship between accuracy (probable limit of error, PLE[2]) and the number of sample points in the UNE CRA Region. Figure 1 shows that the accuracy target can be achieved for estimates of total volume if a stratum has a minimum of around 20 sample points. Accuracy is not greatly improved by the measurement of more than 50 – 60 sample points. Estimates of the volume of all high value products are less accurate; Figure 2 shows that target accuracy can be achieved for this parameter by the measurement of around 45 points per stratum.

Table 9 shows that, for estimates of total volume, accuracy targets have been met in 25 out of the 31 strata, that is, 25 out of the 31 strata have PLEs of 30% or less. These strata contain 92% of the total volume estimated by the inventory, so it can be said that accuracy targets have been met for 92% of the total volume in the UNE CRA Region. Table 12 shows that, for estimates of high value volume, accuracy targets have been met in 8 out of the 31 strata. These strata contain 42% of the total estimated volume of high value wood in UNE.

[2] Probable limit of error (PLE) is the confidence interval, expressed as a percentage of the mean. It is a convenient name for an established statistical concept, not a new statistic.

Stratum statistics for the LNE CRA Region are shown in Tables 15 (total standing volume), 16 (total standing merchantable volume), 17 (total standing large high value volume), 18 (total standing high value volume), 19 (total standing low value volume) and 20 (total standing pulp volume).

Relationships between accuracy and the number of sample points for the LNE CRA Region are shown in Figures 3 and 4. Accuracy targets for total volume can be achieved with a minimum of about 20 sample points per stratum (Figure 3), while about 40 plots are need to estimate the volume of high value products (Figure 4).

Table 15 shows that target PLE has been met in 25 out of the 31 strata; these strata have 95% of the total LNE volume. Corresponding data for the volume of all high value products are 11 out of 31 strata (Table 18), for 69% of the high value volume. These results indicate that the forests of LNE are more uniform than the forests of UNE.

Accuracy targets for total volume have been met for the bulk of the volume in both UNE and LNE. Lower accuracy for sub-sets of the total volume (the product volumes) are a commonly seen result in forest inventory. The individual products found in a stand occur as varying proportions - depending on initial stand condition, treatment history, and uncontrolled events such as fire - of a quantity that is itself highly variable. This result, and its consequences, are analogous to the problem of compartment-level estimates, described earlier in this report. An inventory designed to sample variation within the merchantable fraction of the forest would require a prohibitive number of plots.

Both time and cost prevented the establishment of sufficient plots to bring all strata to the targeted level of accuracy.

3.3 STRATUM STATISTICS, PLANTATION

Stratum statistics for the eucalypt plantation are shown in Tables 21 (total standing volume), 22 (total standing merchantable volume), 23 (total standing large high value volume), 24 (total standing high value volume), 25 (total standing low value volume) and 26 (total standing pulp volume).

Because plantations were inventoried with a constant 20 sample points per stratum, no statements can be made about the effect of the number of sample points on accuracy.

3.4 DATA FOR WOOD FLOW

These results are relevant to objective 2 of the strategic inventory. Fundamental to the projection of growth is the idea of a yield table. A yield table presents anticipated yields from a stand over time (Vanclay, 1994).

Yield tables for native forests were estimated by the yield simulator, which will be the subject of a separate report. Input to the yield simulator took the form of a “tree list”, which was simply a list of raw tree data, as measured in the inventory. Models to estimate future growth (also the subject of a separate report) were run against this data to produce yield tables. The important point to note here is that models used in native forest were tree-based models.

While the yield table approach was also used to estimate wood flows in plantations, plantation growth models described growth in terms of stand parameters (in contrast to models for native forest which were based on individual trees). Plot-level statistics were the data provided by the inventory to estimate long-term wood flows in plantations.

3.5 ASSIGNMENT OF VOLUME

The results of the strategic inventory have been used to assign volumes at the compartment level, using the process described earlier in this report. However, for reasons which were also explained earlier in this report, compartment-level accuracy cannot be achieved without a significant redesign of the inventory and a much larger sample. The results of this inventory are not accurate at the compartment level, and are therefore of little use and may even be misleading when applied to small areas.

3.6 SPATIAL LINKS

The spatial link objective has been met by the creation and maintenance of an ARC/INFO point coverage, which records the location of all inventory plots. The coverage can be intersected with other ARC/INFO coverages, as required.

4. TABLES

4.1 KEY TO TABLE HEADINGS

The tables which follow have identical column headings, which are described below.

Stratum	Stratum label
n	Number of sample points in the stratum
Max	Maximum observed value for the parameter (m^3/ha)
Min	Minimum observed value for the parameter (m^3/ha)
Average	Arithmetic mean value for the parameter (m^3/ha)
SD	Standard deviation for the parameter (m^3/ha)
PLE	Probable limit of error, the confidence interval expressed as a percentage of the mean. Confidence limit is calculated with the standard formula, t * se

TABLE 9. TOTAL STANDING VOLUME, UPPER NORTH EAST CRA REGION

Stratum	N	Max	Min	Average	SD	PLE
1	8	450.0	99.9	232.5	109.0	39
2	13	949.7	30.0	316.2	223.5	43
3	12	309.1	132.9	184.7	47.5	16
4	25	307.1	65.5	160.5	61.5	16
5	16	283.6	71.6	154.2	70.8	24
6	19	533.6	0.0	234.4	131.8	27
7	16	376.4	21.4	187.6	97.4	28
8	20	716.1	81.5	249.0	161.1	30
9	7	265.3	135.3	197.0	58.6	28
10	12	292.6	91.0	186.5	70.0	24
11	12	473.4	114.2	234.3	108.1	30
12	23	1009.3	91.6	388.7	244.2	27
13	11	454.8	0.0	250.1	141.8	38
14	19	533.9	75.2	212.3	107.6	24
15	25	369.8	22.5	158.7	83.1	22
16	49	726.8	44.2	273.0	138.3	15
17	26	697.2	110.8	285.2	116.1	16
18	43	1000.4	66.5	257.7	159.7	19
19	60	1052.1	4.7	316.4	178.9	15
20	49	816.9	63.8	213.4	119.3	16
21	109	602.7	19.9	197.1	95.2	9
22	99	426.3	46.9	164.4	66.5	8
23	41	463.1	64.7	241.6	92.8	12
24	41	592.7	63.3	238.0	115.1	15
25	32	801.4	58.1	278.4	180.8	23
26	19	577.9	0.4	244.1	163.5	32
27	32	424.9	78.2	193.9	82.5	15
28	78	376.3	60.7	174.4	73.6	10
29	42	465.2	59.1	149.3	75.1	16
30	10	427.2	114.1	205.7	95.3	33
31	10	417.8	140.8	248.1	81.5	23

TABLE 10. TOTAL STANDING MERCHANTABLE VOLUME, UPPER NORTH EAST CRA REGION

Stratum	N	Max	Min	Average	SD	PLE
1	8	186.7	33.3	104.0	63.5	51
2	13	625.9	25.2	200.4	173.6	52
3	12	275.0	81.0	143.2	57.0	25
4	25	266.0	39.2	126.3	60.0	20
5	16	280.0	24.3	114.1	73.2	34
6	19	441.2	0.0	144.5	105.2	35
7	16	350.1	0.0	161.8	91.6	30
8	20	520.9	0.0	191.5	123.1	30
9	7	241.3	63.7	162.4	74.7	43
10	12	271.5	66.3	155.0	68.4	28
11	12	309.6	33.5	166.0	83.4	32
12	23	672.8	0.0	196.5	168.2	37
13	11	335.9	0.0	148.9	99.5	45
14	19	307.9	51.1	151.6	78.9	25
15	25	347.2	8.5	123.1	85.6	29
16	49	487.0	0.0	147.6	118.8	23
17	26	365.6	0.0	147.5	110.0	30
18	43	362.6	0.0	152.0	91.6	19
19	60	521.7	0.0	201.7	130.8	17
20	49	285.3	41.7	147.1	67.5	13
21	109	459.6	2.8	144.3	87.8	12
22	99	419.4	4.3	119.9	71.1	12
23	41	425.3	0.0	180.1	105.8	19
24	41	403.1	0.0	165.1	90.9	17
25	32	594.7	50.2	213.5	154.6	26
26	19	530.1	0.0	199.2	154.8	37
27	32	406.5	22.1	140.3	74.4	19
28	78	334.7	5.2	137.5	67.1	11
29	42	287.5	10.9	98.6	54.0	17
30	10	384.4	74.4	182.5	91.4	36
31	10	280.8	93.7	183.5	56.9	22

TABLE 11. TOTAL STANDING VOLUME OF LARGE HIGH VALUE PRODUCTS, UPPER NORTH EAST CRA REGION

Stratum	n	Max	Min	Average	SD	PLE
1	8	57.1	0	15.0	21.6	120
2	13	140.8	0	36.5	49.3	82
3	12	126.9	0	22.3	36.9	105
4	25	86.7	0	14.7	19.5	55
5	16	38.7	0	8.7	11.9	73
6	19	60.5	0	22.1	19.0	42
7	16	126.7	0	22.0	33.2	81
8	20	145.9	0	32.8	37.6	54
9	7	59.8	0	19.9	21.5	100
10	12	53.0	0	20.3	19.6	61
11	12	156.8	0	55.4	41.0	48
12	23	264.5	0	44.4	56.9	55
13	11	84.6	0	24.8	24.8	67
14	19	96.3	0	16.7	25.4	74
15	25	135.6	0	14.4	32.3	93
16	49	153.7	0	32.0	34.6	31
17	26	156.8	0	21.2	34.2	65
18	43	132.3	0	28.0	32.6	36
19	60	281.9	0	44.5	48.4	28
20	49	109.1	0	22.1	25.8	33
21	109	159.6	0	20.3	29.4	27
22	99	104.3	0	11.3	19.0	33
23	41	203.3	0	31.5	40.4	41
24	41	150.1	0	25.0	31.5	40
25	32	269.7	0	50.4	66.7	48
26	19	246.1	0	70.3	75.8	52
27	32	76.7	0	22.5	21.5	35
28	78	88.2	0	15.4	17.8	26
29	42	43.3	0	9.4	12.7	42
30	10	60.6	0	16.7	19.9	85
31	10	79.9	0	33.2	27.5	59

TABLE 12. TOTAL STANDING VOLUME OF ALL HIGH VALUE PRODUCTS, UPPER NORTH EAST CRA REGION

Stratum	n	Max	Min	Average	SD	PLE
1	8	90.3	0.0	33.9	37.7	93
2	13	205.1	0.0	58.4	66.9	69
3	12	140.3	5.3	47.8	38.4	51
4	25	98.4	1.7	32.9	22.9	29
5	16	166.6	0.0	27.8	41.4	79
6	19	186.7	0.0	43.7	44.4	49
7	16	202.6	0.0	63.1	51.2	43
8	20	149.5	0.0	60.4	41.3	32
9	7	132.5	13.8	51.5	38.1	68
10	12	125.2	6.1	39.9	33.2	53
11	12	186.1	0.0	72.2	49.1	44
12	23	288.3	0.0	55.5	62.8	49
13	11	103.5	0.0	37.1	29.9	54
14	19	122.3	0.0	30.4	32.7	52
15	25	146.0	0.0	21.9	35.9	67
16	49	169.9	0.0	38.7	42.8	32
17	26	174.1	0.0	28.6	38.5	54
18	43	231.6	0.0	44.3	45.7	32
19	60	342.4	0.0	57.9	58.6	26
20	49	144.0	0.0	35.8	33.1	27
21	109	225.9	0.0	32.2	35.6	21
22	99	129.7	0.0	22.0	26.3	24
23	41	206.8	0.0	40.7	43.4	34
24	41	173.9	0.0	37.1	37.9	32
25	32	308.0	0.0	75.6	80.5	38
26	19	325.8	0.0	97.8	93.8	46
27	32	121.7	0.0	35.4	29.1	30
28	78	107.0	0.0	32.0	24.8	18
29	42	54.3	0.0	15.8	15.0	30
30	10	60.6	0.0	28.6	19.2	48
31	10	79.9	0.0	39.6	28.4	51

TABLE 13. TOTAL STANDING VOLUME OF ALL LOW VALUE PRODUCTS, UPPER NORTH EAST CRA REGION

Stratum	n	Max	Min	Average	SD	PLE
1	8	24.7	0.0	6.4	8.7	114
2	13	59.3	0.0	17.2	20.8	73
3	12	35.3	0.0	6.5	10.6	104
4	25	45.0	0.0	11.7	14.4	51
5	16	40.6	0.0	8.3	11.1	71
6	19	42.9	0.0	12.6	11.5	44
7	16	25.9	0.0	6.5	6.8	55
8	20	78.5	0.0	14.2	20.9	69
9	7	15.8	0.0	4.2	6.3	140
10	12	65.0	0.0	15.8	20.5	83
11	12	26.3	0.0	7.7	10.2	86
12	23	126.1	0.0	21.8	30.9	61
13	11	22.5	0.0	8.1	7.6	63
14	19	147.7	0.0	25.8	33.8	63
15	25	84.2	0.0	17.0	20.9	51
16	49	117.3	0.0	19.2	26.1	39
17	26	101.5	0.0	13.5	21.5	64
18	43	73.6	0.0	16.4	18.6	35
19	60	96.1	0.0	25.0	27.7	29
20	49	90.9	0.0	13.7	19.4	41
21	109	67.0	0.0	13.8	16.0	22
22	99	100.5	0.0	11.1	13.9	25
23	41	108.8	0.0	23.7	24.1	32
24	41	96.8	0.0	18.5	24.2	41
25	32	103.6	0.0	18.8	22.4	43
26	19	67.2	0.0	15.0	17.9	57
27	32	60.5	0.0	12.8	15.7	44
28	78	108.2	0.0	14.8	18.9	29
29	42	40.5	0.0	9.8	11.7	37
30	10	94.4	0.0	35.3	35.5	72
31	10	111.8	0.0	22.4	33.1	106

TABLE 14. TOTAL STANDING VOLUME OF PULP, UPPER NORTH EAST CRA REGION

Stratum	n	Max	Min	Average	SD	PLE
1	8	74.7	9.4	40.3	26.7	55
2	13	208.1	15.0	74.6	63.4	51
3	12	105.0	32.4	59.2	25.7	28
4	25	112.6	16.2	54.3	28.7	22
5	16	104.9	18.0	52.6	26.1	26
6	19	207.2	0.0	58.7	55.1	45
7	16	140.6	0.0	64.8	34.9	29
8	20	227.2	0.0	78.2	59.8	36
9	7	165.3	30.8	81.9	48.8	55
10	12	90.8	17.3	53.8	23.5	28
11	12	132.0	19.6	57.2	32.3	36
12	23	210.8	0.0	55.9	66.8	52
13	11	137.6	0.0	61.8	43.4	47
14	19	174.0	16.6	52.2	34.2	32
15	25	174.7	3.7	44.8	36.6	34
16	49	186.6	0.0	44.9	46.0	29
17	26	202.9	0.0	54.9	54.2	40
18	43	155.9	0.0	58.0	42.4	23
19	60	249.1	0.0	64.1	56.3	23
20	49	173.3	5.9	58.9	35.4	17
21	109	156.8	0.0	54.0	33.1	12
22	99	138.6	0.0	52.0	32.9	13
23	41	151.3	0.0	66.7	47.2	22
24	41	219.1	0.0	57.0	38.3	21
25	32	266.0	19.6	74.3	60.5	29
26	19	151.3	0.0	50.7	41.7	40
27	32	296.6	3.4	56.5	50.7	32
28	78	158.2	0.0	56.3	29.9	12
29	42	161.6	0.0	46.0	32.3	22
30	10	104.4	35.9	60.8	20.5	24
31	10	120.4	0.0	62.5	51.2	59

Figure 1. Effect of number of sample points on PLE, total volume in Upper North East CRA Region

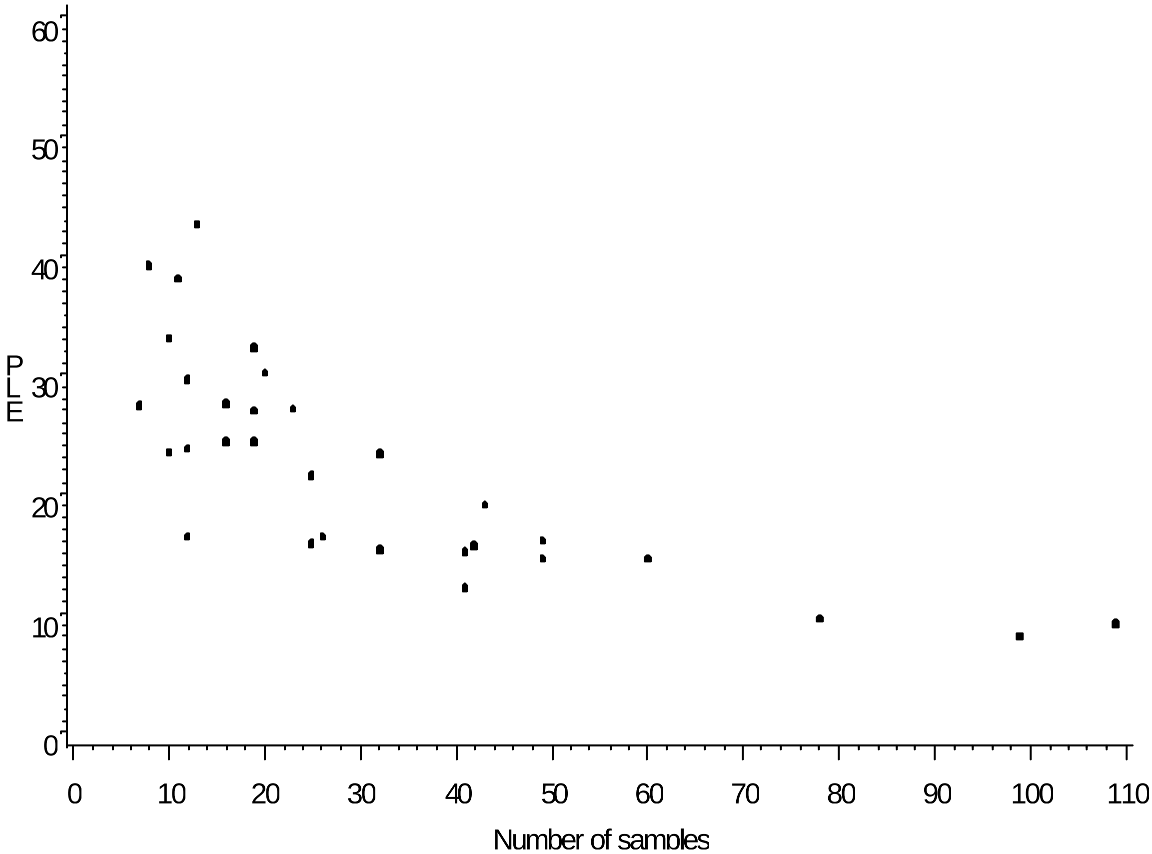
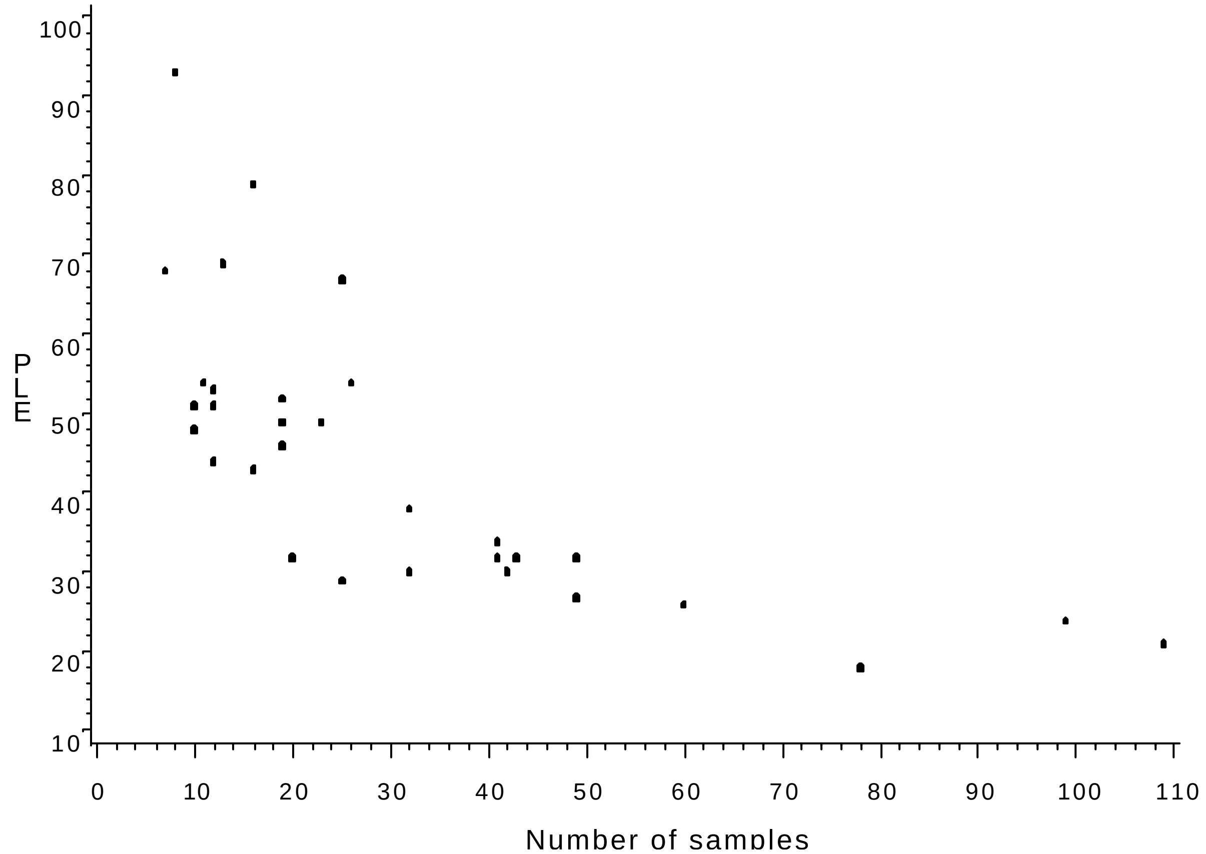


Figure 2. Effect of number of sample points on PLE, volume of all high value products, in Upper North East CRA Region


100
90
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70
60
50
40
30
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PLE
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20
30
40
50
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70
80
90
100
110
Number of samples

TABLE 15. TOTAL STANDING VOLUME, LOWER NORTH EAST CRA REGION

Stratum	n	Max	Min	Average	SD	PLE
1	18	634.7	104.2	272.6	156.9	29
2	12	446.5	103.9	272.5	105.8	25
3	22	454.5	28.0	182.3	118.0	29
4	19	255.9	38.4	120.1	62.6	25
5	21	394.6	50.9	128.4	87.0	31
6	28	516.2	58.2	253.5	120.3	18
7	63	612.1	44.3	296.9	145.0	12
8	49	706.3	36.1	279.1	132.7	14
9	49	692.6	89.8	239.8	133.7	16
10	18	448.0	107.3	233.8	98.5	21
11	8	653.1	184.1	395.9	195.4	41
12	19	815.1	172.4	420.5	203.5	23
13	6	908.5	243.9	451.5	284.2	66
14	1	383.0	383.0	383.0		
15	4	377.0	92.3	254.1	123.6	77
16	15	457.4	150.1	307.7	104.0	19
17	5	580.7	263.6	358.3	128.1	44
18	35	760.9	50.4	297.3	157.9	18
19	105	1159.4	74.3	346.2	202.5	11
20	85	640.0	46.5	260.2	114.3	9
21	19	437.0	60.6	202.9	104.3	25
22	39	431.9	57.6	204.5	99.2	16
23	107	1727.3	33.2	355.7	223.2	12
24	42	652.8	36.6	260.5	128.6	15
25	39	609.9	44.0	258.3	116.0	15
26	91	730.2	12.8	266.0	143.2	11
27	88	560.8	55.6	214.0	103.4	10
28	35	456.3	57.3	192.9	87.7	16
29	39	290.2	23.6	168.5	72.5	14
30	79	795.8	0.0	260.9	142.6	12
31	18	332.9	80.7	208.5	76.9	18

TABLE 16. TOTAL STANDING MERCHANTABLE VOLUME, LOWER NORTH EAST CRA REGION

Stratum	n	Max	Min	Average	SD	PLE
1	18	578.7	61.8	168.3	144.2	43
2	12	404.4	28.9	197.5	101.5	33
3	22	373.4	11.3	134.3	90.9	30
4	19	220.8	6.9	83.9	57.9	33
5	21	358.8	11.4	89.7	76.7	39
6	28	371.6	0.0	174.4	111.0	25
7	63	587.7	0.0	241.0	133.9	14
8	49	434.5	0.0	184.8	100.6	16
9	49	608.9	0.0	178.2	112.2	18
10	18	325.4	85.6	167.4	71.6	21
11	8	530.9	80.9	176.8	149.5	71
12	19	615.4	0.0	220.1	176.6	39
13	6	760.2	131.7	348.3	290.6	88
14	1	339.8	339.8	339.8		
15	4	226.4	79.4	168.8	68.0	64
16	15	397.0	11.8	227.3	123.1	30
17	5	456.3	193.5	304.6	97.0	40
18	35	724.0	5.1	226.9	153.0	23
19	105	754.4	0.0	214.7	147.5	13
20	85	625.1	16.4	202.3	107.6	11
21	19	238.2	46.9	137.1	50.8	18
22	39	341.4	18.3	146.8	82.1	18
23	107	1713.6	23.2	274.8	205.4	14
24	42	502.1	0.0	210.7	113.7	17
25	39	544.5	32.2	198.5	108.7	18
26	91	533.4	0.0	187.2	125.4	14
27	88	528.3	0.0	158.4	90.1	12
28	35	390.3	20.6	153.4	80.9	18
29	39	263.9	6.2	130.6	67.4	17
30	79	594.9	0.0	211.3	111.9	12
31	18	313.7	50.1	178.2	81.4	23

TABLE 17. TOTAL STANDING LARGE HIGH VALUE VOLUME, LOWER NORTH EAST CRA REGION

Stratum	n	Max	Min	Average	SD	PLE
1	18	131.2	0.0	36.9	41.6	56
2	12	54.0	0.0	20.8	17.6	54
3	22	49.9	0.0	8.3	14.1	75
4	19	26.9	0.0	5.6	8.7	75
5	21	27.3	0.0	2.6	6.3	112
6	28	67.5	0.0	11.1	16.7	58
7	63	276.7	0.0	74.4	69.5	24
8	49	210.8	0.0	33.3	44.0	38
9	49	169.7	0.0	17.8	32.2	52
10	18	92.9	0.0	20.4	26.1	64
11	8	73.5	0.0	25.2	30.5	101
12	19	315.1	0.0	56.9	78.0	66
13	6	133.4	0.0	41.3	49.9	127
14	1	53.8	53.8	53.8		
15	4	31.4	0.0	17.3	14.4	133
16	15	73.6	0.0	16.9	23.0	75
17	5	54.1	0.0	21.2	23.9	140
18	35	206.9	0.0	55.1	63.0	39
19	105	178.7	0.0	35.0	36.5	20
20	85	167.8	0.0	24.1	36.3	32
21	19	52.2	0.0	16.7	17.8	51
22	39	98.0	0.0	19.5	27.8	46
23	107	228.6	0.0	34.6	41.7	23
24	42	161.8	0.0	24.0	35.1	45
25	39	204.3	0.0	55.0	45.5	27
26	91	175.7	0.0	33.6	40.3	25
27	88	95.7	0.0	15.7	20.5	28
28	35	218.2	0.0	31.1	44.4	49
29	39	53.2	0.0	11.7	15.7	44
30	79	156.1	0.0	18.8	29.0	35
31	18	72.6	0.0	15.5	20.7	66

TABLE 18. TOTAL STANDING VOLUME OF ALL HIGH VALUE PRODUCTS, LOWER NORTH EAST CRA REGION

Stratum	n	Max	Min	Average	SD	PLE
1	18	295.9	0.0	69.8	79.5	57
2	12	66.0	0.0	39.9	20.5	33
3	22	105.9	0.0	27.4	28.1	45
4	19	46.2	0.0	15.7	13.8	42
5	21	68.8	0.0	15.3	20.1	60
6	28	99.9	0.0	24.5	23.4	37
7	63	373.8	0.0	111.2	80.7	18
8	49	254.5	0.0	61.2	61.0	29
9	49	187.7	0.0	40.7	41.4	29
10	18	175.5	4.0	57.9	49.0	42
11	8	127.2	0.0	37.6	45.5	101
12	19	323.9	0.0	70.1	78.1	54
13	6	133.4	0.0	44.5	48.7	115
14	1	70.2	70.2	70.2		
15	4	31.4	0.0	18.3	14.0	121
16	15	89.1	0.0	26.1	26.0	55
17	5	61.3	0.0	25.9	25.8	124
18	35	234.4	0.0	73.0	73.4	35
19	105	181.8	0.0	45.2	40.5	17
20	85	212.6	0.0	36.8	40.3	24
21	19	107.5	0.0	35.0	22.9	31
22	39	120.9	0.0	27.7	31.9	37
23	107	232.9	0.0	43.3	44.5	20
24	42	182.8	0.0	31.9	40.3	39
25	39	250.3	7.1	80.4	50.6	20
26	91	201.2	0.0	46.9	47.5	21
27	88	101.3	0.0	30.1	25.2	18
28	35	245.1	0.0	53.2	51.1	33
29	39	75.0	0.0	22.5	19.4	28
30	79	174.7	0.0	27.0	34.2	28
31	18	107.1	0.0	26.3	31.2	59

TABLE 19. TOTAL STANDING VOLUME OF LOW VALUE PRODUCTS, LOWER NORTH EAST CRA REGION

Stratum	n	Max	Min	Average	SD	PLE
1	18	34.4	0.0	6.0	9.1	75
2	12	136.3	0.0	27.4	38.3	89
3	22	52.6	0.0	11.7	17.6	67
4	19	21.3	0.0	3.7	6.5	85
5	21	18.5	0.0	2.1	4.4	95
6	28	97.3	0.0	15.6	23.7	59
7	63	130.8	0.0	15.0	22.9	38
8	49	100.3	0.0	19.2	22.4	34
9	49	153.2	0.0	15.4	26.5	49
10	18	52.8	0.0	8.9	15.2	85
11	8	58.2	0.0	23.0	18.0	65
12	19	86.8	0.0	27.5	29.3	51
13	6	117.8	6.2	41.2	40.3	103
14	1	48.9	48.9	48.9		
15	4	24.5	0.0	9.3	10.6	180
16	15	80.2	0.0	35.1	24.9	39
17	5	51.8	0.0	26.6	22.3	104
18	35	122.3	0.0	21.2	26.5	43
19	105	210.8	0.0	38.5	43.4	22
20	85	172.6	0.0	33.7	32.6	21
21	19	35.2	0.0	11.3	11.5	49
22	39	77.7	0.0	22.0	21.0	31
23	107	179.5	0.0	30.4	32.2	20
24	42	82.8	0.0	26.4	24.3	29
25	39	94.9	0.0	16.0	24.3	49
26	91	152.4	0.0	25.4	28.8	24
27	88	104.8	0.0	19.2	22.9	25
28	35	49.5	0.0	10.4	12.2	40
29	39	116.3	0.0	18.7	23.8	41
30	79	98.0	0.0	22.9	24.8	24
31	18	57.8	0.0	17.5	19.8	56

TABLE 20. TOTAL STANDING VOLUME OF PULP, LOWER NORTH EAST CRA REGION

Stratum	n	Max	Min	Average	SD	PLE
1	18	203.8	14.8	55.3	42.5	38
2	12	241.3	11.1	81.6	63.1	49
3	22	226.8	5.5	63.6	49.5	34
4	19	101.8	5.1	40.1	28.5	34
5	21	187.7	8.5	48.7	41.1	38
6	28	299.3	0.0	91.7	68.6	29
7	63	221.3	0.0	67.3	44.7	17
8	49	169.5	0.0	65.1	41.4	18
9	49	169.2	0.0	80.1	40.6	15
10	18	135.3	17.8	74.1	34.3	23
11	8	271.6	21.4	73.3	82.6	94
12	19	140.9	0.0	57.0	45.6	39
13	6	265.6	8.0	115.0	100.4	92
14	1	141.8	141.8	141.8		
15	4	137.9	47.2	72.1	43.9	97
16	15	288.7	5.9	128.5	90.4	39
17	5	293.6	45.8	161.1	89.5	69
18	35	242.9	4.2	80.7	55.6	24
19	105	263.1	0.0	71.7	56.7	15
20	85	191.5	0.0	80.5	42.5	11
21	19	107.6	26.5	60.3	27.6	22
22	39	131.8	9.8	57.4	31.7	18
23	107	420.5	12.0	119.5	82.9	13
24	42	255.1	0.0	99.6	63.1	20
25	39	230.3	0.0	54.6	47.4	28
26	91	202.8	0.0	68.7	50.1	15
27	88	253.3	0.0	70.4	47.7	14
28	35	143.2	3.7	61.5	33.4	19
29	39	142.6	5.2	57.4	34.2	19
30	79	285.4	0.0	103.0	63.2	14
31	18	174.7	16.5	92.3	40.3	22

Figure 3. Effect of number of sample points on PLE, total volume in Lower North East CRA Region

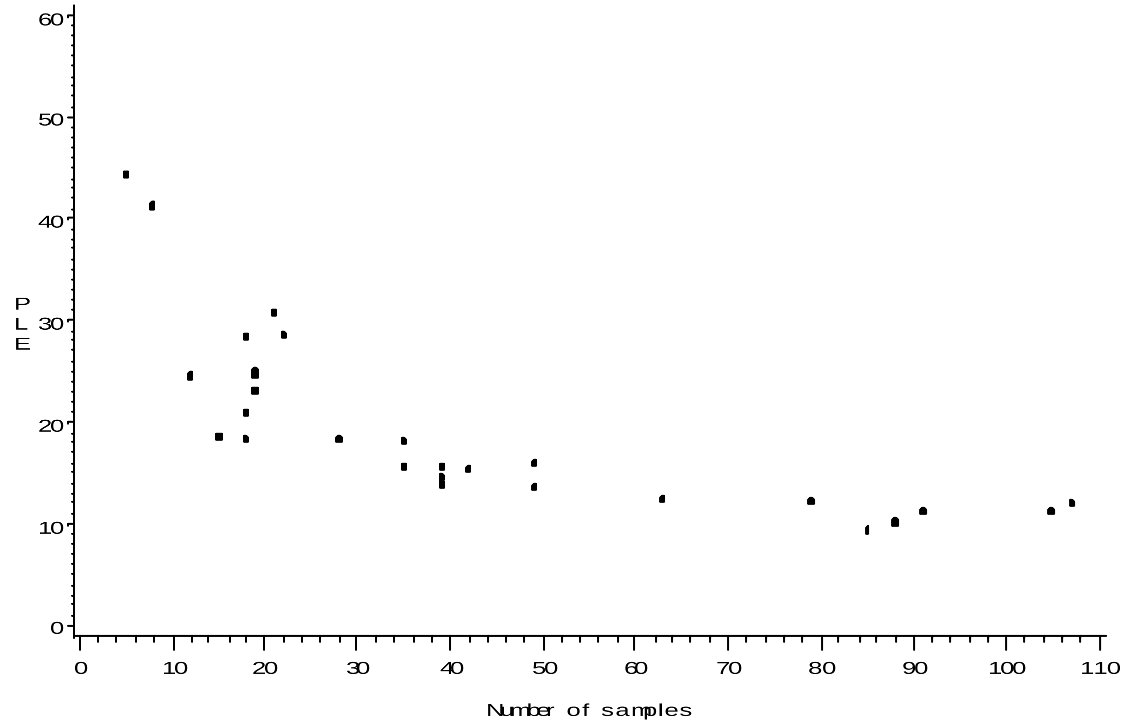

Figure 4. Effect of number of sample points on PLE, volume of all high value products, in Lower North East CRA Region

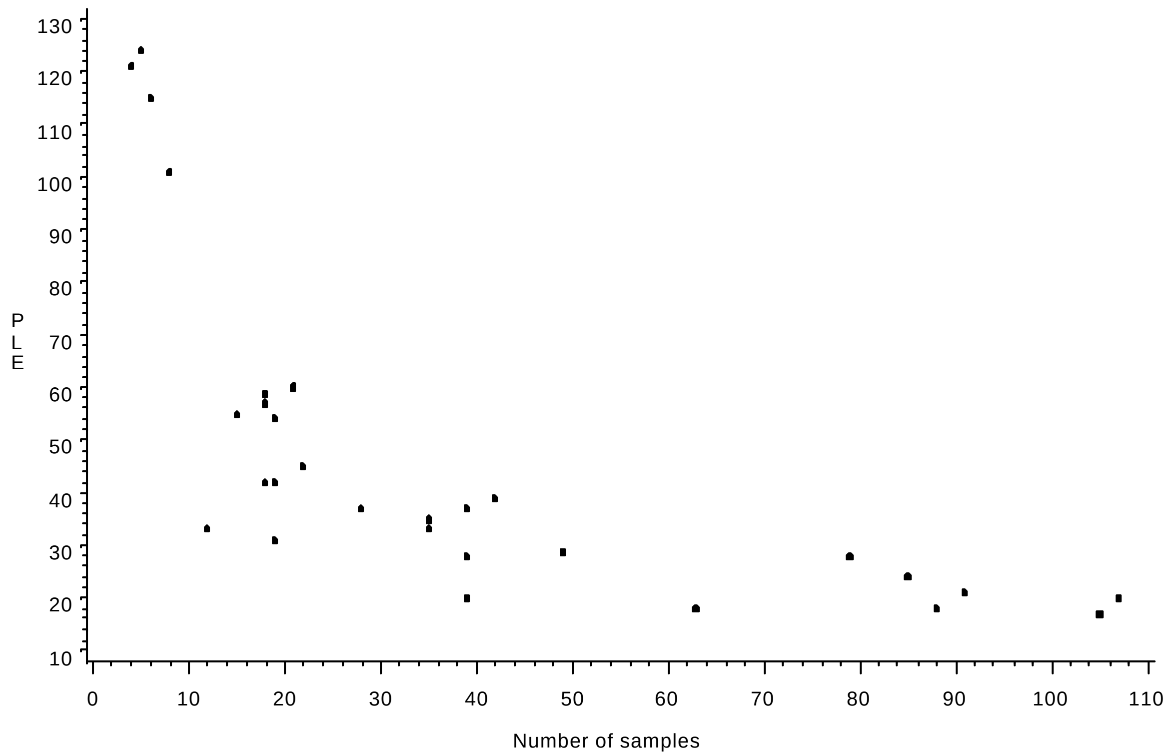

TABLE 21. TOTAL STANDING VOLUME, HARDWOOD PLANTATIONS

Stratum	n	Max	Min	Average	SD	PLE
1	20	463.0	0.0	204.5	144.4	33
2	20	358.2	55.5	178.9	96.9	25
3	20	307.8	0.0	129.5	99.7	36
4	20	431.5	0.0	138.2	117.1	40
5	20	532.1	0.0	117.4	142.1	57
6	20	636.6	0.0	228.9	182.9	37
7	20	962.1	0.0	301.3	230.2	36
8	20	329.7	10.4	137.9	86.6	29
9	20	406.2	0.0	166.8	113.3	32
10	20	337.7	0.0	156.4	86.2	26
11	20	329.4	0.0	119.8	89.3	35
12	20	617.7	0.0	155.4	167.6	51
13	20	303.6	0.0	89.7	88.9	46
14	20	405.7	27.4	248.2	116.7	22
15	20	525.3	0.0	190.9	127.2	31
16	20	296.9	0.0	182.8	72.0	18
17	20	547.4	4.6	212.6	146.2	32
18	20	349.0	0.0	166.2	88.2	25
19	20	507.9	0.0	222.6	145.5	31
20	20	378.1	0.0	189.4	125.2	31
21	20	461.5	0.0	226.7	122.9	25
22	20	504.0	0.0	188.3	134.2	33
23	20	402.1	0.0	175.4	101.9	27
24	20	355.8	0.0	201.5	89.8	21
25	20	269.7	0.0	166.2	75.9	21
26	20	279.8	0.0	146.8	70.5	22
27	20	286.1	0.0	116.7	87.6	35
28	20	525.8	0.0	155.7	140.4	42
29	20	406.3	7.9	214.6	110.2	24
30	20	257.7	117.8	182.1	39.1	10
31	20	350.8	0.0	170.8	93.2	26
32	20	645.0	0.0	233.1	148.9	30
33	20	541.0	49.3	251.7	118.6	22
34	20	270.7	0.0	80.6	81.2	47
35	20	437.9	0.0	184.5	133.8	34
36	20	321.2	0.0	131.9	109.6	39
37	20	472.4	0.0	235.5	119.9	24
38	20	279.1	0.0	67.3	80.2	56
39	20	348.0	0.0	129.3	98.8	36
40	20	388.2	0.0	154.0	128.2	39
41	20	248.6	0.0	109.5	58.2	25
42	20	314.7	0.0	143.7	99.0	32
43	20	428.5	0.0	89.5	114.6	60
44	20	406.5	0.0	164.7	109.4	31
45	20	380.1	0.0	179.8	95.4	25
46	20	463.0	0.0	158.8	121.3	36
47	20	317.0	0.0	120.5	84.4	33
48	20	263.0	0.0	116.7	105.0	42
49	20	291.9	0.0	115.9	95.0	38

TABLE 22. TOTAL STANDING MERCHANTABLE VOLUME, HARDWOOD PLANTATIONS

Stratum	n	Max	Min	Average	SD	PLE
1	20	453.1	0.0	200.5	141.7	33
2	20	355.6	55.5	176.2	95.4	25
3	20	307.8	0.0	127.6	99.0	36
4	20	416.3	0.0	134.1	113.8	40
5	20	532.1	0.0	115.1	140.9	57
6	20	629.5	0.0	224.5	180.0	38
7	20	949.2	0.0	267.0	228.1	40
8	20	319.9	0.0	130.4	86.7	31
9	20	406.2	0.0	160.1	113.2	33
10	20	329.3	0.0	146.3	84.1	27
11	20	329.4	0.0	110.4	84.5	36
12	20	617.7	0.0	152.4	166.9	51
13	20	303.6	0.0	82.0	87.9	50
14	20	387.0	27.4	245.7	115.2	22
15	20	521.9	0.0	188.4	127.6	32
16	20	290.8	0.0	180.7	70.9	18
17	20	547.4	0.0	208.5	146.9	33
18	20	334.1	0.0	158.9	88.1	26
19	20	499.0	0.0	217.9	143.7	31
20	20	378.1	0.0	185.3	123.1	31
21	20	452.4	0.0	221.1	122.5	26
22	20	500.0	0.0	186.6	133.5	33
23	20	394.3	0.0	169.6	101.7	28
24	20	331.2	0.0	191.9	85.4	21
25	20	263.5	0.0	160.5	75.3	22
26	20	279.8	0.0	141.3	68.4	23
27	20	275.2	0.0	108.3	83.3	36
28	20	511.6	0.0	154.2	137.7	42
29	20	402.4	7.9	212.8	108.7	24
30	20	257.7	117.8	181.1	38.8	10
31	20	350.8	0.0	167.4	92.3	26
32	20	642.0	0.0	223.8	145.9	31
33	20	516.8	39.3	243.4	116.3	22
34	20	268.5	0.0	74.4	79.8	50
35	20	385.0	0.0	175.7	126.3	34
36	20	319.2	0.0	125.9	107.2	40
37	20	460.9	0.0	227.0	115.8	24
38	20	270.9	0.0	61.6	77.9	59
39	20	348.0	0.0	117.2	97.9	39
40	20	386.9	0.0	151.4	127.1	39
41	20	242.2	0.0	104.7	58.4	26
42	20	273.8	0.0	137.6	91.9	31
43	20	419.4	0.0	87.1	112.7	61
44	20	406.5	0.0	158.7	108.0	32
45	20	361.1	0.0	175.1	93.0	25
46	20	450.2	0.0	156.4	119.3	36
47	20	300.2	0.0	115.0	82.4	34
48	20	252.6	0.0	111.7	101.4	42
49	20	289.4	0.0	109.2	92.1	39

TABLE 23. TOTAL STANDING LARGE HIGH VALUE VOLUME, HARDWOOD PLANTATIONS

Stratum	n	Max	Min	Average	SD	PLE
1	20	158.0	0.0	34.8	51.2	69
2	20	57.4	0.0	16.9	17.4	48
3	20	69.8	0.0	4.8	16.4	160
4	20	54.7	0.0	5.4	14.8	129
5	20	161.9	0.0	17.1	45.2	124
6	20	174.7	0.0	23.5	41.0	82
7	20	130.3	0.0	13.7	32.5	111
8	20	67.9	0.0	8.0	18.8	109
9	20	82.0	0.0	8.2	23.4	133
10	20	0.0	0.0	0.0	0.0	
11	20	14.2	0.0	0.7	3.2	209
12	20	408.9	0.0	42.7	103.1	113
13	20	174.4	0.0	9.8	39.0	186
14	20	218.2	0.0	83.0	57.1	32
15	20	274.8	0.0	32.5	64.7	93
16	20	62.5	0.0	10.3	19.0	86
17	20	191.5	0.0	31.5	46.2	69
18	20	73.7	0.0	4.9	17.1	162
19	20	139.1	0.0	25.5	36.0	66
20	20	148.8	0.0	26.8	44.0	77
21	20	93.2	0.0	15.0	29.2	91
22	20	210.6	0.0	32.6	48.9	70
23	20	44.3	0.0	4.7	12.1	120
24	20	49.9	0.0	4.6	14.1	145
25	20	15.3	0.0	0.8	3.4	209
26	20	13.4	0.0	0.7	3.0	209
27	20	0.0	0.0	0.0	0.0	
28	20	117.1	0.0	27.8	39.5	66
29	20	133.0	0.0	45.2	41.0	42
30	20	86.5	0.0	20.5	21.7	50
31	20	80.4	0.0	16.3	23.5	68
32	20	274.0	0.0	25.8	64.8	117
33	20	117.8	0.0	9.7	27.1	131
34	20	36.8	0.0	3.1	9.8	147
35	20	72.0	0.0	13.9	23.6	80
36	20	26.7	0.0	1.3	6.0	209
37	20	121.5	0.0	7.3	27.5	175
38	20	79.1	0.0	4.0	17.7	209
39	20	136.3	0.0	20.1	44.8	104
40	20	146.9	0.0	28.2	39.0	65
41	20	31.4	0.0	3.0	8.1	124
42	20	18.3	0.0	0.9	4.1	209
43	20	64.5	0.0	11.2	22.2	93
44	20	189.1	0.0	16.7	43.5	122
45	20	78.9	0.0	9.5	20.2	100
46	20	79.5	0.0	8.9	19.6	103
47	20	13.9	0.0	0.7	3.1	209
48	20	53.2	0.0	4.0	13.0	153
49	20	0.0	0.0	0.0	0.0	

TABLE 24. TOTAL STANDING VOLUME OF ALL HIGH VALUE PRODUCTS, HARDWOOD PLANTATIONS

Stratum	n	Max	Min	Average	SD	PLE
1	20	320.20	0.0	121.73	103.38	40
2	20	217.40	32.6	97.08	57.52	28
3	20	166.70	0.0	61.39	59.23	45
4	20	214.50	0.0	60.34	53.62	42
5	20	369.40	0.0	65.37	95.79	69
6	20	327.10	0.0	122.03	105.81	41
7	20	358.70	0.0	111.17	99.86	42
8	20	219.20	0.0	56.28	65.75	55
9	20	258.40	0.0	73.39	73.46	47
10	20	108.80	0.0	48.57	38.25	37
11	20	113.20	0.0	37.28	36.29	46
12	20	433.00	0.0	80.30	112.25	65
13	20	192.20	0.0	33.16	55.21	78
14	20	277.60	13.2	163.14	81.44	23
15	20	349.40	0.0	117.71	90.51	36
16	20	196.00	0.0	104.29	53.30	24
17	20	353.80	0.0	126.52	98.81	37
18	20	165.40	0.0	76.03	54.05	33
19	20	346.70	0.0	121.15	94.89	37
20	20	249.10	0.0	109.03	82.43	35
21	20	226.90	0.0	111.11	72.03	30
22	20	322.00	0.0	104.52	77.99	35
23	20	213.60	0.0	75.81	60.11	37
24	20	159.30	0.0	65.43	47.98	34
25	20	158.80	0.0	58.18	47.46	38
26	20	134.30	0.0	42.35	32.79	36
27	20	132.10	0.0	35.21	41.57	55
28	20	330.30	0.0	94.86	90.52	45
29	20	331.70	1.4	146.59	84.84	27
30	20	162.70	58.1	120.93	30.23	12
31	20	212.70	0.0	95.88	57.60	28
32	20	439.30	0.0	109.86	97.59	42
33	20	266.70	11.2	116.36	79.62	32
34	20	171.30	0.0	22.15	42.07	89
35	20	169.60	0.0	83.62	60.19	34
36	20	162.10	0.0	44.47	52.81	56
37	20	222.90	0.0	94.08	64.53	32
38	20	161.30	0.0	17.38	38.56	104
39	20	224.20	0.0	52.43	72.08	64
40	20	260.00	0.0	94.93	82.92	41
41	20	122.20	0.0	47.83	36.55	36
42	20	148.50	0.0	56.14	45.83	38
43	20	282.80	0.0	43.85	69.75	74
44	20	249.40	0.0	81.20	69.01	40
45	20	235.10	0.0	94.92	65.79	32
46	20	209.20	0.0	80.28	60.82	35
47	20	116.90	0.0	45.55	37.46	38
48	20	143.40	0.0	48.17	45.87	45
49	20	121.90	0.0	25.23	37.14	69

TABLE 25. TOTAL STANDING VOLUME LOW VALUE PRODUCTS, HARDWOOD PLANTATIONS

Stratum	n	Max	Min	Average	SD	PLE
1	20	40.3	0.0	4.1	11.0	125
2	20	21.6	0.0	2.0	5.4	127
3	20	0.0	0.0	0.0	0.0	
4	20	178.8	0.0	9.6	39.9	195
5	20	35.2	0.0	4.5	11.0	116
6	20	16.4	0.0	1.4	4.4	147
7	20	41.6	0.0	2.7	9.6	164
8	20	0.0	0.0	0.0	0.0	
9	20	15.8	0.0	1.3	4.1	148
10	20	0.0	0.0	0.0	0.0	
11	20	0.0	0.0	0.0	0.0	
12	20	78.0	0.0	8.0	19.7	116
13	20	37.6	0.0	1.9	8.4	209
14	20	44.8	0.0	6.5	11.9	86
15	20	43.4	0.0	3.6	10.4	136
16	20	0.0	0.0	0.0	0.0	
17	20	15.2	0.0	1.4	4.4	145
18	20	12.9	0.0	0.6	2.9	209
19	20	25.4	0.0	2.7	7.2	123
20	20	17.3	0.0	0.9	3.9	209
21	20	35.8	0.0	2.5	8.5	158
22	20	49.4	0.0	3.1	11.3	168
23	20	0.0	0.0	0.0	0.0	
24	20	15.4	0.0	1.3	4.1	147
25	20	0.0	0.0	0.0	0.0	
26	20	0.0	0.0	0.0	0.0	
27	20	14.1	0.0	0.7	3.2	209
28	20	18.6	0.0	2.1	5.2	118
29	20	9.2	0.0	1.9	2.7	67
30	20	9.5	0.0	1.4	2.9	95
31	20	14.0	0.0	1.5	3.6	112
32	20	23.7	0.0	1.7	5.7	156
33	20	12.9	0.0	0.6	2.9	209
34	20	14.1	0.0	0.7	3.2	209
35	20	13.0	0.0	1.8	4.3	115
36	20	11.3	0.0	0.6	2.5	209
37	20	37.6	0.0	1.9	8.4	209
38	20	18.4	0.0	0.9	4.1	209
39	20	23.2	0.0	2.6	6.7	121
40	20	31.7	0.0	1.9	7.1	174
41	20	0.0	0.0	0.0	0.0	
42	20	18.5	0.0	1.8	5.7	144
43	20	38.3	0.0	1.9	8.6	209
44	20	32.8	0.0	1.6	7.3	209
45	20	23.0	0.0	1.2	5.1	209
46	20	32.7	0.0	2.8	7.8	134
47	20	17.2	0.0	0.9	3.8	209
48	20	12.1	0.0	0.6	2.7	209
49	20	19.4	0.0	1.0	4.3	209

TABLE 26. TOTAL STANDING PULP VOLUME, HARDWOOD PLANTATIONS

Stratum	n	Max	Min	Average	SD	PLE
1	20	135.0	0.0	61.9	41.9	32
2	20	148.3	15.4	62.8	41.9	31
3	20	133.2	0.0	57.2	43.9	36
4	20	140.4	0.0	52.7	39.1	35
5	20	157.4	0.0	37.3	42.0	53
6	20	267.1	0.0	82.3	69.6	40
7	20	585.2	0.0	122.2	129.0	49
8	20	96.2	0.0	62.7	30.7	23
9	20	160.8	0.0	71.2	48.3	32
10	20	195.4	0.0	80.4	48.3	28
11	20	164.5	0.0	60.6	47.9	37
12	20	153.7	0.0	51.6	48.9	44
13	20	134.8	0.0	39.6	42.1	50
14	20	124.0	7.9	59.5	32.9	26
15	20	114.7	0.0	56.2	35.6	30
16	20	156.5	0.0	64.1	40.7	30
17	20	218.7	0.0	65.3	52.1	37
18	20	162.0	0.0	69.2	42.4	29
19	20	149.5	0.0	79.3	49.2	29
20	20	137.8	0.0	62.5	46.5	35
21	20	160.2	0.0	89.5	49.6	26
22	20	202.5	0.0	66.7	53.2	37
23	20	168.7	0.0	79.9	44.1	26
24	20	237.9	0.0	105.6	55.1	24
25	20	138.9	0.0	86.9	38.8	21
26	20	149.7	0.0	84.9	39.4	22
27	20	125.4	0.0	61.6	39.5	30
28	20	165.4	0.0	48.0	45.1	44
29	20	115.3	5.5	54.7	29.6	25
30	20	84.0	31.1	48.8	15.6	15
31	20	124.4	0.0	57.9	32.5	26
32	20	167.6	0.0	88.8	46.6	25
33	20	212.8	24.1	107.2	45.9	20
34	20	121.2	0.0	44.1	40.8	43
35	20	187.5	0.0	73.5	58.7	37
36	20	134.3	0.0	69.9	53.9	36
37	20	192.0	0.0	109.1	49.1	21
38	20	114.5	0.0	36.0	40.5	53
39	20	139.2	0.0	49.7	35.1	33
40	20	119.7	0.0	46.2	36.9	37
41	20	149.2	0.0	49.6	31.3	30
42	20	202.3	0.0	66.7	59.7	42
43	20	130.2	0.0	34.1	40.9	56
44	20	139.9	0.0	63.0	41.7	31
45	20	123.6	0.0	66.4	31.7	22
46	20	209.0	0.0	59.7	52.4	41
47	20	168.9	0.0	57.3	46.3	38
48	20	154.5	0.0	53.4	52.6	46
49	20	201.3	0.0	69.3	55.6	38

APPENDIX A - FIELD PROCEDURES FOR EUCALYPT PLANTATION – MARVL INVENTORY

APPENDIX B - MARVL SYSTEM ANALYSIS

APPENDIX C - STRATEGIC INVENTORY – FIELD MANUAL

APPENDIX D - STRATEGIC INVENTORY PROJECT AUDITING METHODOLOGY OUTLINE

APPENDIX E - STRATEGIC INVENTORY AUDIT REPORT (UNE AND LNE)

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State Forests of NSW

Field Procedures

For

Eucalypt Plantation

MARVL Inventory

Table of Contents

1. INTRODUCTION

This manual has been written as a guide for the measurement of MARVL primary bounded plots in eucalypt plantations on the North Coast.

While attempting to give an explanation of correct procedures for most aspects of MARVL plot measurement it cannot be expected to cover all possible situations encountered in the field. If, having read the relevant part of this manual, you are still unsure about any aspect of plot measurement you should contact State Forests' Resource Assessment Team at Coffs Harbour.

Scott Arnold, Elspeth Baalman & Damian Walsh

2. MARVL INVENTORY EQUIPMENT CHECKLIST

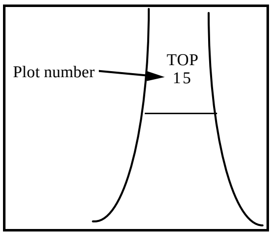
- Map of area to be inventoried, with plot location information
- Plot size, age class, species, thinning information and tally proformas
- Hip chain
- Hip chain cotton (keep a good supply)
- Compass
- Clino (preferably Suunto PM-5/1520 D)
- Vertex Hypsometer (with spare batteries)
- 30 or 50 metre tape
- Spray paint (keep a good supply)
- Diameter tape
- Set of field notes
- Calculator (or slope correction tables)
- Field Computer

3. LOCATING PLOTS

From the plot location notes read off the bearing and distance to the plot you intend to measure. Check to ensure you know the correct plot size.

The plot centre should be located from the take-off point (TOP). The TOP should be marked from some definitive feature on the ground, preferably one that has been surveyed such as a road or boundary fence. A hip-chain (not the trip meter in the vehicle) should be used to locate the take off point at some point along the road, usually from an intersection. Mark the TOP, along with the plot number, on a tree or other easily visible spot nearest the TOP, as per Figure 1.

Figure 1. TOP Identification

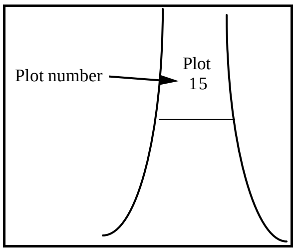


Check that you have all necessary equipment before leaving the vehicle.

Use hip-chain and compass to locate plot point. The plot should be established exactly where the hip-chain and compass bearing take you. For slope greater than 10° measured distances need to be corrected to give horizontal distance, refer to Appendix 1. If the plot point is in some way "different" to the general area, feel free to make note of this in the comments section at the plot level of the data entry file.

Mark the centre of the plot with a small painted cross on the ground. If the plot centre is disturbed during measurement ensure that it is repainted before leaving the plot. The plot number should be painted on the tree nearest the plot point, as per Figure 2.

Figure 2. Plot Centre Identification



4. SETTING OUT PLOTS

Once each plot has been located a quick check should be made to ensure that the plot is true plantation (planted in rows or obviously even aged) and of the correct species. Appendix 5 (**Source**: Forest Trees of Australia, Boland et al, 1984) provides botanical identification for each species represented in current eucalypt plantations. Bark, leaf, inflorescence and fruit characteristics should be checked to ensure the correct species is present. If an error is suspected, samples of leaves and fruit should be collected (recording strata and plot number) and a note made in the comments section of which planted species is present. If a plot is located in an area suspected not to be plantation, the plot must be measured, this should also be noted in the comments. Similarly, if the stratum is classed as thinned and no evidence of harvesting is visible within or surrounding the plot, and vice versa for unthinned strata, this should also be noted.

4.1 Plot Size

MARVL plots should have 15-25 target trees contained within the plot. Target trees in this instance represent the planted species over 10 cm dbhob. Plot size within any one stratum must not be changed. If you set your first plot in Strata 1 as a 0.03 ha plot all other plots in that strata have to be 0.03 ha. This means you have to consider the least number of trees to expect in all plots in any stratum - not just the first plot. The plot size can be different in other strata.

Table 1. Expected Number of Trees per Plot by Stocking Class

Stocking Rate	***Plot size (ha)***	***Plot radius***	***Average No. trees***	***Expected range***
100-400 s/ha (200 average)	**0.10**	**17.84 m**	**20**	**(10-40)**
400-800 s/ha (600 average)	**0.03**	**9.77 m**	**18**	**(12-24)**
800+ s/ha (1000 average)	**0.02**	**7.98 m**	**20**	**(16-40)**

4.2 Slope Correction

The first thing to be done in establishing a bounded plot is to measure, and allow for, the slope of the plot. The slope of the plot must be measured in order to make sure that the area occupied by the plot is always equivalent to the required plot size. On slopes greater than 5^0

the correct radius of the plot should be looked up on the “MARVL Bounded Plot Slope Correction Table” provided as Appendix 2.

Plot slope is determined by measuring the slope of the steepest part of the plot as well as the slope in the opposite direction. The two readings are averaged to get plot slope (ignoring the sign of the readings). Where a plot falls on the cap of a ridge measure the slope angle down either side of the ridge. Similarly if the plot falls in a gully you measure the slope up either side. Remember, when taking slope readings you should take readings to a point at the same height as your eye, not to ground level.

4.3 Marking Plot Boundary

Having measured the average slope of the plot and determine the new radius, the next thing to do is set out the plot boundary. This is best done using the Vertex hypsometer or equivalent to lay out a circle surrounding the plot point.

If one is using the Vertex hypsometer to mark out the plot boundary the following method should be used:

One person should hold the transponder 1.3 metres directly above the plot point while another person sweeps around the plot perimeter measuring the distance of all trees which appear close to the plot radius. The hypsometer should be held at the middle of the side of the tree at 1.3 metres when measuring distances. While most trees will be clearly in or out, any which are within 20 centimetres of the plot radius will need to be checked exactly using a tape measure.

In this case, one person should hold the end of the 30 or 50 metre tape directly above the plot point marked on the ground while another person holds the other end of the tape at the middle of the side of the tree at 1.3 metres. At all times the tape should be held tight, straight (no bending around trees, branches, etc) and parallel to the ground. If the middle of the side of the tree at 1.3 metres above the ground is closer to the plot point than the plot radius (or exactly equal to it), then the tree is in, otherwise the tree is out. Please take care when checking "close" trees because one tree in or out of a plot can make a difference of several hundred cubic metres!!

If another measuring device is used then the measuring standard should be equivalent to that outlined above.

4.4 Edge Plots

Where a plot point falls at the edge of the planted area - but not actually on a road or in a retention area - and a normal circular plot will not fit entirely within the planted area you should use the "Mirage method" for edge plots, see Figure 3.

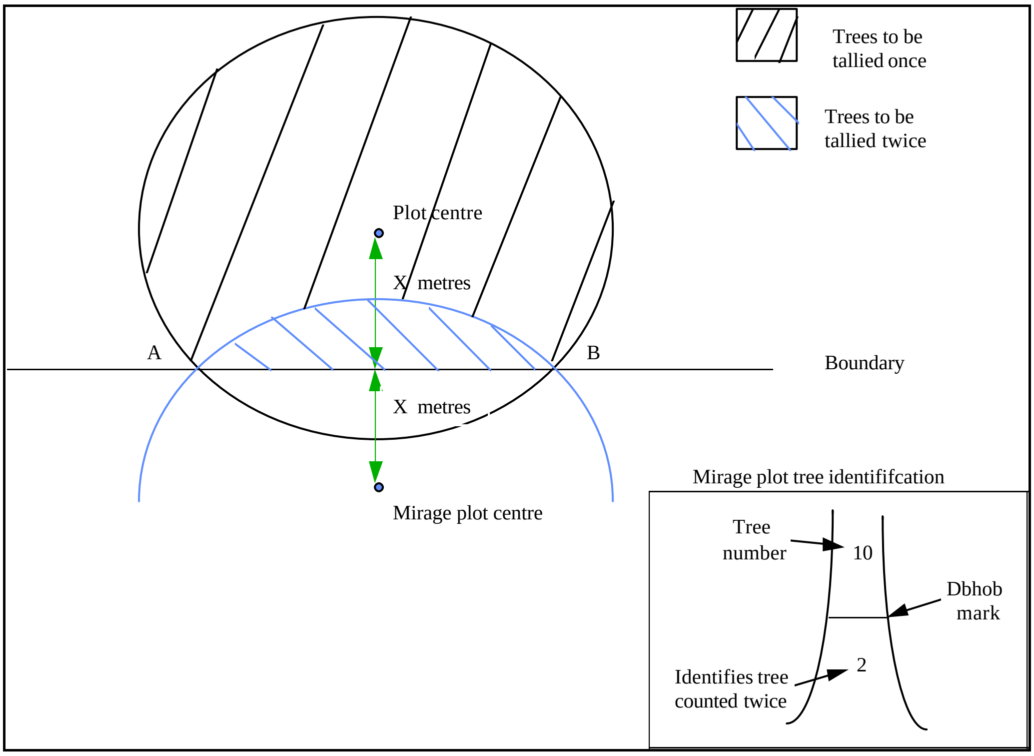
The idea of these plots is to be able to sample the "edge effect" without changing the plot size within any stratum.

The first part of this method involves setting out and measuring the plot as usual. You should then measure the shortest, straight line distance from the plot point to the edge of the stratum/compartment (labelled "X metres" on Figure 3). You should also mark the two points (labelled "A" and "B" on Figure 3) where the plot radius intersects with the stratum/compartment boundary.

The next step is to set out the distance "X metres" beyond the edge to locate the "Mirage Plot Point". From the "mirage" point you use the same plot radius as for the original plot to set out another plot radius between points "A" and "B".

All trees which tally twice should be indicated by painting "2" underneath the dbhob mark. You should make a note in the comments section each time you establish an edge plot.

Figure 3. Mirage Plot Layout

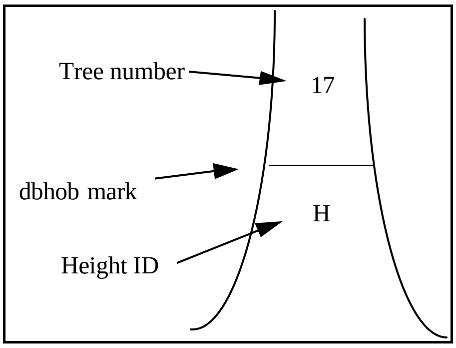


5. HEIGHTING TREES

There are two different height samples that need to be taken at each plot, tree heights to predict all tree heights (MARVL height trees) and Mean Dominant Height (MDH).

All trees selected for heighting need to be identified. The different sampling methods used do not need to be treated separately. As such an "H" should be painted underneath the dbhob mark of any height tree, as illustrated by Figure 4.

Figure 4. Height Tree Identification



5.1 Selecting Height Trees for MARVL Heights

Three trees in each plot are <u>normally</u> measured for height. MARVL uses the heights and diameters from the height trees to develop a Height-Diameter curve which is used to predict the heights of all trees not actually measured for height. This means that the height trees should include the whole range of tree diameters in the area.

Trees selected for heighting should be of the planted species and selected across the range of diameters by selecting one smaller-than-average tree, one average tree and one larger-than-average tree at each plot. You should not always select the smallest, average and largest tree from each plot. As MDH sampling aims to sample the largest trees in the stand, only the 'small' and 'medium' sized height trees will be required for MARVL heights.

You should avoid trees with severe leans or dead tops. Heighting multiple-leaders is fine if they are common in the plot and surrounds.

Where a plot has many suppressed, shorter trees present a third height tree should be selected from these shorter trees. This does not include trees which are short due to having a broken stem.

5.2 Mean Dominant Height

Mean dominant height is defined as an average of the heights of the 40 "fattest" (largest diameter) trees per hectare in a stand. It is used because it is a repeatable measurement of stand height indicating site. The number of height trees to be measured within a plot for the calculation of mean dominant height depends on the plot size. In an effort to ensure that the tallest trees are selected, two more than the number of fattest trees required are measured. Table 2 indicates the number of height trees required for a range of plot sizes.

Table 2. Number of MDH Height Trees Required by Plot Size

Plot Size	Number of Trees	
(ha)	to be measured	included in mean
0.02	4	2
0.03	4	2
0.10	6	4

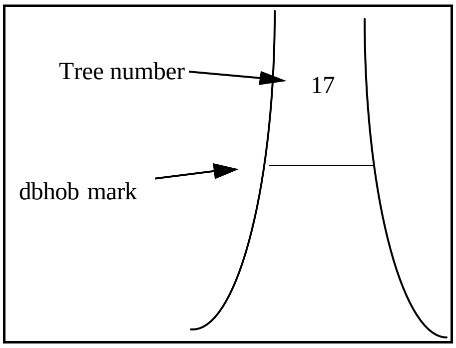
For example, if the plot size is 0.1 ha then the six fattest trees within the plot need to be measured to derive mean dominant height. Similarly, if the plot size was 0.03 ha the four fattest trees within the plot would need to be measured. A minimum of four trees are required per plot.

6. MEASURING TREES

Only those trees of the plantation species greater than 10 cm dbhob should be measured using the MARVL inventory system as described below. Experience has shown that substantial areas of eucalypt plantation are invaded with other species, especially Turpentine, Casuarina and Acacia. These trees will not be assessed to avoid unnecessary sampling, and an ocular tally by diameter class will be made (refer Section 9).

Each tree selected as a target tree must have the dbhob mark painted around the circumference of the tree at breast height exactly, and the tree number clearly marked on the face closest to the plot centre. Figure 5 indicates the identification required.

Figure 5. Target Tree Identification



6.1 Diameter at Breast Height Over Bark (dbhob)

6.1.1 Measuring Point

There is a set of rules which define dbhob and how to measure it. The rules are:

1. Breast Height is 1.3 metres above ground level measured along the stem. Where the tree is on a slope, 1.3m is measured on the uphill side of the tree. Where the tree is on a lean, 1.3m is measured on the underside of the lean.
2. Trees which fork above 1.3m are considered to be one tree, but if the two leaders are separate at 1.3m each leader is treated as a separate tree.
3. Where a swelling occurs at 1.3m, two points, unaffected by swellings or limbs, equal distances above and below 1.3m should be selected so two unaffected measurements are then averaged to give an estimate of dbhob.

The measurer should paint the point(s) on the tree where the diameter measurement(s) have been made.

6.1.2 Tape & Placement

The tape should be placed around the tree perpendicular (that is, at right angles) to the axis of the stem at 1.3m. If there is lichen or loose bark at 1.3m they should be gently cleared so as not to remove any firm bark from the tree.

On larger trees care should be taken to ensure the tape does not "get the droops" around the back of the tree. The tape should always go directly around the stem at the point of measurement.

6.1.3 Taking Readings

All diameter measurements should be measured, called and recorded in millimetres. Where a part millimetre occurs always round down.

6.1.4 Multiple Leaders

Trees which fork above 1.3m are considered to be a single tree. Trees which have physically separated below 1.3m are considered to be two (or possibly more) different trees.

In situations where a tree forks right at 1.3m and the 1.3m point is swollen as a result of the fork, the tree should be treated as two separate trees with the diameters measured at the lowest point where the new leaders have assumed a normal shape.

7. ASSESSING TREES USING THE DICTIONARY

7.1 Overview

Trees in MARVL plots are assessed for stem quality characteristics - not products. The assessor should not attempt to break the tree up into "logs" of any sort. In general each tree should be viewed overall and then assessed for major features on a metre-by-metre basis.

The stem quality characteristics used to describe the trees are limb size, sweep and externally visible defects (insect damage and spiral grain). Although these characteristics may have definite numeric values the majority of the tree description is open to interpretation of the stem quality codes (refer to Eucalypt Plantation MARVL Dictionary - Appendix 3).

There will always be some variation in how the same tree is described, however it is most important that the key features of a tree are always recognised.

Consistent interpretation of the dictionary is vital to getting meaningful inventory results. As a means of achieving this it is recommended that your "calibration" of limb size and sweep be refreshed periodically by revisiting plots measured earlier in the inventory.

If a section of a tree borders between two codes always describe the section as being the poorer of the two choices. For example, if you can't decide if some limbs are smaller or larger than 20% of stem diameter, then assess that section of the tree as having limbs larger than 20% of stem diameter.

Viewing each tree from several angles definitely helps the assessor to pick up all the key features of the tree, particularly sweep and insect damage. Except in the case of very simple trees, all trees should be assessed from at least two angles.

Remember, as there is no reasonable means of actually measuring a tree for stem quality your best estimate is the best that can be hoped for. Take your time with close calls and try not to let your interpretation of the dictionary "drift" over time.

7.2 Limb Size

The first thing to note about limb size is that any limb, no matter how small, constitutes unpruned stem. If you are assessing pruned trees the person at the base of the tree is in the best position to assess the pruned height of the tree. Allowance should be made for the angle of limbs when giving the length of tree sections.

7.3 Sweep

This is where the greatest variation in interpretation will occur. The sweep table is based on minimum acceptable sweep limits for sawlogs. Consistency is very important, so use the allowable sweep tables in the dictionary to help make close decisions.

As mentioned before, occasional revisiting of older plots and viewing trees from more than one position will definitely help sweep interpretation accuracy and consistency.

7.4 Other Damage

Where damage is observed and considered serious, then the appropriate length section of the tree should be described as waste. Insect damage, as indicated by swellings along the stem of the tree and/or dead or dying crowns, should also be taken into account and described appropriately. Spiral grain is another defect that needs identification and appropriate description.

7.5 Multiple Leaders

Each of the leaders is treated as a new tree and so needs a diameter estimate for the taper model. Measuring a nearby tree of equal size is the best method of providing an indication of the leader diameters.

To avoid confusion between assessor and booker when describing multiple leaders you should complete one leader before starting on the other(s). If one of the leaders divides again you should describe the "single" leader first and do the re-dividing leader last in order to leave room for the additional lines needed for each of the leaders.

7.6 Crown Condition

Each tree in the plot is assessed for its Crown Condition. The definitions of the are the same as for State Forests' PGP system:

1	Good	Leafy, vigorous
2	Fair	Average
3	Poor	Senescent, diseased or damaged

7.7 Dominance Class

Each tree in the plot is also assessed for its Dominance Class. The definitions of the Dominance Classes are the same as for State Forests' PGP system:

1	Dominant	Tree with crown extending above the general canopy, receiving f light from above & partly from the sides; a larger than average tree the stand.
2	Co-dominant	Tree crown forms part of the general canopy, receives full light fr above but comparatively little light from the sides.
3	Sub-dominant	Tree shorter than the previous two classes, but with a crown extendi into general canopy, receiving a little direct light from above, but no from the sides.
4	Suppressed	Tree crown entirely below canopy level, receiving no direct light fr above or sides.

7.8 Logging Impediment

Logging Impediment is supposed to describe any "environmental" reason why a tree would not be available for harvesting during a routine harvesting operation. These include slopes greater than 30^o and water-course prescriptions.

Where a plot falls in, or near, a creek and some, or all, of the trees in the plot would be in a filter/protection strip of some sort, you should apply a 10 metre exclusion zone along the bank of the creek. All trees within that 10 metre exclusion zone are given "E" for their Logging Impediment.

7.9 Stem Deterioration Point

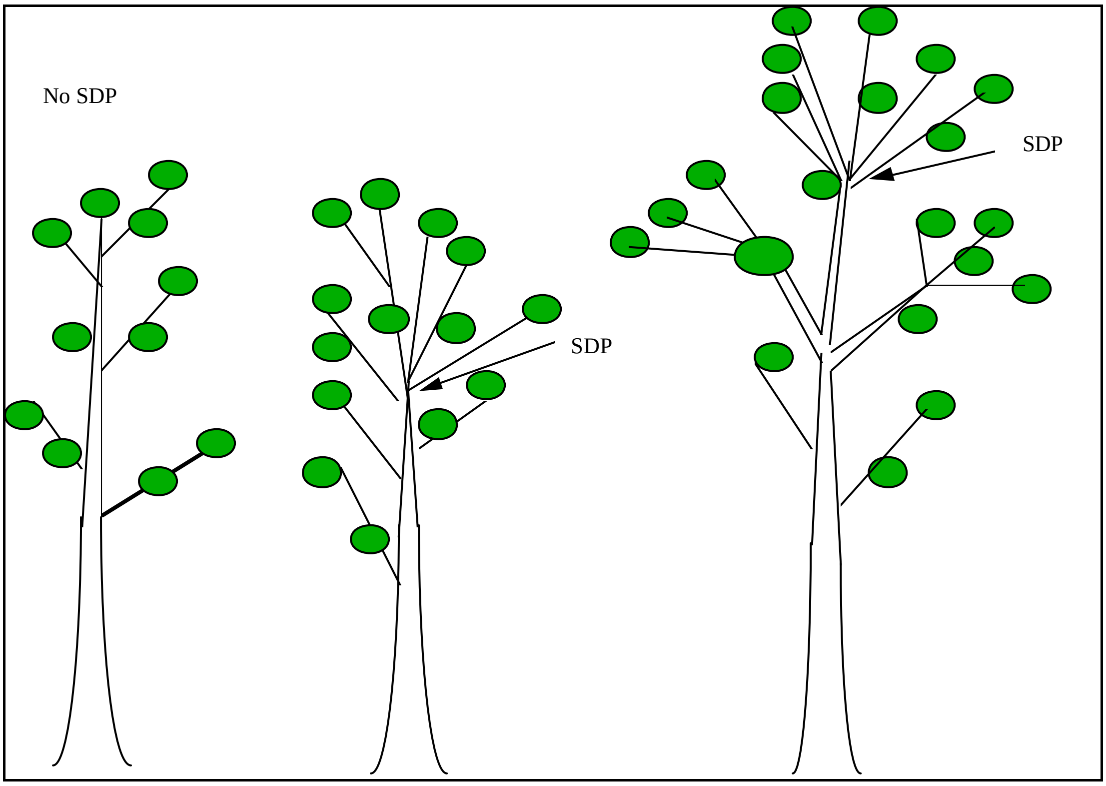
Stem Deterioration Point (SDP) is defined as **the point beyond which no single leader can be readily identified**. Stem Deterioration Point is a recently developed term meant to indicate crown break and allow objective classification for the end of the main stem in deliquescent species. It is critical to ensure that future stem height predictions are not over-estimated.

The emphasis is on the physical characteristics of the stem and crown. A relatively young spar which maintains a conical apical growing point is unlikely to have a Stem Deterioration Point. However an older mature stem which "breaks-up" into permanent branches in the upper crown, and has no recognisable leader or main stem, will have an obvious Stem Deterioration Point. As tree height growth is initiated from the top of the tree, it is important that such a point is recorded so that no further stem height growth would be assumed for the tree.

This information is recorded by assessing the stem to the SDP and coding the remaining height to the top of the tree with the "T" MARVL description code. Otherwise a tree without a SDP should be coded to the top with the last MARVL description code. While generally older trees will tend to have more obvious SDP's, this characteristic can be present on even the smallest sapling, especially in the instance of suppressed advance growth which have suffered crown damage.

It should be born in mind however that as this code effectively "kills" stem height growth beyond that point for future predictions. Therefore it should be carefully assessed, and for younger trees only used when the assessor is confident that the stem is not capable of "straightening out" if released.

Figure 6. Examples of Stem Deterioration Point



When assessing SDP it is important to bear in mind that the term was designed to describe utilisable and potential 'logs'.

8. TREE DESCRIPTIONS

Only those trees of the planted species should described using the MARVL system. Tree descriptions must be booked in a cumulative way. For example, if a Blackbutt tree, with a 50.7 cm dbhob in a harvestable area, has a half metre waste ("W") section at the stump, then ten metres of high quality material with branches less than 20% of stem diameter ("A"), then ten metres of lower quality material with branches less than 20% of stem diameter ("B"), up to the crown break (Stem Deterioration Point), the tree description should look like this**:**

Tree No.	Spp Code	DBH (mm)	Logging Imped.	Crown Condition	Dominance Class	MARVL Tree Description
1	BBT	507	A	1	2	W0.5 A10.5 B20.5 T

If the tree was a height tree and a total height of 30.7 was measured, then the height follows the final MARVL tree description code (T in this instance) as;

Tree No.	Spp Code	DBH (mm)	Logging Imped.	Crown Condition	Dominance Class	MARVL Tree Description
1	BBT	507	A	1	2	W0.5 A10.5 B20.5 T30.7

If a section of a tree borders between two codes always describe the section as being the poorer of the two choices.

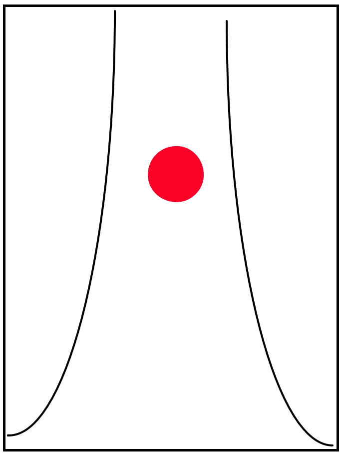
Viewing each tree from several angles definitely helps the assessor to pick up all the key features of the tree. Except in the case of very simple trees, all trees should be assessed from more than one perspective.

9. TALLY OF NON-PLANTATION SPECIES

While other species or ingrowth stems are not important from a timber yield perspective, an estimation of basal area is required to indicate total stand competition. Non-plantation species greater than 10 cm dbhob that fall within a plot are not assessed using the MARVL inventory system. Instead these trees will be tallied in 5 cm diameter classes purely by ocular estimation.. This should be a standard gate tally system, hardcopy proformas will be provided. Examples of non-planted species include Turpentine (*Syncarpia glomifera*), Casuarina spp. and Acacia spp.

Tallied trees should be identified with (preferably with another paint colour) circular 'spots', also facing towards the centre of the plot. The mark should be painted at approximately breast height.

Figure 7. Other Species Tally Tree Identification



Example Other Species Tally Proforma

		Dbhob size class (cm)						Other class (specify)		
Stratum	Plot	10 to 15	15 to 20	20 to 25	25 to 30	30 to 35	35 to 40			
1	3									

10. APPENDICES

Appendix 1. Horizontal Distance Slope Correction Table

[Slope distance = horizontal distance/Cos(slope)]

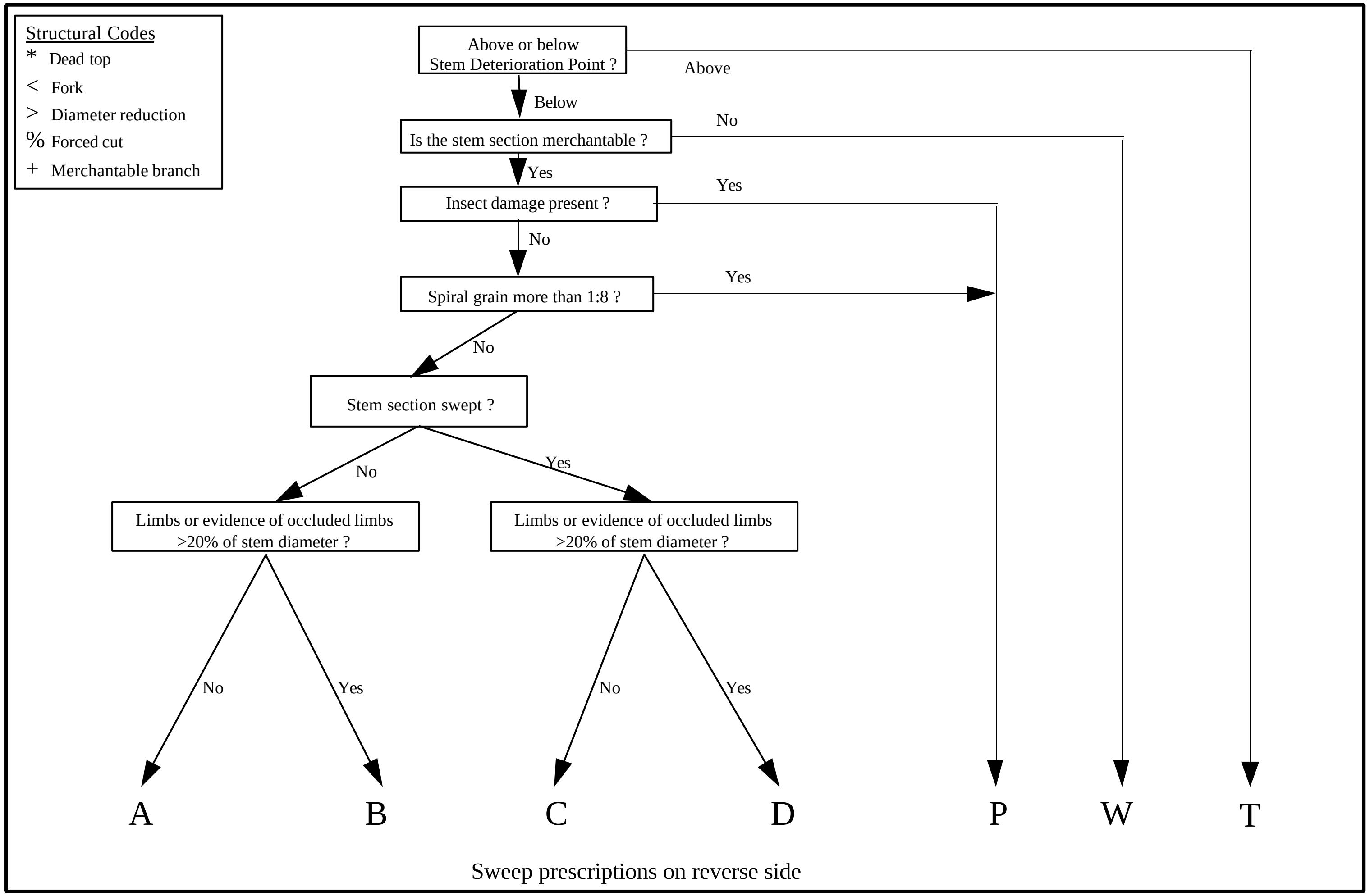
	Horizontal (hip-chain) Distance (m)												
Slope	**2**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**35**	**40**	**45**	**50**	**100**
1	2.0	5.0	10.0	15.0	20.0	25.0	30.0	35.0	35.0	40.0	45.0	50.0	100.0
5	2.0	5.0	10.0	15.1	20.1	25.1	30.1	35.1	35.1	40.2	45.2	50.2	100.4
10	2.0	5.1	10.2	15.2	20.3	25.4	30.5	35.5	35.5	40.6	45.7	50.8	101.5
11	2.0	5.1	10.2	15.3	20.4	25.5	30.6	35.7	35.7	40.7	45.8	50.9	101.9
12	2.0	5.1	10.2	15.3	20.4	25.6	30.7	35.8	35.8	40.9	46.0	51.1	102.2
13	2.1	5.1	10.3	15.4	20.5	25.7	30.8	35.9	35.9	41.1	46.2	51.3	102.6
14	2.1	5.2	10.3	15.5	20.6	25.8	30.9	36.1	36.1	41.2	46.4	51.5	103.1
15	2.1	5.2	10.4	15.5	20.7	25.9	31.1	36.2	36.2	41.4	46.6	51.8	103.5
16	2.1	5.2	10.4	15.6	20.8	26.0	31.2	36.4	36.4	41.6	46.8	52.0	104.0
17	2.1	5.2	10.5	15.7	20.9	26.1	31.4	36.6	36.6	41.8	47.1	52.3	104.6
18	2.1	5.3	10.5	15.8	21.0	26.3	31.5	36.8	36.8	42.1	47.3	52.6	105.1
19	2.1	5.3	10.6	15.9	21.2	26.4	31.7	37.0	37.0	42.3	47.6	52.9	105.8
20	2.1	5.3	10.6	16.0	21.3	26.6	31.9	37.2	37.2	42.6	47.9	53.2	106.4
21	2.1	5.4	10.7	16.1	21.4	26.8	32.1	37.5	37.5	42.8	48.2	53.6	107.1
22	2.2	5.4	10.8	16.2	21.6	27.0	32.4	37.7	37.7	43.1	48.5	53.9	107.9
23	2.2	5.4	10.9	16.3	21.7	27.2	32.6	38.0	38.0	43.5	48.9	54.3	108.6
24	2.2	5.5	10.9	16.4	21.9	27.4	32.8	38.3	38.3	43.8	49.3	54.7	109.5
25	2.2	5.5	11.0	16.6	22.1	27.6	33.1	38.6	38.6	44.1	49.7	55.2	110.3
26	2.2	5.6	11.1	16.7	22.3	27.8	33.4	38.9	38.9	44.5	50.1	55.6	111.3
27	2.2	5.6	11.2	16.8	22.4	28.1	33.7	39.3	39.3	44.9	50.5	56.1	112.2
28	2.3	5.7	11.3	17.0	22.7	28.3	34.0	39.6	39.6	45.3	51.0	56.6	113.3
29	2.3	5.7	11.4	17.2	22.9	28.6	34.3	40.0	40.0	45.7	51.5	57.2	114.3
30	2.3	5.8	11.5	17.3	23.1	28.9	34.6	40.4	40.4	46.2	52.0	57.7	115.5
31	2.3	5.8	11.7	17.5	23.3	29.2	35.0	40.8	40.8	46.7	52.5	58.3	116.7
32	2.4	5.9	11.8	17.7	23.6	29.5	35.4	41.3	41.3	47.2	53.1	59.0	117.9
33	2.4	6.0	11.9	17.9	23.8	29.8	35.8	41.7	41.7	47.7	53.7	59.6	119.2
34	2.4	6.0	12.1	18.1	24.1	30.2	36.2	42.2	42.2	48.2	54.3	60.3	120.6
35	2.4	6.1	12.2	18.3	24.4	30.5	36.6	42.7	42.7	48.8	54.9	61.0	122.1
36	2.5	6.2	12.4	18.5	24.7	30.9	37.1	43.3	43.3	49.4	55.6	61.8	123.6
37	2.5	6.3	12.5	18.8	25.0	31.3	37.6	43.8	43.8	50.1	56.3	62.6	125.2
38	2.5	6.3	12.7	19.0	25.4	31.7	38.1	44.4	44.4	50.8	57.1	63.5	126.9
39	2.6	6.4	12.9	19.3	25.7	32.2	38.6	45.0	45.0	51.5	57.9	64.3	128.7
40	2.6	6.5	13.1	19.6	26.1	32.6	39.2	45.7	45.7	52.2	58.7	65.3	130.5
41	2.7	6.6	13.3	19.9	26.5	33.1	39.8	46.4	46.4	53.0	59.6	66.3	132.5
42	2.7	6.7	13.5	20.2	26.9	33.6	40.4	47.1	47.1	53.8	60.6	67.3	134.6
43	2.7	6.8	13.7	20.5	27.3	34.2	41.0	47.9	47.9	54.7	61.5	68.4	136.7
44	2.8	7.0	13.9	20.9	27.8	34.8	41.7	48.7	48.7	55.6	62.6	69.5	139.0
45	2.8	7.1	14.1	21.2	28.3	35.4	42.4	49.5	49.5	56.6	63.6	70.7	141.4

Appendix 2. Bounded Plot Slope Correction Table

[radius =((10000 x plot size)/(π x Cos (slope)))^0.5]

	Plot Size (ha)		
Slope	**0.1**	**0.03**	**0.02**
0	17.84	9.77	7.98
1	17.84	9.77	7.98
2	17.85	9.78	7.98
3	17.85	9.78	7.98
4	17.86	9.78	7.99
5	17.88	9.79	7.99
6	17.89	9.80	8.00
7	17.91	9.81	8.01
8	17.93	9.82	8.02
9	17.95	9.83	8.03
10	17.98	9.85	8.04
11	18.01	9.86	8.05
12	18.04	9.88	8.07
13	18.07	9.90	8.08
14	18.11	9.92	8.10
15	18.15	9.94	8.12
16	18.20	9.97	8.14
17	18.24	9.99	8.16
18	18.29	10.02	8.18
19	18.35	10.05	8.21
20	18.40	10.08	8.23
21	18.46	10.11	8.26
22	18.53	10.15	8.29
23	18.60	10.19	8.32
24	18.67	10.22	8.35
25	18.74	10.26	8.38
26	18.82	10.31	8.42
27	18.90	10.35	8.45
28	18.99	10.40	8.49
29	19.08	10.45	8.53
30	19.17	10.50	8.57
31	19.27	10.55	8.62
32	19.37	10.61	8.66
33	19.48	10.67	8.71
34	19.59	10.73	8.76
35	19.71	10.80	8.82
36	19.84	10.86	8.87
37	19.96	10.93	8.93
38	20.10	11.01	8.99
39	20.24	11.08	9.05
40	20.38	11.16	9.12
41	20.54	11.25	9.18
42	20.70	11.34	9.26
43	20.86	11.43	9.33
44	21.04	11.52	9.41
45	21.22	11.62	9.49

Eucalypt Plantation MARVL Dictionary



Developed by Northern Region Inventory Unit, 1996.

APP

Appendix 3a. Allowable Sweep for Eucalypt Plantation MARVL

Section Length (m)	Centre Diameter of Section (cm)									
	5	10	15	20	25	30	35	40	45	50
1.0	0.4	0.8	1.3	1.7	2.1	2.5	2.9	3.3	3.8	4.2
1.5	0.6	1.3	1.9	2.5	3.1	3.8	4.4	5.0	5.6	6.3
2.0	0.8	1.7	2.5	3.3	4.2	5.0	5.8	6.7	7.5	8.3
2.5	1.0	2.1	3.1	4.2	5.2	6.3	7.3	8.3	9.4	10.4
3.0	1.3	2.5	3.8	5.0	6.3	7.5	8.8	10.0	11.3	12.5
3.5	1.5	2.9	4.4	5.8	7.3	8.8	10.2	11.7	13.1	14.6
4.0	1.7	3.3	5.0	6.7	8.3	10.0	11.7	13.3	15.0	16.7
4.5	1.9	3.8	5.6	7.5	9.4	11.3	13.1	15.0	16.9	18.8
5.0	2.1	4.2	6.3	8.3	10.4	12.5	14.6	16.7	18.8	20.8
5.5	2.3	4.6	6.9	9.2	11.5	13.8	16.0	18.3	20.6	22.9
6.0	2.5	5.0	7.5	10.0	12.5	15.0	17.5	20.0	22.5	25.0
6.5	2.7	5.4	8.1	10.8	13.5	16.3	19.0	21.7	24.4	27.1
7.0	2.9	5.8	8.8	11.7	14.6	17.5	20.4	23.3	26.3	29.2
7.5	3.1	6.3	9.4	12.5	15.6	18.8	21.9	25.0	28.1	31.3
8.0	3.3	6.7	10.0	13.3	16.7	20.0	23.3	26.7	30.0	33.3
8.5	3.5	7.1	10.6	14.2	17.7	21.3	24.8	28.3	31.9	35.4
9.0	3.8	7.5	11.3	15.0	18.8	22.5	26.3	30.0	33.8	37.5
9.5	4.0	7.9	11.9	15.8	19.8	23.8	27.7	31.7	35.6	39.6
10.0	4.2	8.3	12.5	16.7	20.8	25.0	29.2	33.3	37.5	41.7
10.5	4.4	8.8	13.1	17.5	21.9	26.3	30.6	35.0	39.4	43.8
11.0	4.6	9.2	13.8	18.3	22.9	27.5	32.1	36.7	41.3	45.8
11.5	4.8	9.6	14.4	19.2	24.0	28.8	33.5	38.3	43.1	47.9
12.0	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0
12.5	5.2	10.4	15.6	20.8	26.0	31.3	36.5	41.7	46.9	52.1
13.0	5.4	10.8	16.3	21.7	27.1	32.5	37.9	43.3	48.8	54.2
13.5	5.6	11.3	16.9	22.5	28.1	33.8	39.4	45.0	50.6	56.3
14.0	5.8	11.7	17.5	23.3	29.2	35.0	40.8	46.7	52.5	58.3
14.5	6.0	12.1	18.1	24.2	30.2	36.3	42.3	48.3	54.4	60.4
15.0	6.3	12.5	18.8	25.0	31.3	37.5	43.8	50.0	56.3	62.5

Appendix 4. Eucalypt Plantation Tree Species Codes

Code	Botanical Name	Common name
ASB	*Eucalyptus agglomerata*	Blue leaved Stringybark
BBT	*Eucalyptus pilularis*	Blackbutt
DWG	*Eucalyptus dunnii*	White Gum
FLG	*Eucalyptus grandis*	Flooded Gum
GIB	*Eucalyptus paniculata*	Grey Ironbark
GMM	*Eucalyptus cloeziana*	Gympie Messmate
MAG	*Eucalyptus viminalis*	Manna Gum
NIB	*Eucalyptus crebra*	Narrow leaved Ironbark
PYR	*Eucalyptus pyrocarpa*	Large fruited Blackbutt
QBX	*Eucalyptus quadrangulata*	White topped Box
RMY	*Eucalyptus resinifera*	Red Mahoghany
SBG	*Eucalyptus saligna*	Sydney blue Gum
SPG	*Eucalyptus maculata*	Spotted Gum
SSB	*Eucalyptus laevopinea*	Silvertop Stringybark
TWD	*Eucalyptus microcorys*	Tallowwood

MARVL system analysis

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1998

Table of contents

Introduction

MARVL is a forest inventory method designed to provide detailed information on the potential yield and log size distribution likely to result from felling a stand of trees. The method was first described by Deadman and Goulding (1978). The acronym MARVL is derived from "**M**ethod for **A**ssessment of **R**ecoverable **V**olume by **L**og Types".

The purposes of this document are to:

briefly describe the forest inventory process

identify the role of MARVL in forest inventory process, and,

describe in detail the MARVL method in relation to the forest inventory process.

Much of the MARVL method is based on standard forest mensuration techniques. What is emphasised in this report are operations which are unusual, are poorly documented, or are unique to MARVL.

Overview of forest inventory

Husch *et al*. (1982) define forest inventory as:

> "...the procedure for obtaining information on the quantity and quality of the forest resource and many of the characteristics of the land area on which the trees are growing."

Husch *et al*. give the following checklist of items which may need to be considered in the planning of a forest inventory:

1. Purpose of the inventory
2. Background information
   Past surveys, maps, reports etc
3. Description of the area
   Location, size, terrain, accessibility
4. Information required for the final report
   Tables, graphs, maps, narrative report
5. Inventory design
   Estimation of area, determination of timber quantity, size and shape of sampling units, sampling method, precision
6. Procedures for aerial photograph interpretation
7. Procedures for field work
   Location and establishment of sampling units, current stand information, recording of observations, data conversion and editing
8. Compilation and calculation procedures
   Instructions for reduction of field measurements
9. Final report

10. Maintenance

Storage and retrieval of data

Item 8 in this list is directly provided for by MARVL; MARVL has indirect bearing on items 4, 5, 7, 9 and 10.

Overview of the MARVL method

MARVL was developed in New Zealand in response to perceived deficiencies in the existing plantation inventory procedure. Deadman and Goulding (1978) listed the principal deficiencies as:

1. an inability to provide detailed product breakdown, particularly when it was necessary to differentiate the merchantability of individual stands for diverse markets,

2. the inability of current inventory to provide detailed information at the stand level.

MARVL differs from other inventory systems in that it separates the field assessment of size and quality of stems from the actual cross-cutting. When the stand is cruised, no attempt is made to divide the stem into logs or estimate merchantable limits at any point on the tree. (Lawrence, 1986).

Use of MARVL involves 3 basic steps (NZFRI, 1995):

1. inventory design,

2. sampling of stand(s) to assess tree size, structure and quality,

3. analysis of the sample data to determine potential product yield.

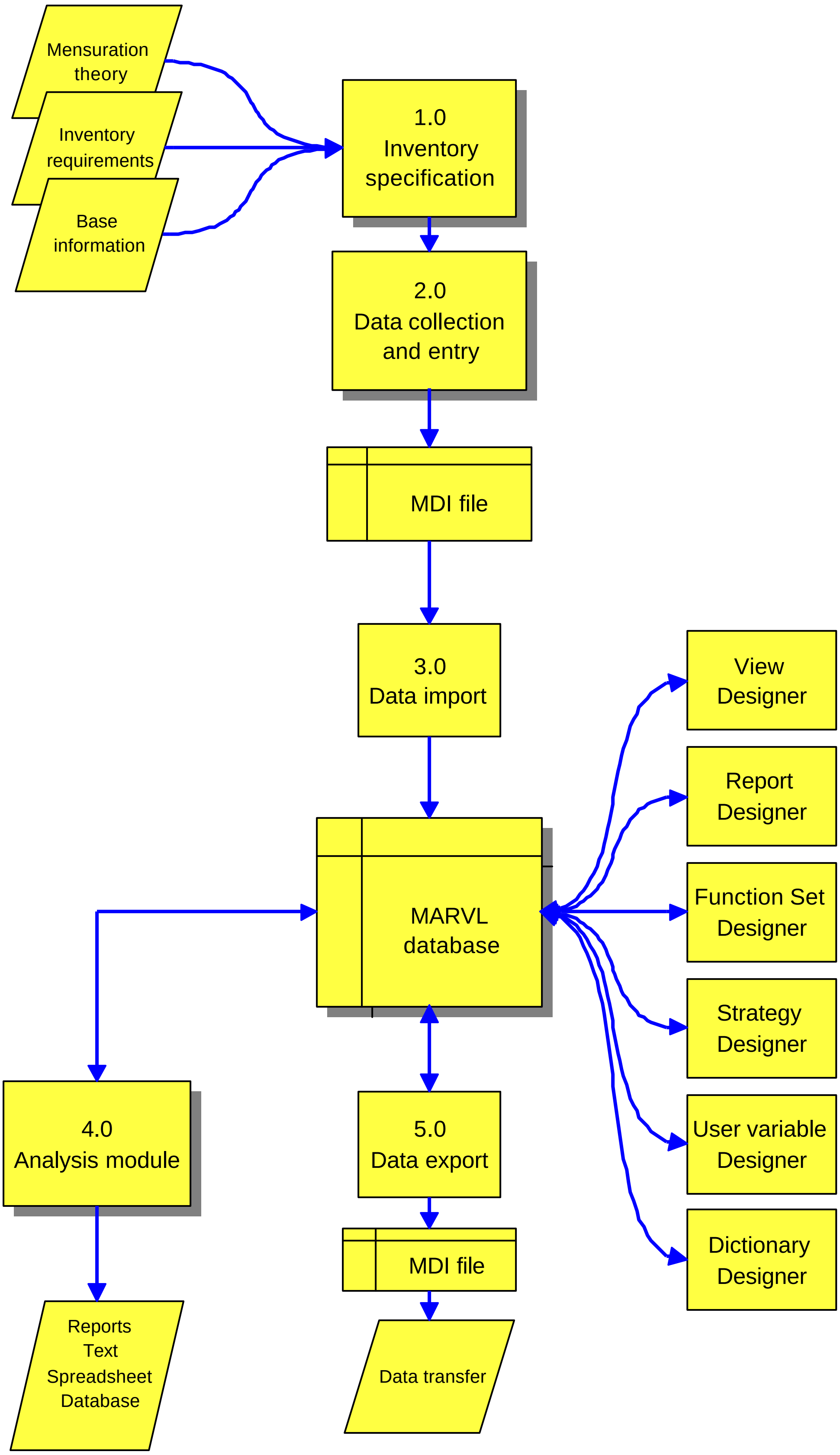
At step 1, MARVL supports the use of fixed area plots ("bounded" plots in MARVL literature), horizontal point and horizontal line samples, which may be used in simple or stratified designs. There is a "double sampling" option at the plot level.

Step 2 is referred to in MARVL literature as "cruising". Standard tree size indices (such as DBHOB, height) are measured in this step. There is the facility for the inclusion of "user-defined" variables. In addition, each tree is described by structural and quality codes.

Step 3 is accomplished with the Analyse module of MARVL. This module enables the user to produce 1 or more reports, using 1 or more views as input, with 1 or more cutting strategies, to 1 or more projection dates.

Reports may be either standard, or custom. A "view" is a named list of plots (NZFRI, 1995). A group of views is called a "plan". Inventory data may be projected to a specified date if suitable growth models are available. A "cutting strategy" is a list of rules which define products in terms of permissible quality codes, minimum/maximum dimensions, value and acceptable species.

Figure 1. MARVL system flow chart



The MARVL system

The MARVL system is described in detail in this section. Processes and the flow of data in the MARVL system is illustrated in Figure 1. This diagram shows only the basic outline of MARVL; many interactions between the components have been omitted from this diagram for the sake of clarity. These interactions are explained in the following text.

Components of the MARVL system

Inventory specification

Process 1.0 of Figure 1 (which corresponds to item 5 of the Husch *et al*. (1982) list) is discussed in this section.

Sampling issues

The issue of inventory design is, to a certain extent, external to MARVL. MARVL understands a limited number of inventory design types, inventory designs outside this subset can't be processed. The issue of whether a particular design is more suitable for a particular job than some other design will not be solved by MARVL.

MARVL samples may be either fixed area plots, horizontal point or horizontal line samples, in either a simple or stratified design. Fixed area plots within the same stratum must be of the same area.

Double, or 2-phase, sampling relies on a close correlation between some easily-measured variable, the "auxiliary variate", and a variable of interest that is not so easy to measure. The first phase involves measuring the auxiliary variate, (basal area, for instance) on a large sample. The second phase involves measuring the variable of interest, volume for example, (and the auxiliary variate if the second phase sample is not drawn from the first phase sample) on a smaller sample. (Cochran, 1977; De Vries, 1986).

MARVL application of double sampling is explained as follows: Fully-measured plots are termed "primary plots". "Secondary plots" are measured for basal area only. Statistics, such as volume, are adjusted by the ratio of basal area per hectare over the entire sample (secondary plots plus primary plots) to the basal area per hectare of the fully measured plots (primary plots only). Because tree volume is a function of basal area and height, basal area can be expected to be a good predictor of volume if average tree size is reasonably uniform within a stratum (NZFRI, 1995).

Use of the terms of "primary" and "secondary" samples in the context of double sampling does not accord with terms used in standard texts. This is confusing. The first phase of this 2-phase sample is primary plus secondary plots. The second phase is the sample of primary plots.

Decisions about what variables need to be measured to achieve the aims of the inventory are an essential part of inventory design. MARVL provides a set of default inventory variables, which are adequate for simple inventories. For more complex jobs, user defined variables may be added. These variables are discussed in following sections.

Default variables

MARVL has a set of default variables at both the plot and tree level. These are listed in Table 1.

Table 1. MARVL default variables

Level	Variable
Plot	Unique plot key
	User who last modified the data
	Date and time the data were changed
	Plot number
	Inventory name
	Dictionary name
	Year plot was planted
	Year plot was measured
	Month plot was measured
	Number of trees in the plot (live and dead)
	Slope
	Plot type (fixed area, horizontal point or line)
	Plot area (if fixed area)
	Plot length (if horizontal line)
	BAF (if horizontal point or line)
	Live basal area
	Live stocking
	Mean top diameter
	GIS link key
	Description of plot
Tree	Unique plot key
	Tree number
	Stocking represented by this tree
	DBH
	Height
	Live/dead
	Species
	Collapsed stem description

The meaning of most of these variables will be apparent; comments on some of the less obvious variables follow.

The distinction between unique plot key and plot number should be remembered. The unique key is generated by MARVL to ensure that all plots in the database are uniquely identified. The plot number is the plot identifier assigned by the inventory designer. 2 separate inventories could both have a plot number 1, their identity in the database is maintained with the unique key.

Year plot was planted can be safely ignored for regrowth forest; a default value can be entered here. This field is useful for plantations.

Mean top diameter is defined as the root mean square (RMS) of the 100 largest DBH live trees per hectare. Mean top height is obtained by solving the height/diameter function for a tree of mean top diameter (NZFRI, 1995).

GIS link key is yet another unique identifier for the plot, used in conjunction with template, notification or query files (see section titled “Linking MARVL and GIS”).

Stocking represented by this tree is generated by MARVL, and is the frequency used in conversion of the plot data to a per hectare basis. Its value is set by the system. It is not normally accessible to the user, it may be modified by growth models to account for mortality. (Lawrence, pers. comm.)

User defined variables

Default plot and tree level variables may be supplemented by user defined variables, of which there are 3 types (NZFRI, 1995):

1. tree user variables, associated with trees in a plot,

2. plot user variables, associated with each plot,

3. plot extra variables.

Tree and plot user variables may be either numeric, or “ordinal”. Interval or ratio variables are handled by numeric user variables. Ordinal variables would be better called “categorical” variables, because, in practice, they may be either nominal or ordinal (see Husch *et al.* (1982) for a discussion of scales of measurement.)

Minima, maxima, measurement units, and display formats may be specified for numeric variables.

A lists of legal values may be specified for each ordinal variable.

Plot extra variables are, in effect, user defined default variables. While the definitions for both plot user variables and plot extra variables are stored in the same table, the values of plot extra variables are stored in the plot table itself. (Values for plot user variables are stored in a separate table.) Plot extra variables may be of the string type, plot user variables may not. Plot extra variables may not be used in a cutting strategy, whereas (beginning with MARVL V3.3) plot user variables may be (Mein, pers. comm.). NZFRI (1995) recommends that the creation of plot extra variables not be undertaken lightly.

Data collection and entry

An expanded version of process 2.0 of Figure 1, data collection and entry, is shown in Figure 2. This process is a sub-item of item 8, with elements of item 7 of the Husch *et al*. (1982) list. In brief summary, this process involves:

creation of a template data interchange file (process 2.1)
field data collection (process2.21)
data entry (process 2.22)

The end result of this process is an interchange file which contains the data for the entire inventory. The process described above, is relevant to a manual system, where inventory data are hand written on plot sheets. If electronic field data capture is used, field data collection and data entry are collapsed into a single step (process 2.3).

Aspects of process 2.0, including tree description methods, are discussed in this section.

Field measurement

The field measurement process of an inventory is normally described in a document specific to each inventory. This document should state what is to be measured, and give precise instructions as to how each variable is to be measured, and how it is to be recorded.

Data entry

The method by which collected data are transferred to (and from) the MARVL database is outlined in this section. The method is described in detail in NZFRI (1997).

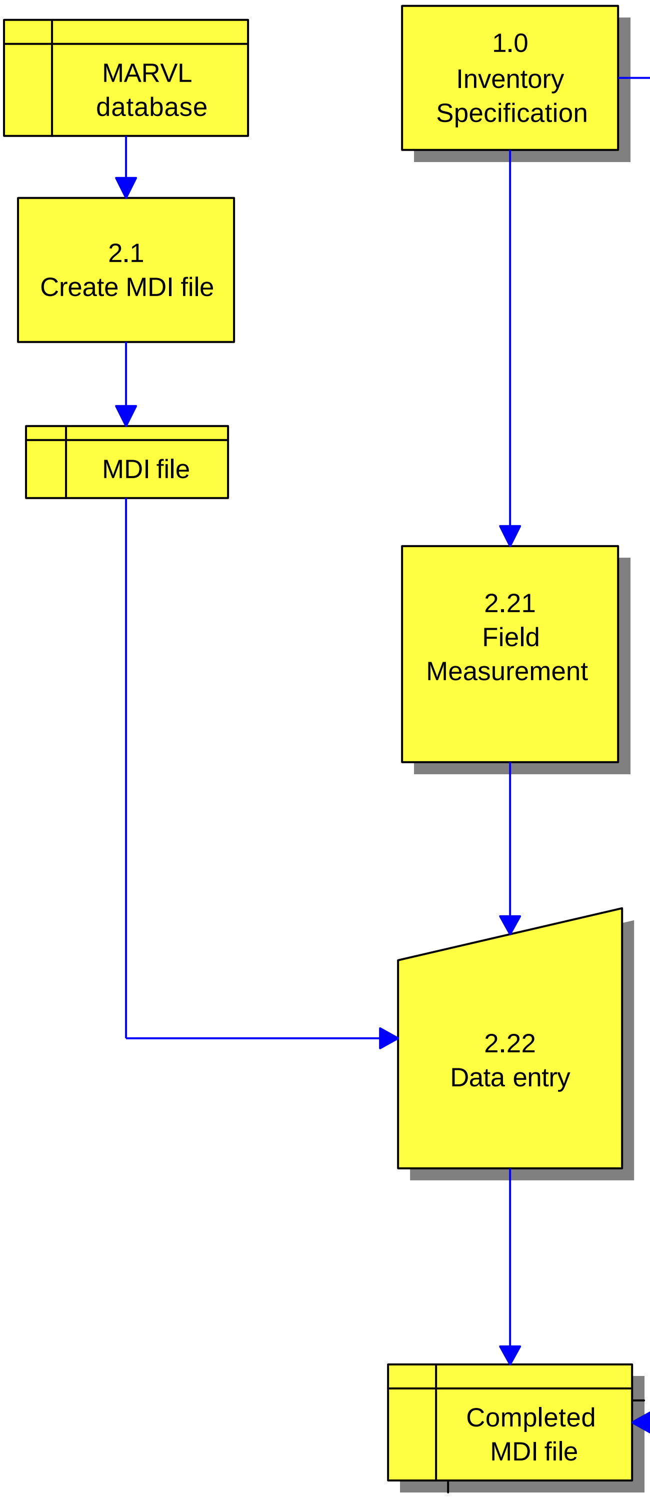
The MARVL data capture program MARVLDE3 is used to collect MARVL inventory data, either on a PC in the office, entering data from hand written plot sheets, or in the field, entering data directly into a DOS-based portable data recorder (PDR). A series of menus and data entry screens (forms) allows the user to:

1. enter data at the inventory, stratum and plot level,

2. edit existing data,

3. transfer data from one computer to another, typically to or from a PDR.

Figure 2. MARVL data collection and entry



MARVLDE3 can be configured for different screens, default file locations, file transfer settings and range checks (among others). Range checking is particularly important for data quality. 2 levels of range check are available. The first level merely requests confirmation of suspicious values from the operator. Values outside second level ranges are not accepted by the program.

Data entry, editing and transfer is based on files known as MARVL Data Interchange (MDI) files. MDI files are used to:

1. store inputs from a data capture program, for transfer to the MARVL database,

2. transfer data from 1 MARVL installation to another (different database, site or company).

The “data” referred to here includes such objects as views, dictionaries, cutting strategies, function sets, species code lists and user defined variables, as well as measured plot and tree data.

An MDI file must exist before any data can be physically entered. At a minimum, this file must contain a quality code dictionary, 1 or more function sets (see note below) and a species code list, and optionally, may contain other objects noted above. This file is created using the Export utility of the View Designer.

Function sets may be assigned to individual strata; this assignment is made during data entry. If more than 1 function set is required, they will need to be present in the MDI file.

When transferring data, the MDI file may contain 1 or more entire inventories (with their associated dictionaries, function sets and user-defined variables). 1 or more plans (with their associated views), or individual objects such as cutting strategies. These files are also created using the Export utility of the View designer.

The MARVL system requires that all data for an inventory be present in a single MDI file for import. This is easy enough to manage for a small inventory, but for larger inventories, or inventories where there is more than 1 crew entering data, there is currently no formal method for merging individual MDI files. This problem can be circumvented by editing MDI files using a text editor, but care is needed when using this method because of the complex format of MDI files. Another work-around is to use the View Designer (see below), which can be used to import multiple data sets from a single field inventory into the MARVL database as separate inventories (Pont, pers. comm.).

The contents of MDI files are loaded into the MARVL database using an Import utility, a function of the View Designer. Both the View designer and the MARVL database are described in later sections.

Tree description codes

Each tree in a MARVL inventory is completely described by a series of codes. The description method is discussed in this section.

There are 2 types of description code: structural codes and quality codes.

Structural codes describe the morphology of the tree, and are listed in Table 2.

Table 2. MARVL structural codes

Code	Meaning
*	Broken or dead top
>	Diameter reduction
<	Fork (or reduction and forced cut)
%	Forced cut
+	Merchantable branch

"Quality" is a classification of all or part of a tree stem in terms of those factors which have been found to have a significant impact on log value. Deadman and Goulding (1978) noted that the product yield of a [radiata pine]stand [in New Zealand] is influenced by both the characteristics of the stand and by the method of cross-cutting the stems. Gordon and Lawrence (1995) noted that the main external stem features which affect log quality [in New Zealand] are pruning, branch size and sweep, other features that may be important include fluting/buttressing, out-of round, nodal length, nodal swelling and wood damage.

Quality classification is fundamental to the MARVL method, and is implemented by defining 1 or more "quality codes". Quality codes are specified in a "quality code dictionary", which serves 2 purposes (NZFRI, 1995):

1. it tells MARVL which letters of the alphabet will be used as quality codes,

2. it provides the user with an opportunity to document the exact meaning of each code, and to describe the intended area of application of the dictionary.

In the formulation of a quality code dictionary, it is necessary to assign a single letter of the alphabet to a log quality class, and to fully describe that quality class. Any letters may be assigned to any quality class. Parts of the tree coded with letters not found in the quality code dictionary are discarded as waste.

Robust quality codes are fundamental to MARVL. Quality codes should be kept as independent as possible from particular log product specifications, to fully exploit the ability of MARVL to re-analyse inventory data to a different set of log product specifications. In particular, length or diameter constraints must not be included in the definition of quality codes (Gordon and Lawrence, 1995).

A number of New Zealand authors recommend the use of a decision tree to implement quality codes.

Data import (and export)

Completed MDI files are transferred to the MARVL database using an Import facility (process 3.0 in Figure 1). This facility is part of the View Designer, and is described in a following section.

Analysis

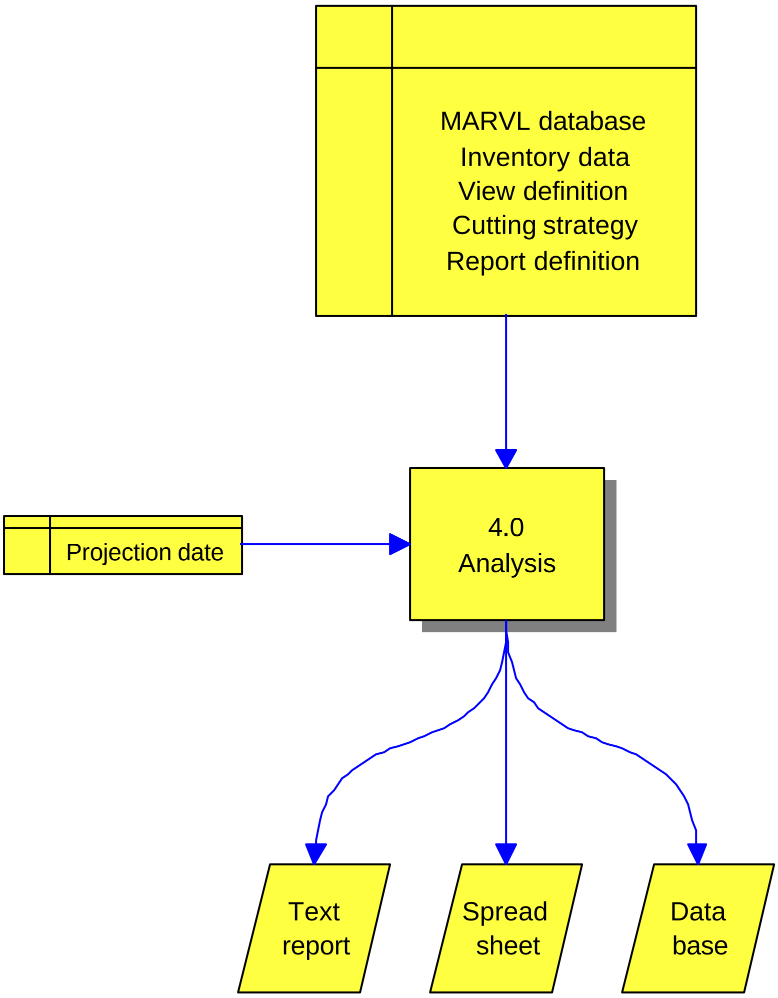
The Analyse module is the heart of MARVL. The analysis module uses data from the database to produce reports. This process is described in Figure 3, and represents item 8 in the Husch *et al*. (1982) list.

An analysis may be done on a single view, or a plan, which is a named group of views. One or more projection dates may be selected; a date of 0/0 processes the data as measured. One or more cutting strategies may be selected. One or more reports may be selected. The analysis module produces 1 report for each combination of projection data, cutting strategy. The optimisation program is run for each requested report; the process can be time-consuming if many reports are requested.

Analyses may be run interactively, or by using a batch file. Batched analyses, perhaps run overnight, may be the answer for large and/or complex jobs.

The optimisation process is described in the next section. The reporting process and cutting strategies are described in following sections.

Figure 3. MARVL Analyse module



Optimisation

As noted previously, what distinguishes MARVL from other inventory systems is the separation of the field assessment of size and quality of stems from the actual cross-cutting. What this means in terms of the MARVL system is that, in the analysis phase, each tree is converted into logs using the constraints specified by the cutting strategy. The process is (NZFRI, 1995):

1. Each tree is cut at a uniform stump height.

2. Depending on the breakage function used, the tree may be considered to have broken on falling. If this is the case, the part of the tree above the predicted break point is discarded as waste.

3. The tree is trimmed by making cuts at all forks (structural code =“<“) and forced cuts (structural code=“%”). The results of this trimming are termed “pieces”.

4. Each of the pieces that remains is analysed using the cutting strategy to find the combination of log types and lengths that gives the greatest total value, while satisfying all of the size and quality constraints of the log types. This step is called “optimisation”.

The optimisation step is based on a dynamic programming method originally conceived by Pnevmaticos and Mann (1972) (Deadman and Goulding, 1978). The method actually used in MARVL 3 is described in detail in NZFRI (1995); major points are repeated here.

MARVL attempts to cut logs at a limited number of (equally-spaced) points along the stem. It further assumes that any log that may be cut will fit exactly between two of these positions. The distance between adjacent stem positions under this model is called the “round-off” length, because all log lengths and stem heights (relative to the stump) are rounded-off to multiples of this length.

It is important, in selecting a round-off length, to balance precision and system performance. Very small round-off lengths increase running time. An analysis that uses a round-off length of 0.25m would take about 4 times as long to run as an analysis that uses 1.0m. If you wish to cut 3m and 4m logs and use a round-off length of 0.7m, MARVL would actually cut 2.8m and 4.2m logs, these being the nearest multiples of the round-off lengths.

Random log lengths are far slower to analyse than fixed lengths, because, at every position along a stem, MARVL has to consider every possible log length that could be cut there. An option here may be to represent the random lengths as a few fixed lengths.

You may supply a value for the cost of making a saw cut. The main reason for doing this is to encourage cutting of a long log in preference to 2 short logs of the same value.

Stem diameters and volumes are calculated with stored or programmed taper and volume functions. Functions to be used are specified by the user.

View Designer

MARVL analyses are based on 1 or more “views”; a view is a named list of plots. Views are managed with the “View Designer”.

The View Designer performs several functions:

data import/export
view definition
view validation
view management
pilot survey (estimation of required number of samples)
configuration

Data import/export

The data import/export facility is primarily used for importing data into the MARVL database from an MDI file. Typically, all the data from a single inventory will be in the MDI file, and this will be imported into the database when data entry is complete. Data export is also managed with MDI files.

Other data import functions include:

import MQF (GIS query) file (see “Linking MARVL and GIS” below)
import SQL query (using standard SQL commands)
import a database file

Other export functions are;

export inventory template file (with GIS-located points)
export MicroMARVL file (export V2 files)

View definition

As noted above, a “view” in MARVL is a named list of plots. The plots in a view may comprise all or some of the plots from an entire inventory, or some or all of the plots from more than 1 inventory. For analysis convenience, a group of views may be gathered into a “plan”, a named list of views.

Views are presented in the View Designer as a series of plot, group and stratum lines. The group referred to here is a growth group, a group of plots measured on the same date, and which are grown forward together. A sample section of a typical view is shown in Table 3. In Table 3, stratum lines are indicated with “===”; group lines are indicated with “- - - ” and plot lines are indicated with the word “Plot”.

Table 3. Typical MARVL View Designer window

```
=== 100.00          Coastal Species
--- 7/1997
          Plot14017 Strategic Inventory  Bounded    39
          Plot14017 Strategic Inventory  Bounded    32
--- 6/1997
          Plot14017 Strategic Inventory  Bounded    39
```

Stratum, group and plot lines may be customised to meet user requirements. This is discussed in “Configuration”, below.

View validation

All views must be validated to ensure that they are capable of analysis (NZFRI, 1995). Validation rules confirm that:

within a growth group,
- the number of plots is within the limits set by PlotsInGroup[1],
- PLEs for basal area and stocking are within limits set by GroupPLEBA and GroupPLESPH,
- there are no duplicate plots,

within a stratum,
- all secondary plots have the same type and same size,
- there is at least 1 primary plot, and that all primary plots have the same type and size,
- there are no duplicate plots,
- the function set name is valid,
- the area is within limits set by StratumAreaRange,

within a view,
- there are no plots duplicated between strata (except for height only plots, which may be shared to create a common height regression).

View management

At the base level, all the plots from a single inventory (referred to as a design inventory in MARVL literature) form a default view. New views are created by copying the required parts from 1 or more views, and pasting them to a new view. Parts may be copied from more than 1 inventory. New views must be validated before they can be analysed.

Views may be saved or deleted.

Pilot survey

[1] Values for PlotsInGroup, GroupPLEBA, GroupPLESPH and StratumAreaRange are set in the configuration file, MARVL.INI.

The Pilot Survey facility may be used to estimate the required number of samples. PLE calculations are based on data from a subsample of plots.

Configuration

Plot, group and stratum lines may be customised to meet user requirements. Fields to be displayed, and the order in which they are displayed, are selected in a dialog box. Information fields, and formatting fields available for customising are shown in Table 4.

Table 4. Customising field available in the View Designer

Line type	Variables	Formatting
Stratum	Area	---
	Function set	===
		comma
		space
		'Stratum'
Group	BA CI/PLE	---
	BA Mean	===
	DBH Mean	comma
	Double sampling ratio	space
	Established year	tab
	Measure date	'Group'
	No of primary plots	
	No of secondary plots	
	Stocking CI/PLE	
	Stocking Mean	
Plot	Area	---
	BA	===
	BAF	comma
	Database plot key	space
	DBH Mean	tab
	Design inventory	'Plot'
	Dictionary name	
	Established year	
	Heights in regression	
	Heights in regression (Ab)	
	Horizontal line length	
	Last modified (by user)	
	Last modified (date)	
	Mean top diameter	
	Measured date	
	Plot number	
	Plot type	
	Plot type (Ab)	

	Primary/secondary
	Primary/secondary (Ab)
	Stocking
	Trees (count)

Note: "Ab" in Table 4 stands for "abbreviated'.

Report Designer

Results of inventories processed by MARVL are obtained as reports. Reports may be output in the form of text files or in spreadsheet or database form. The Report Designer is used to create new reports, or to modify existing reports.

Report Characteristics

A MARVL report consists of one or more "sections". All reports are specified in their own "Report Definition File", which have the extension RPD, and which contain the following information:

report description,
output file name, with append/overwrite option,
output format, may be text, worksheet, or database,
list of included sections, with codes to describe the level (plot, stratum or population) and to show/not show titles and totals.

Report sections

Report sections may be either "built-in", which can't be modified, or "custom", which can be modified (NZFRI, 1995). Built-in report sections are listed in Table 5.

Table 5. MARVL built-in report sections

Name	Description
LogGroup	Allows log types to be grouped together to calculate statistics
LogTrace	Lists each log produced by the bucker
Strategy	Population level only. Prints the strategy used to produce this set of results
Dictionary	Population level only. Prints the dictionaries needed by the strategy
Functions	Stratum level only. Prints the function set used to produce this set of results
InventoryDescription	Population level only. Prints the description field from the inventory table, and some other useful information
PlotDescription	Plot level only. Description of the plot including plot type, area and number
StratumDescription	Stratum level only. Stratum area, number of primary and secondary

plots and the double sampling ratio

Custom report sections are defined in a file titled REPORT.INI. This file may contain 1 or more section definitions. A text editor may be used to add new section definitions to this file, or to modify existing report sections.

Custom report sections are defined with a report definition language, that is described in detail in NZFRI (1995); a summary of this information is provided here.

Lists of allowable report analysis variables (just called "variables") are given in NZFRI (1995). There are 4 variable lists, for logs, pieces, trees and plots. (See Appendix 3 for complete lists.) For any 1 report section, variables may be selected from only 1 list. Generally, variables form the column headings of the new report section (but see below for modifications). Class variables form the row headings, these must also be selected from the lists of allowable variables. Class widths, a start-point and a number of classes may be specified for class variables. Variables may be grouped using "By variables" (allowable variables also listed). A given variable may not be available for use in all categories (analysis, class or by variable). Statistics such as errors may be included for some analysis variables. User-defined variables may be used in reports definitions, subject to some restrictions.

Samples of custom report section definitions are shown in Appendix 4.

MARVL reports may be though of, somewhat arbitrarily, as belonging to 1 of 2 categories, standard reports or custom reports. MARVL is supplied with 5 reports already installed, these are the standard reports. Standard reports are very general in nature, so will cover a wide range of possible output requirements. Custom reports are all other possible reports.

Standard reports

Standard reports may be composed of both built-in and custom report sections; custom sections of standard reports may be modified as required. Care is need when modifying report section definitions; any single section definition may be used in more than 1 report. If modifications to a standard report are required, the best approach may be to copy the entire definition to a new report definition file, and edit the new file, and/or the REPORT.INI file, as required.

Standard MARVL reports include:

- standard population report
- standard population and stratum report
- standard population, stratum and plot report
- Log trace
- Yield table

Standard population reports, standard population and stratum reports and standard population, stratum and plot reports contains the following report sections:

InventoryDescription
Strategy
Dictionary
Functions
StandingResource
StandardResource
LiveStandingTrees
CutoverResidue
ExtractableStems
ProductAnalysis
CuttingWaste
LogGroup

The difference between these 3 reports is the level at which results are reported.

The Log trace report is intended for diagnostic or investigative use, it contains a single built-in section only, LogTrace. This report writes the results of the optimisation process for each tree in the selected view to the selected output form.

The Yield table report contains a single custom section, YieldTable. A yield table presents anticipated yields from a stand at various points in time (Vanclay, 1994). Because there are currently no native forest growth models that are compatible with MARVL, yield tables for native forests can't be produced with MARVL as yet.

Custom reports

As noted above, a custom report consists of 1 or more custom report sections, with the option of 1 or more built-in sections.

Custom report sections may be created from scratch by the user, using a text editor to modify the REPORT.INI file, creating a new report section using the report definition language described above. Existing report sections may be modified by the same method.

Function Set Designer

Functions to be used in the calculations for a given inventory are selected by the user with the Function Set Designer. A Function Set is a named list of functions.

MARVL has been built around the use of functions for:

stem breakage,
growth models,
growth adjustments,
height/age relationships,
height/DBHOB relationships,

taper and volume.

The use of a taper and volume function and either a height/age or a height/DBHOB relationship - supplied by the user or fitted by MARVL - is mandatory. The use of other functions is optional.

Breakage models predict the height at which a tree stem will break on felling. That part of the tree above the break point is classed as waste. There is a “no breakage” option, which is the option currently used for regrowth forests in NSW.

Growth models may be used to project inventory data in time. Growth models are currently all one-offs, each has a unique functional form, and coefficients are built into the model form (Mein, pers. comm.).

Growth adjustment tables specify the proportion of annual growth that has occurred on a monthly basis. (NZ growth models for softwood species are based on monthly time increments; Lawrence, pers. comm.)

Height/age and height/DBHOB relationships are used to estimate a height for unmeasured trees, so that taper and volume functions, which use height as an independent variable, can be applied. Height/age functions tend to be one-offs, there are some models that share functional forms (Mein, pers. comm.). Height/age relationships are of no relevance to regrowth forest where age is not known, but may be relevant to native species plantations.

Height/DBHOB relationships may be specified as a function, or as a conversion table specified by the user. If a function is specified, a function is fitted to the measured data for each stratum in the inventory.

Taper and volume functions are used to predict stem diameters and volumes. Taper and volume functions must be “compatible”, that is, total volume estimates, based on integration of a taper equation, should be identical to those given by a tree volume equation (Demaerschalk, 1972). The reason for the requirement of compatibility is so that volume estimated by summing volume estimates of parts of the stem exactly equals the estimated volume of the entire stem.

In a mixed-species forest, there are often groups of species, which have similar characteristics, but which are different from other groups. Similar species may be grouped using “function groups” (NZFRI, 1995).

MARVL software comes with numerous functions already installed. Most of these are applicable only to exotic species in New Zealand. Currently, the only functions of relevance to regrowth forests in NSW are taper and volume functions for blackbutt, flooded gum, and “coastal species” (blackbutt plus flooded gum), based on taper models developed by Muhairwe (1995).

MARVL recognises a couple of standard forms of each function; functions forms for breakage, height/DBHOB, taper and volume are listed in Appendix 2. If relationships in one of these forms are known, coefficients can be entered into a text file in standard form, and installed in the software using a translate utility. If relationships are not in standard form, they must be programmed.

MARVL assigns functions sets at the stratum level, it is possible to use different function sets for different strata within the 1 inventory. This assignment is made in the data entry phase.

Strategy Designer

A “cutting strategy” is a list of product types, each of which is specified by required lengths, minimum and maximum small- and large-end diameters, permitted quality codes, value, acceptable species (Anon, 1990). Beginning with V3.3 of MARVL, user variables may be used in a cutting strategy. Cutting strategies are created or modified with the Strategy Designer.

A cutting strategy is based on a quality code dictionary, but, unlike a plot, a cutting strategy can refer to more than 1 dictionary, so that plots cruised to different sets of quality codes can be analysed as a single inventory (NZFRI, 1995).

It is important to understand that the “value” specified in a cutting strategy does not need to be an actual dollar amount. It may be an actual market value, an internal transfer price, or an artificial price. If an artificial price is used, its magnitude should accurately reflect relative value to the user (NZFRI, 1995).

Any number of cutting strategies may be applied to a single inventory.

User-variable Designer

The significance of user defined variables was discussed in as earlier section. Plot and tree user variables are created or modified with the User-variable Designer.

Plot extra variables are created by modifying the database structure itself (NZFRI, 1995).

Dictionary Designer

Quality code dictionaries are created or modified with the Dictionary Designer. Quality codes and the Dictionary are discussed in a previous section “Tree description codes”.

The MARVL database

Plot and inventory data are stored in a database to provide safe access to the data by multiple users, and to formalise the relationships between the data entities that MARVL uses (NZFRI, 1995). Data are transferred into the MARVL database from MDI files using an import utility, as described elsewhere.

MARVL was developed and tuned to run best with Borland Paradox database software, but other database software may be used. Borland SQL Links for Windows is a set of drivers supported by MARVL that will directly connect to Oracle, SQL Server, Sybase, Interbase or Informix. MARVL can use other database products that have an ODBC driver, but with a reduction in performance.

The MARVL database may be installed either locally, or on a network server, so it is available to multiple users. MARVL runs fastest when using its database on a local hard disk.

The database schema is shown in Appendix 5.

Other important files

There are a number of files crucial to the running of MARVL that are not stored as part of the MARVL database. These are:

Configuration files. System-wide defaults are stored in a file called MARVL.INI. Settings for each user are stored in a separate file , MARVLUSR.INI. Individual user preferences will overrride system settings (NZFRI, 1995). The data entry program, MARVLDE3, also has its own configuration file, MARVLDE3.INI.

Reports. Each report is defined in a file with the extension RPD. Report sections are defined in a file called REPORT.INI.

Data interchange. Files with the extension MDI are used to import/export data.

Templates. Plot points generated by GIS are stored in a file with an MDF extension.

Notifications. Notification of plot locations (to GIS) are stored in files with an extension MNF.

Query files. Plots selected with GIS are stored in a file with the extension MQF.

The creation and use of template, notification and query files is explained in the following section.

Linking MARVL and GIS

MARVL may be linked to GIS by a variable called GIS Link Key. This key is known to both MARVL and the GIS. There are 2 ways to assign a GIS Link Key (NZFRI, 1995):

1. Unique values can be generated by the GIS, MARVL is informed of these values by a Template (MDF) file. The MDF file is read by the view designer, which produces a template inventory file (an MDI file) with empty plots, ready for filling in.

2. Unique values can be generated by MARVL. MARVL informs the GIS of these values by a Notification (MNF) file.

If plots are linked to a GIS as described above, is possible to:

1. select plots on the GIS,

2. use the View Designer to create new views based on this selection,

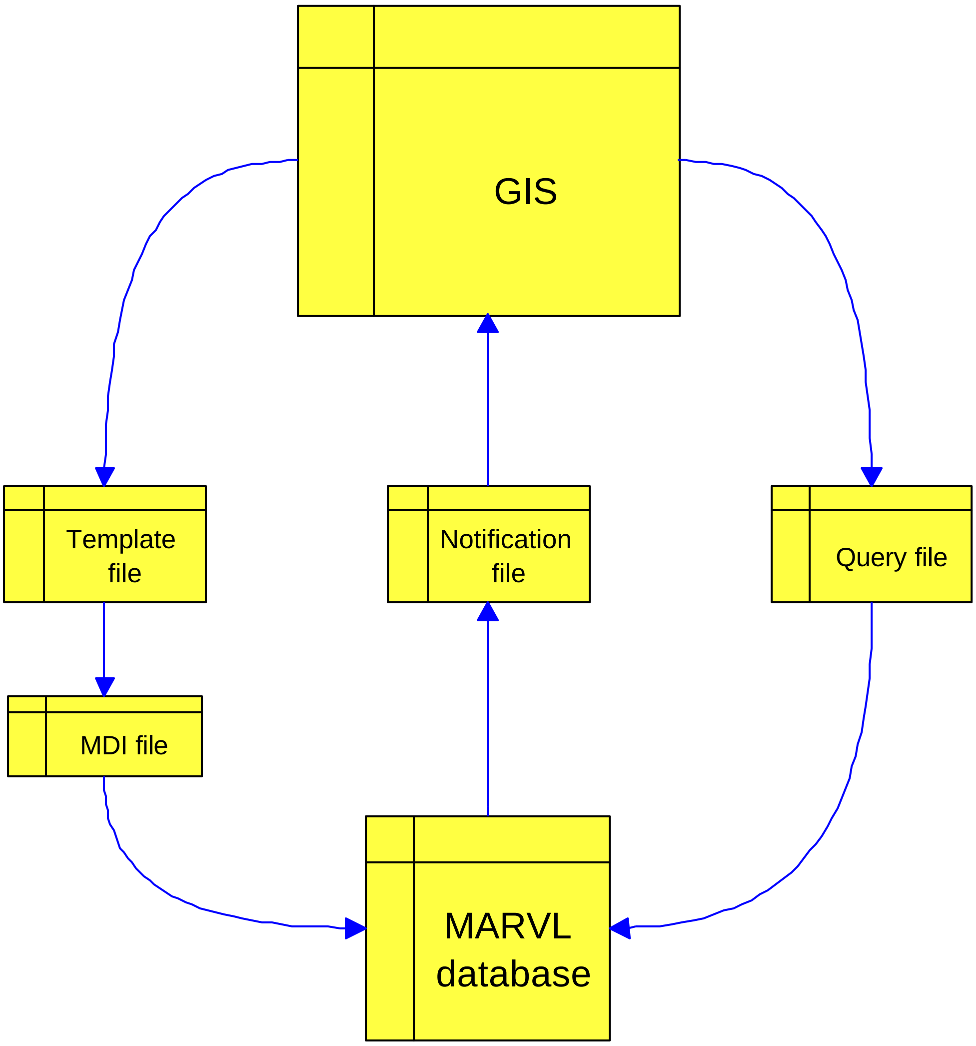
3. use the View Designer to assign function sets, validate and save the view,

4. use the Analyse module to analyse the new views.

The GIS selection is communicated to MARVL with a Query (MQF) file. Arc/Info macros to maintain and execute this link have been described by Hock (1996)

Th flow of information betwen MARVL and GIS is shown schematically in Figure 4.

Figure 4. Flow of information between MARVL and GIS.



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Appendix 1. List of standard formulas used by MARVL

Notation

Symbols used in this section are listed below.

i	number of trees in a plot, i = 1 to n
D_{Bi}	DBHOB of ith tree
D_i	DOB, ith tree
d_i	DUB, ith tree
b_i	double bark thickness, $D_i - d_i$
H_i	height of ith tree
h_i	level above ground of a point on the stem, ith tree
l_i	distance from the top of the tree ith tree, $H_i - h_i$
R	l_i / H_i
g_i	basal area of ith tree
w_i	frequency of ith tree
X	per hectare characteristic
x_i	any characteristic of ith tree
A	plot area, ha (fixed area plots)
L	plot length (horizontal line plots)
F	basal area factor (horizontal point or line sample)
N	Plot stocking density (stems/ha)
G	Plot basal area (m^2/ha)
K	π / 40 000
T_0	Year of planting (plantation)
T_1	Year of measurement

Per hectare estimates

In general, the value of any per hectare stand characteristic, X, is estimated as follows:

$$\hat{X} = \sum_{i=1}^{n} w_i \, x_i$$

where $w_i = 1 / A$ (fixed area plot)

$w_i = F / g_i$ (horizontal point sample)

$w_i = 1000 \frac{\sqrt{F}}{D_{Bi} \, L}$ (horizontal line samples

Stocking density

$$\hat{N} = \sum_i w_i$$

Plot basal area

$$\hat{G} = \sum_i w_i \, g_i$$

In the case of point samples, this formula simplifies to:

$$\hat{G} = F \; n$$

Per tree estimates of the characteristic X are found by:

$$\hat{x} = \frac{\hat{X}}{\hat{N}}$$

$$= \frac{\sum_i w_i \; x_i}{\sum_i w_i}$$

Appendix 2. List of standard function forms.

Stem breakage

Source: BREAKTAB.TXT, symbols are defined in Appendix 1

Equation 1

$$h_{bi} = b_1 + b_2 H_i + b_3 H_i^2 + b_4 s_p + b_5 s_p^2 + b_6 s_p H_i$$

Equation 2

$$h_{bi} = H_i \left[b_1 + (1 - b_1)\left(1 - e^{(-b_2 H_i)}\right)^{b_3} \right]$$

Height/age relationships

Function types:

1 (approximate height/age curve)

2 (no growth)

3 (percentage growth)

4 (explicit height/age curve)

5 - 22 (normal height/age curve)

All currently installed models are of the form:

$$H_i = a\left[1 - \exp\left(-b\left(T_1 - T_0\right)\right)\right]^c$$

Height/DBHOB relationships

Source: HTDBHTAB.TXT, symbols defined in Appendix 1.

Pettersen 1:

$$\frac{D_{Bi}}{\left(H_i - bh\right)^{0.4}} = a\ D_{Bi} + b$$

Pettersen 2:

$$\frac{1}{\left(H_i - bh\right)^{0.4}} = a\ + b\left(\frac{1}{D_{Bi}}\right)$$

Logarithmic:

$$\ln H_i = a\ + b\left(\frac{1}{D_{Bi}}\right)$$

Taper functions

Source: TAPERTAB.TXT, symbols defined in Appendix 1.
Taper function 01:

$$d_i^2 = \left[\frac{V_i}{K H_i}\right]\left[b_1 R_i^1 + b_2 R_i^2 + b_3 R_i^3 + b_4 R_i^4 + b_5 R_i^5 + b_6 R_i^{b_7} + b_8 R_i^{b_9}\right]$$

$$where\ \ d_i = DUB\, at\, length\ l_i\ \ from\ tree\ tip$$

Taper function 07:

$$d_i = D_i - B_i \qquad \text{(sectional measurement)}$$

Taper function 08:

$$D_i^2 = D_{Bi}^2\left[b_c\, R_i^{\left(\frac{b_1}{H_i^{b_2}}\right)}\right] + \left[\frac{b_3}{\left(D_{Bi}\, H_i\right)^{b_4}} R_i^{b_5}\right]$$

$$where\, b_c = 1 - \left[\frac{b_3}{\left(D_{Bi}\, H_i\right)^{b_4}}\right]\left[1 - \frac{bh}{H_i}\right]^{b_5} / \left[1 - \frac{bh}{H_i}\right]^{\frac{b_1}{H_i^{b_2}}}$$

$$d_i^2 = D_i^2\left[b_7 + b_8\, R_i + b_9\, R_i^{b_{10}}\right]$$

Taper function 09:

$$D_i^2 = \left[\frac{D_{Bi}\, H_i}{H_i - bh}\right]^2\left[b_c\, R_i^{b_1} + b_2\, R_i^{b_3} + b_4\, R_i^{b_5}\right]$$

$$where\, b_c = \left[1 - \frac{bh}{H_i}\right]^2 - b_2\left[1 - \frac{bh}{H_i}\right]^{b_3} - b_4\left[1 - \frac{bh}{H_i}\right]^{b_5} / \left[1 - \frac{bh}{H_i}\right]^{b_1}$$

$$d_i^2 = D_i^2\left[b_7 + b_8\, R_i + b_9\, R_i^{b_{10}}\right]$$

Taper function 10:

$$D_i^2 = D_{Bi}^2\left[b_c\, R_i^{b_1} + b_2\, R_i^{b_3}\right]$$

$$where\, b_c = \left[1 - b_2\left(1 - \frac{bh}{H_i}\right)^{b_3}\right] / \left[1 - \frac{bh}{H_i}\right]^{b_1}$$

$$d_i^2 = D_i^2\left[b_7 + b_8\frac{D_i}{D_{Bi}}\right]^2$$

Taper function 11:

$$D_i^2 = \left[\frac{D_{Bi}\,H_i}{H_i - bh}\right]^2\left[b_1 + b_2\,R_i^{(b_3\,D_{Bi})}\right]$$

$$d_i^2 = D_i^2\left[b_7 + b_8\,R_i\right]$$

Taper function 13:
2-segment model. Quadratic (upper) and hyperbolic (lower) functions, with a variable joint point. (Equation?)

Taper function 14:

$$d = b_1\,D_{Bi}^{b_2}\,b_3^{D_{Bi}}\left[1 - \sqrt{\frac{h_i}{H_i}}\right]^{\left[b_4\left(\frac{h_i}{H_i}\right) + b_5\left(\frac{h_i}{H_i}\right)^2 + b_6\left(\frac{h_i}{H_i}\right)^3 + b_7\left(\frac{H_i}{h_i}\right) + b_8\,D_{Bi} + b_9\,H_i + b_{10}\left(\frac{D_{Bi}}{H_i}\right)\right]}$$

Taper function 15:

$$D_i^2 = b_1\,D_{Bi}^{b_4} + b_2\,e^{\left(-b_3\,h_i^{0.25}\right)}$$

$$where\, b_2 = \left[D_{Bi}^2 - b_1\,D_{Bi}^{b_5}\right] / \; e^{\left(-b_3\,bh^{0.25}\right)}$$

$$d_i^2 = b_7 + b_8\,D_i^2$$

Volume functions

Source: VOLUMTAB.TXT, symbols defined in Appendix 1.

Volume table 01:

$$V_i = D_{Bi}^{b_1} \left[\frac{H_i^2}{H_i - bh} \right]^{b_2} e^{b_3} + b_4$$

Volume table 02:

$$V_i = b_i + b_2 \, D_{Bi}^2 \frac{H_i}{10000} + b_3 \frac{D_{Bi}^2}{10\,000} + b_4 \, H_i + b_5 \frac{D_{Bi} \, H_i}{10000}$$

Volume table 03:

$$\log(V_i) = b_1 \log(D_{Bi}) + b_2 \log(H_i) + b_3 \frac{D_{Bi}^2}{10\,000} + b_4$$

Volume table 04:

$$V_i = b_1 \, D_{Bi}^{b_2} \, H^{b_3}$$

Volume table 05:

$$V_i = \left[b_1 \, D_{Bi}^2 \frac{H_i^2}{H_i - bh} + b_2 \right] / \; 1000$$

Volume table 06:

$$V_i = b_1 \left(D_{Bi}^2 \, H_i \right)^{0.9} / \; 10000$$

Volume table 07:

$$V_i = \sum (\text{sec}\, tional \;\, volumes)$$

Volume tables 08 - 11

Integral of taper function types 08 - 11

Volume table 12:

$$V_i = \left[b_1 H_i + b_2 D_{Bi}^2 H_i + b_3 H_i^2 + b_4 D_{Bi}^2 H_i^2 \right] / \left[H - bh \right]$$

Volume tables 13, 14, 15

Integral of taper function types 13, 14, 15

Appendix 3. MARVL variables

Lists of variables available for the definition of report sections follow. Variables in any one report section may be selected from only 1 list. Variable characteristics are:

If there is a V in column 1, this variable can appear in a “Variables=” line.

If there is a C in column 2, this variable can appear in a “Classvariable=” line.

If there is a B in column 3, this variable can appear in a ByVariable=” line.

If there is an E in column 4, this variable can have a +ERROR after it on a “Variables=” line

If there is a P in column 5, this variable can have a +PERCENT.

Log level variables

Variable name	1	2	3	4	5
LOG_SPECIES		C			
LOG_VALUE	V	C		E	P
LOG_SED	V	C		E	P
LOG_SED_MIN	V				
LOG_SED_MAX	V				
LOG_LED	V	C		E	P
LOG_LED_MIN	V				
LOG_LED_MAX	V				
LOG_LENGTH	V	C		E	P
LOG_LENGTH_MIN	V				
LOG_LENGTH_MAX	V				
LOG_VOLUME	V	C		E	P
LOG_SIZE	V				
LOG_COUNT	V				P
LOG_TYPE	V	C	B		
LOG_TYPE_USER	V	C	B		
LOG_KIND	V	C	B		
LOG_GROUP		C	B		
LOG_TAPER	V			E	P

Piece level variables

Variable name	1	2	3	4	5
PIECE_SPECIES		C	B		
PIECE_VALUE	V	C		E	P
PIECE_SED	V	C		E	P
PIECE_SED_MIN	V				
PIECE_SED_MAX	V				
PIECE_LED	V	C		E	P
PIECE_LED_MIN	V				
PIECE_LED_MAX	V				
PIECE_LENGTH	V	C		E	P
PIECE_LENGTH_MIN	V				
PIECE_LENGTH_MAX	V				
PIECE_VOLUME	V	C		E	P
PIECE_SIZE	V				
PIECE_COUNT	V				P
PIECE_NUM_LOGS	V				P
PIECE_IS_EXTRACTED	V	C	B		P

Tree level variables

Variable name	1	2	3	4	5
TREE_SPECIES		C	B		
TREE_DBH	V	C		E	P
TREE_VOLUME_TOTAL	V	C		E	P
TREE_VOLUME_RECOV	V	C		E	P
TREE_VOLUME_EXTR	V	C		E	P
TREE_VOLUME_CROWN	V	C		E	P
TREE_VOLUME_STUMP	V	C		E	P
TREE_VOLUME_BREAK	V	C		E	P
TREE_VALUE	V	C		E	P
TREE_IS_EXTRACTED	V	C	B		P
TREE_IS_ALIVE	V	C	B		P
TREE_HEIGHT_TOP	V	C		E	P
TREE_HEIGHT_BREAK	V	C		E	P
TREE_COUNT	V				P
TREE_BA	V	C		E	P
TREE_IS_MALFORMED	V	C	B		P
TREE_IS_BROKEN	V	C	B		P
TREE_SIZE	V				
TREE_SIZE_EXTR	V				
TREE_SIZE_RECOV	V				

Plot level variables

Variable name	1	2	3	4	5
PLOT_MEAN_DBH	V			E	P
PLOT_DBH_MEAN_TOP	V			E	P
PLOT_HEIGHT_MEAN_TOP	V			E	P
PLOT_HEIGHT_MEAN	V			E	P
PLOT_VOLUME_TOTAL	V			E	P
PLOT_VOLUME_RECOV	V			E	P
PLOT_VOLUME_EXTR	V			E	P
PLOT_VOLUME_CROWN	V			E	P
PLOT_VOLUME_STUMP	V			E	P
PLOT_VOLUME_BREAK	V			E	P
PLOT_BA	V			E	P
PLOT_SPH	V			E	P

Appendix 4 Example report section definitions

```
[StandingResource]
Name=Standing Resource
ClassVariable=TREE_IS_ALIVE
Variables=TREE_VOLUME_TOTAL +ERROR TREE_COUNT +PERCENT TREE_BA +ERROR
+PERCENT TREE_DBH
Levels=PLOT STRATUM POPULATION

[StandardResource]
Variables=PLOT_HEIGHT_LIVE PLOT_DBH_MEAN_TOP PLOT_HEIGHT_MEAN_TOP
ShowTitles=TRUE
ShowTotals=FALSE
Levels=POPULATION

[VolumeAnalysis]
Name=Volume Analysis
Variables=TREE_VOLUME_TOTAL +ERROR TREE_VOLUME_RECOV +ERROR TREE_COUNT
TREE_SIZE
ClassVariable=TREE_IS_EXTRACTED
Levels=PLOT STRATUM POPULATION
ShowTotals=FALSE
ShowTitles=TRUE

[LiveStandingTrees]
Name=Live Standing Trees
Variables=TREE_VOLUME_TOTAL +ERROR TREE_COUNT TREE_SIZE
ClassVariable=TREE_IS_RECOVERED
Levels=PLOT STRATUM POPULATION
ShowTotals=TRUE
ShowTitles=TRUE

[CutoverResidue]
Name=Cutover Residue
Variables=LOG_VOLUME +ERROR
ClassVariable=LOG_KIND
ShowTotals=FALSE
ShowTitles=TRUE
FirstClass=0
NumberOfClasses=2
Levels=PLOT STRATUM POPULATION

[ExtractableStems]
Name=Extractable Stems (stump and breakage removed)
Variables=TREE_VOLUME_EXTR +ERROR TREE_COUNT TREE_SIZE_EXTR
ClassVariable=TREE_IS_RECOVERED
Levels=PLOT STRATUM POPULATION
ShowTotals=TRUE
ShowTitles=TRUE

[CuttingWaste]
Variables=LOG_VOLUME_EXTR +ERROR
ClassVariable=LOG_KIND
ShowTotals=FALSE
ShowTitles=FALSE
FirstClass=2
```

```
NumberOfClasses=1
Levels=PLOT STRATUM POPULATION
```

```
[ProductAnalysis]
Name=Product Analysis
Variables=LOG_VOLUME +ERROR +PERCENT LOG_VALUE +PERCENT LOG_COUNT
LOG_SIZE
ClassVariable=LOG_TYPE_USER
Levels=STRATUM POPULATION
ShowTotals=TRUE
ShowTitles=TRUE

[StockTable]
Name=Stock Table
Variables=LOG_COUNT LOG_VOLUME +ERROR +PERCENT LOG_VALUE
ByVariable=LOG_TYPE_USER
ClassVariable=LOG_SED
Levels=POPULATION
ShowTitles=TRUE
NumberOfClasses=25
ClassWidth=40
FirstClass=0

[StandTable]
Name=Stand Table
Variables=TREE_COUNT TREE_IS_MALFORMED TREE_IS_EXTRACTED TREE_HEIGHT_TOP
TREE_HEIGHT_BREAK TREE_VOLUME_TOTAL TREE_VOLUME_RECOV
ClassVariable=TREE_DBH
Levels=POPULATION
ShowTitles=TRUE
NumberOfClasses=25
ClassWidth=40
FirstClass=0

[LengthDist]
Name=Log Length Distribution
Variables=LOG_VOLUME LOG_VALUE LOG_COUNT LOG_SED
ByVariable=LOG_TYPE
ClassVariable=LOG_LENGTH
Levels=PLOT STRATUM POPULATION
ShowTitles=TRUE
NumberOfClasses=40
ClassWidth=0.25
FirstClass=1

[PieceVolume]
Name=Piece Volume Distribution
Variables=PIECE_COUNT PIECE_SED PIECE_LED PIECE_LENGTH
ByVariable=PIECE_IS_EXTRACTED
ClassVariable=PIECE_VOLUME
ShowTitles=TRUE
Levels=PLOT STRATUM POPULATION

[YieldTable]
Name=Yield Table
Variables=LOG_VOLUME +ERROR +PERCENT LOG_VALUE +PERCENT LOG_COUNT
ClassVariable=LOG_TYPE
ShowTitles=TRUE
Levels=PLOT STRATUM POPULATION
```

```
[LogTrace]
Name=Log Trace
ShowTitles=TRUE
Levels=PLOT STRATUM POPULATION
```

```
[StratumDescription]
Levels=STRATUM POPULATION

[CentreDiameterUnderBark]
Levels=POPULATION

[DominanceDistribution]
Name=Dominance distribution
Variables=TREE_COUNT
ClassVariable=TREE_DBH
NumberOfClasses=40
ClassWidth=50
FirstClass=200
ByVariable="Dominance"
```

Appendix 5. MARVL database schema

```
------ Import ------
Extra :     Extra data for MicroMARVL v2.x import
Inventry    *     Text(20)    Inventory Name
Stratum     *     Int(10)     Stratum Number
PlotNum     *     Int(5)      Plot Number within Forest/Cpt/Stand/Meas
EstabYr           Int(4)      Established Year: when plot was planted
MeasYear          Int(4)      Year plot was measured
MeasMnth          Int(2)      Month plot was measured
Species           Text(5)     Tree Species
GISLink           Long(10)    Connection to unique Plot ID in GIS

ExtrDict    :     Extra Data: Inventory --> Dictionary link
Inventry    *     Text(20)    Inventory Name
Dictnary          Text(20)    Dictionary name

ExtrFunc    :     Extra Data: Inventory --> Function Set link
Inventry    *     Text(20)    Inventory Name
Stratum     *     Int(10)     Stratum Number
FuncName          Text(20)    Function Set Name


------ Misc ------
Forest      :     Valid Forest codes
Forest      *     Text(4)     Forest Name
LongName          Text(30)    Long name
Owner       Text(40)    Owner of forest
Region            Text(2)     Location of forest

Species     :     List of all legal tree species codes
Species     *     Text(5)     Tree Species
Botanic           Text(25)    Botanical name
Common            Text(25)    Common name


------ Function ------
Function    :     Set of volume, taper, breakage, growth, height
equations
FuncName    *     Text(20)    Function Set Name
LastUser          Text(10)    Name of user who last modified this
DateUser          Timestamp   Date & Time this was last changed
IsLocked          Int(1)      Function Set cannot be changed
GmodType          Text(1)     Growth model type
GmodNum           Int(4)      Growth model number
HmodType          Text(1)     Height model type
HmodNum           Int(4)      Height model number
Adjust            Int(4)      Monthly Growth adjustment table
HtType            Text(1)     Height/Diameter type L=log P=Pett1 Q=Pett2
T=Table
HtTable           Int(4)      Height/Diameter Curve table (HtType='T')
Descript          Memo  Description of Function Set

FunGroup    :     Groups of table / model numbers in a function set
FuncName    *     Text(20)    Function Set Name
```

FuncGrp	*	Text(20)	Function Group Name
Volume		Int(4)	Tree Volume table number
Taper		Int(4)	Tree Taper table number
Breakage		Int(4)	Tree breakage table number

```
FunSpecy    :     Which species belong to which function group
FuncName    *     Text(20)    Function Set Name
FuncGrp     *     Text(20)    Function Group Name
Species     *     Text(5)     Tree Species


------ Strategy ------
Strategy    :     Cutting Strategy definition
CutStrat    *     Text(20)    Cutting Strategy name
LastUser          Text(10)    Name of user who last modified this
DateUser          Timestamp   Date & Time this was last changed
IsLocked          Int(1)      Strategy cannot be changed
RoundLen          Real(4,1)   Round off length
StumpHt           Real(4,1)   Stump height (metres)
CutCost           Real(9,7)   Cost of making a cut
Descript          Memo  Description of Strategy

LogType     :     Log type's value and acceptable end diameters
CutStrat    *     Text(20)    Cutting Strategy name
LogType     *     Text(20)    Log Type name
LogKind     *     Int(2)      Stump, Waste, Above-Break, User-Defined
Dollars           Real(8,2)   Log dollar value
MinSED            Real(4,0)   Minimum small end diameter
MaxSED            Real(4,0)   Maximum small end diameter
MaxLED            Real(4,0)   Maximum large end diameter
Descript          Memo  Description of Log Type

LogDict     :     Valid quality codes for each log type in a cutting
strategy
CutStrat    *     Text(20)    Cutting Strategy name
LogType     *     Text(20)    Log Type name
Dictnary    *     Text(20)    Dictionary name
QCodes            Text(26)    Valid qualities
MinLeng           Real(4,1)   Minimum length of MinQCode
MinQCode          Text(26)    Must have at least MinLeng of these
qualities (composite log types)

LogLeng     :     Valid length ranges for Log Types in a cutting strategy
CutStrat    *     Text(20)    Cutting Strategy name
LogType     *     Text(20)    Log Type name
MinLeng     *     Real(4,1)   Minimum log type length
MaxLeng     *     Real(4,1)   Maximum log type length

LogSpecy    :     Log type's allowed species
CutStrat    *     Text(20)    Cutting Strategy name
LogType     *     Text(20)    Log Type name
Species     *     Text(5)     Tree Species

LogGroup    :     LogGroup: definition
CutStrat    *     Text(20)    Cutting Strategy name
LogGroup    *     Text(20)    Log Group name
AvgSED            Real(4,0)   Minimum average small end diameter
MinSED            Real(4,0)   Minimum allowable log type diameter
SpecCut           Int(1)      Cut to SED spec during analysis

LogGrpTy    :     The log types in a log group
CutStrat    *     Text(20)    Cutting Strategy name
```

```
LogGroup    *     Text(20)    Log Group name
LogType     *     Text(20)    Log Type name
```

```
------ Plan ------
LPlan :     Group of Views
LPlan *     Text(20)    Groups a set of inventories
LastUser          Text(10)    Name of user who last modified this
DateUser          Timestamp   Date & Time this was last changed
IsLocked          Int(1)      True if this plan cannot be changed
Descript          Memo  Description of Plan

LPlanInv    :     List of Views in the Plan
LPlan *     Text(20)    Groups a set of inventories
Inventry    *     Text(20)    Inventory Name


------ View ------
Inventry    :     View / Inventory definition
Inventry    *     Text(20)    Inventory Name
LastUser          Text(10)    Name of user who last modified this
DateUser          Timestamp   Date & Time this was last changed
IsLocked          Int(1)      True if this view is locked
IsDesign          Int(1)      True if this is a design inventory
IsValid           Int(1)      True if this view can be analysed
Descript          Memo  Description of View

StrPlot     :     Link view strata to plot keys
Inventry    *     Text(20)    Inventory Name
Stratum     *     Int(10)     Stratum Number
PlotKey     *     Long(10)    Unique plot key
UsHeight          Int(1)      True if height trees from this plot are
added to regression
PlotUse           Int(1)      0 = unused, 1 = Primary, 2 = Secondary plot

Stratum     :     Stratifies plots in a View
Inventry    *     Text(20)    Inventory Name
Stratum     *     Int(10)     Stratum Number
Area        Real(6,2)   Stratum area
FuncName          Text(20)    Function Set Name


------ Plot ------
Plot  :     Plot data
PlotKey     *     Long(10)    Unique plot key
LastUser          Text(10)    Name of user who last modified this
DateUser          Timestamp   Date & Time this was last changed
PlotNum           Int(5)      Plot Number within Forest/Cpt/Stand/Meas
Inventry          Text(20)    Inventory Name
Dictnary          Text(20)    Dictionary name
EstYear           Int(4)      Year plot was planted
MeasYear          Int(4)      Year plot was measured
MeasMnth          Int(2)      Month plot was measured
TreeCoun          Int(3)      Number of trees in plot (live and dead)
Slope       Int(2)      Slope value
PlotType          Int(1)      bounded, angle gauge, count, horiz-line,
LIS
Area        Real(7,5)   Plot area
Length            Real(6,2)   Plot length
Baf         Real(5,2)   Basal Area factor
BArea       Real(5,1)   Live Basal area
```

Stocking	Real(5,0)	Live Stocking
MTopDBH	Real(4,0)	Mean top diameter
GISLink	Long(10)	Connection to unique Plot ID in GIS
Descript	Memo	Description of Plot

```
PlotKey     :     Contains next value for a unique plot key
PlotKey     *     Long(10)    Unique plot key

Tree  :     Tree data (plus stem description)
PlotKey     *     Long(10)    Unique plot key
TreeKey     *     Long(10)    Tree number
TreeWgt           Real(6,1)   Stocking represented by this tree
Dbh         Real(4,0)   Diameter at breast height
Height            Real(5,2)   Height of tallest leader
IsLive            Int(1)      True if tree is alive, False if dead
Species           Text(5)     Tree Species
StemDesc          Memo  Collapsed Stem Description


------ UserVar ------
UserVar     :     User Variable: type, measurement units & valid value
range
UserVar     *     Text(20)    User Variable name
LastUser          Text(10)    Name of user who last modified this
DateUser          Timestamp   Date & Time this was last changed
Minimum           Real(20,5)  Minimum Value
Maximum           Real(20,5)  Maximum Value
Label       Text(20)    Measurement unit
VarType           Int(1)      N(numeric) D(discrete) O(rdinal)
Binding           Int(1)      T(tree), P(plot), E(every plot)
Width       Int(2)      Printing width (including decimal places)
DPlaces           Int(2)      Number of decimal places to print
Descript          Memo  Description of User Variable

TreeUser    :     User Variable values for Trees
PlotKey     *     Long(10)    Unique plot key
TreeKey     *     Long(10)    Tree number
UserVar     *     Text(20)    User Variable name
VarValue          Real(20,5)  Value of Variable

PlotUser    :     Plot user variable values
PlotKey     *     Long(10)    Unique plot key
UserVar     *     Text(20)    User Variable name
VarValue          Real(20,5)  Value of Variable

PlotVar     :     Plot user variables (every plot has this variable)
PlotKey     *     Long(10)    Unique plot key

VarLabel    :     Ordinal user variable value labels
UserVar     *     Text(20)    User Variable name
OrdValue    *     Int(10)     User Variable ordinal value
Label       Text(20)    Label Text

VarCalc     :     Methods describing how to calculate user variable
values
UserVar     *     Text(20)    User Variable name
LastUser          Text(10)    Name of user who last modified this
DateUser          Timestamp   Date & Time this was last changed
Method            Int(10)     Calculation method number

VarDict     :     User Variable to Method to Dictionary link
UserVar     *     Text(20)    User Variable name
```

Dictnary	*	Text(20)	Dictionary name
QCodes		Text(26)	Valid qualities from Dictionary

```
------ Dictnary ------
Dictnary    :     Quality Code Dictionary definition
Dictnary    *     Text(20)    Dictionary name
LastUser          Text(10)    Name of user who last modified this
DateUser          Timestamp   Date & Time this was last changed
IsLocked          Int(1)      Dictionary cannot be changed
Descript          Memo  Description of Dictionary

Dictcode    :     List of valid codes and descriptions in a Dictionary
Dictnary    *     Text(20)    Dictionary name
QCode *     Text(1)     Quality Code
Descript          Memo  Description of Quality Code
```

Strategic inventory

Field manual

State Forests of NSW
1997

TABLE OF CONTENTS

1. INTRODUCTION

This manual has been written as a guide for the measurement of MARVL-based inventory plots in the native forests of State Forests of NSW. It is intended to supplement, not replace formal face-to-face training. The manual describes field procedures for measuring bound primary plots.

Keep in mind that a sample of the plots which you measure will be audited for accuracy of plot location, plot layout and tree measurement/description. State Forests is relying on you to provide information which is - as far as possible - accurate, precise and consistent. Don't take short-cuts with any aspects of plot measurement, take enough time to do the best job you can. Attention to detail is crucial because, like all sampling systems, a small error at the plot or tree level becomes a large error at the inventory level.

While attempting to give an explanation of correct procedures for most aspects of MARVL plot measurement this manual cannot be expected to cover all possible situations encountered in the field. If, having read the relevant part of this manual, you are still unsure about any aspect of plot measurement you should contact your Field Supervisor or Scott Arnold (066) 528900 or (066) 534810 (a.h.), radio call sign 1013.

2. MARVL INVENTORY EQUIPMENT CHECKLIST

Map of plot to be measured, with plot location information

Hip chain

Hip chain cotton (keep a good supply)

Compass

Clino

Wire pegs (keep a good supply)

Vertex Hypsometer (and spare batteries)

30 or 50 metre tape

Spray paint (keep a good supply)

Diameter tape

Proformas (keep a good supply)

Booking board

Pencil & eraser (including spare leads)

Spare folders for storing finished plot sheets

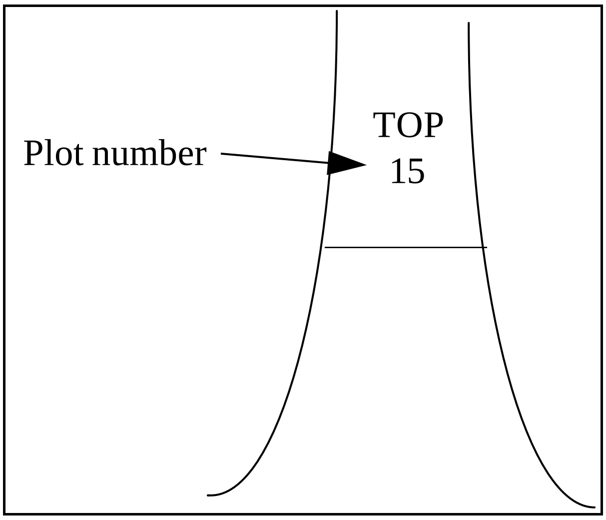
Set of field notes (you're reading them now!)

Scientific calculator

3. LOCATING PLOT POINTS

The plot location information provided by your Field Supervisor describes how to locate a road-side take off point (T.O.P.) for each plot. Using a hip-chain (**not** the trip meter in the vehicle) locate the T.O.P. Mark the T.O.P., along with the plot number, on a tree or other easily visible spot. See Figure 1 below, which shows a T.O.P. marked on a tree.

Figure 1: Marking the T.O.P. for Plot 15.



From the plot location notes read off the bearing and distance to the plot you intend to measure. Check that you have all necessary equipment before leaving the vehicle. Use the hip-chain and compass to locate plot point.

If you are sure there is a more efficient traverse which could be used to locate the plot then that should be used and **ALL** details of how the plot was located (ie: how to locate the T.O.P. and the magnetic bearing and slope distance from the T.O.P. to the plot point) must be recorded in the "comments" section of the proforma.

The plot should be established exactly where the hip-chain and compass bearing take you. If the plot point is in some way "different" to the general area, feel free to make note of this in the comments section of the proforma. **THE PLOT SHOULD NOT BE MOVED FROM THIS SPOT UNLESS YOU ARE SURE YOU ARE IN THE WRONG PLACE.** (Note: you can make an allowance of about 5% of the traverse distance for survey error during the course of locating the plot point.)

3.1 Marking the Plot Point

In situations where the plot point falls on rock, or a log, or any other immovable object you should mark the centre of the plot with a cross of paint on the log or rock. In all other cases a wire peg with flagging tape should be used to mark the plot point. The plot number should be painted on the tree nearest to the plot point. At the end of the measurement work the plot point should be repainted to allow audit crews to easily find the actual plot point.

4. SETTING OUT PLOTS

4.1 Plot Size

The plots in the Strategic Inventories are circular bound plots. The size of the plot will be shown on the plot location information given to you by your Field Supervisor. The plot point mark on the ground is the centre of the plot and the horizontal radius of the plot is 12.62 metres for a 0.05 hectare plot and 17.84 metres for a 0.1 hectare plot.

4.2 Plot Slope

The slope of the plot is measured by standing at the plot point and measuring the slop of the ground in the steepest direction of the plot **and** the slope in the opposite direction. The two readings are **averaged** to get plot slope.

4.3 Slope Correction

In order to ensure that all plots occupy the correct area the slope of the ground needs to be taken into account. This is only critical for trees which are close to the plot boundary. The procedure for allowing for slope is done on an individual tree basis. In other words, each "close tree" (ie within 0.5 metres of the plot radius) must be checked for the slope and the slope distance from the plot point to the middle of the side of the tree at 1.3 metres.

For "close trees" the slope angle to the tree is measured by taking a clino reading from the plot point to the tree (at eye level). The next thing to be done is measure the slope distance from the plot point to the middle of the side of the tree at 1.3 metres. To do this, one person should hold the end of the 30 or 50 metre tape 1.3 metres directly above the plot point marked on the ground while another person holds the other end of the tape at the middle of the side of the tree at 1.3 metres. At all times the tape should be held tight, straight (no bending around trees, branches, etc) and parallel to the ground.

The slope angle and slope distance are looked up in the Slope Correction Table in Appendix 1 on page 19. If the slope distance to the tree is less than, or equal to, the distance shown in the table then the tree is in, otherwise the tree is out. Trees which have been checked but are out should have a cross painted on the tree facing the plot point.

4.4 Marking the Plot Boundary

Having located (and marked) the plot point, the next thing to do is set out the plot boundary. This is best done using the Vertex[§] to lay out a circle surrounding the plot point.

[§] For details on use of the Vertex see "Vertex Hypsometer User Notes" in Appendix 2 on page 20.

One person should hold the transponder 1.3 metres directly above the plot point while another person sweeps around the plot perimeter measuring the distance of all trees which appear close to the plot radius. The hypsometer should be held at the middle of the side of the tree at 1.3 metres when measuring distances. While most trees will be clearly in or out, any which are within 0.5 metres of the plot radius will need to be checked using the slope correction method described in Section 4.2.

Please take care when checking "close" trees because one tree in or out of a plot can make a difference of several hundred cubic metres!!

Which Trees Are In?

Once the boundary of the plot has been determined, **all** trees with a diameter at breast height (1.3 metres) greater than 100 millimetres are recorded. No palms or ferns should be included. No trees which have a DBHob less than 100 millimetres are included.

All "in" trees should have the tree number and DBHob mark painted on them. The tree number is painted on the side of the tree facing the plot point and the DBHob mark is painted on the side of the tree where the 1.3 metres was measured.

For details on measuring and assessing the "in" trees, refer to Section 5 "Measuring Trees", on page 9 and Section 6 "Assessing Trees" on page 12

4.5 Information to be Recorded on the Proforma

There is a list of pieces of information which needs to be recorded for each plot. The following sections contain a description of what each bit of information (or "attribute") means and how it is recorded.

4.5.1 Inventory

In the "Inventory" field of the Plot Header record the Inventory Identifier for the plot you are measuring. The Inventory ID will be provided to you with all the plot location information by your Field Supervisor. The format of the Inventory ID is a two digit number with no leading zeros (eg: 1).

4.5.2 Management Area

In the "MA" field of the Plot Header record the Management Area Identifier for the plot you are measuring. The MA ID will be provided to you with all the plot location information by your Field Supervisor. The format of the MA ID is a two digit number with no leading zeros (eg: 12).

4.5.3 State Forest Name

In the "SF" name field of the Plot Header record the name of the State Forest which contains the plot you are measuring.

4.5.4 Compartment

In the "Cpt. No." field of the Plot Header record the compartment number of the plot you are measuring.

4.5.5 Aspect

In the "Aspect" field of the Plot Header record the record the magnetic bearing of the direction of maximum slope as a 1-digit code. Codes are:

1	0° - 45°
2	45° - 90°
3	90° - 135°
4	135° - 180°
5	180° - 225°
6	225° - 270°
7	270° - 315°
8	315° - 360°
0	Flat - no appreciable aspect

4.5.6 Plot Number

In the "Plot No" field of the Plot Header record the record the five digit plot number shown on the plot location information page, with leading zeros. Eg: 01023 for Plot 1023, or 21008 for Plot 21008.

4.5.7 Stratum

In the "Stratum" field of the Plot Header record the Stratum ID for the plot you are measuring. The Stratum ID will be provided to you with all the plot location information by your Field Supervisor. The format of the Stratum ID is a two digit number with leading zeros (eg: 02).

4.5.8 Plot Size

In the "Plot Size" field of the Plot Header record the size of the plot, in hectares with a leading zero for the decimal place. (eg: 0.05 for a 0.05 hectare plot, or 0.1 for 0.1 hectare plot.) The Plot Size will be provided to you with all the plot location information by your Field Supervisor.

4.5.9 Slope

In the "Slope" field of the Plot Header record the slope of the plot you are measuring. For details on how to measure plot slope refer to Section 4.2 on page 4.

4.5.10 Filter Strip Distance

In the "Filter Strip Distance" field of the Plot Header record the distance from the plot point to the bank of the nearest drainage line requiring a filter strip. If the distance to the nearest drainage line requiring a filter strip is greater than 50 metres, then leave this field blank.

If a definite, unmapped filter strip is found within 50 metres then the location of the drainage line should be added to the map.

4.5.11 Date

In the "Date" field of the Plot Header record the date you started measuring the plot. Record the date using dd/mm/yy format (eg: 24/11/97).

4.5.12 Crew

Record the "Crew Number" for your crew. Your field supervisor will be able to provide you with this number if you are not sure.

4.5.13 Site Height

In the "Site Height" field of the Plot Header record the Site Height of the plot you are measuring. For more details on measuring Site Height refer to Section 5.2 on page 10.

4.5.14 Tree Number

In the "Tree No." column record the tree number (starting from 1) for each tree in the plot you are measuring. Because some trees will take up more than one line on the proforma it is easier to record the tree number as the trees are being measured and assessed, rather than listing all the tree numbers one after the other at the start of tree measuring.

4.5.15 Species Code

In the "Spp Code" column record the standard three letter code for the species of tree you are measuring. A list of standard species codes form Appendix 3 on page 22.

Note that the MARVL computer system can only recognise the standard codes shown in Appendix 3, so if you can't find a code which could apply to the tree you are measuring (note: there are several "general" codes for such occasions) and you "invent" a new code you **must** tell your Field Supervisor.

4.5.16 Diameter (DBHob)

In the “DBH (mm)” column record the diameter of the tree you are measuring in millimetres. For more information on measuring diameters refer to Section 5.1 on page 9.

4.5.17 MARVL Tree Description

In the “MARVL Tree Description” column record the description of the tree you are measuring. For more information on MARVL tree descriptions refer to Sections 6.5 on page 13 and 6.6 on page 15.

4.5.18 Crown Condition

In the column “Crown Condition” record the Crown Condition of the tree you are measuring. For more information on Crown Condition refer to Section 6.1 on page 12.

4.5.19 Dominance

In the column “Dominance” record the Dominance of the tree you are measuring. For more information on Dominance refer to Section 6.2 on page 12.

4.5.20 Hollow Status

In the column “Hollow Status” record the Hollow Status of the tree you are measuring. For more information on Hollow Status refer to Section 6.3 on page 12.

4.5.21 Logging Impediment

In the column “Logging Imped” record the Logging Impediment of the tree you are measuring. For more information on Logging Impediment refer to Section 6.4 on page 12.

5. MEASURING TREES

5.1 Diameter (DBHob)

Measuring Point

Tree diameter obviously changes as you move along the stem of a tree. In general the tree will get thinner as you move towards the tip but there are also changes in diameter caused by limb swellings, damaged points, etc. So for any one tree there are countless diameters you could measure (if you were keen!).

What we need is a consistent diameter measurement point so if two different people measure the same tree we should get the same answer. That consistent measuring point is called "DBHob", standing for Diameter at Breast Height over bark.

There is a set of rules which define DBHob and how to measure it. The rules are:

1. Breast Height is 1.3 metres above ground level measured along the stem. Where the tree is on a slope, 1.3m is measured on the uphill side of the tree. Where the tree is on a lean, 1.3m is measured on the underside of the lean.

2. Trees which fork above 1.3m are considered to be one tree, but if the two leaders are separate at 1.3m each leader is treated as a separate tree.

3. Where a swelling occurs at 1.3m, two points, unaffected by swellings or limbs, equal distances above and below 1.3m should be selected so two unaffected measurements are then averaged to give an estimate of DBHob.

4. In situations where a tree forks right at 1.3m and the 1.3m point is swollen as a result of the fork, the tree should be treated as two separate trees with the diameters measured at the lowest point where the new leaders have assumed a normal shape.

5. The DBHob point is always located by measurement with the DBH stick.

The measurer should paint the point(s) on the tree where the diameter measurement(s) have been made.

Tape & Placement

The tape should be placed around the tree perpendicular (that is, at right angles) to the axis of the stem at 1.3m. If there is lichen or loose bark at 1.3m they should be gently cleared so as not to remove any firm bark from the tree.

On larger trees care should be taken to ensure the tape does not "get the droops" around the back of the tree. The tape should always go directly around the stem at the point of measurement.

Taking Readings
All diameter measurements should be measured, called and booked in millimetres. Where a part millimetre occurs always round down.

Multiple Leaders
Trees which fork above 1.3m are considered to be a single tree. Trees which have physically separated below 1.3m are considered to be two (or possibly three) different trees.

In all instances where a tree which forks at, or near, 1.3 metres gets recorded as two or more trees the section of the tree below the fork should be described as waste.

5.2 Height

Once the Vertex has been calibrated it is ready for use. See Vertex User notes in Appendix 2 on page 20 for more detail on the Vertex hypsometer.

Five trees of commercial species are to be measured for total height. The height information from these trees will be used to predict the heights of all other trees which are not measured for height. The five tree selected for measurement should cover the DBHob size range of the plot and preferably be fairly evenly distributed throughout the size range. All height trees must be "normal" in terms of the height of the tree (ie: no trees with dead or damaged tops or trees with severe lean should be measured). If a plot contains only trees of a narrow DBHob size range (eg: 200-500mm in a TSI'ed compartment) then the five height trees should span that range.

Turn the transponder on and place it at the middle of the side of the tree at 1.3m. The person with the hypsometer should place themselves about as far away from the tree as the tree is tall and in a position where they can see both the transponder and the top of the tree.

Turn the hypsometer on and aim the little red dot at the transponder, hold the orange button down until the red dot disappears, then release the orange button. Once the Vertex has measured the distance, the operator should check the "dist" and "angle" values to make sure the values are reasonable. The red dot should now be flashing, aim the flashing dot at the top of the tree and hold the orange button down until the dot disappears again.

In the lower left-hand corner of the display screen, just above the printing "Height 1" the height of the tree is shown. If you are unsure of the height given you should turn the Vertex off and back on again, then "re-shoot" to the transponder.

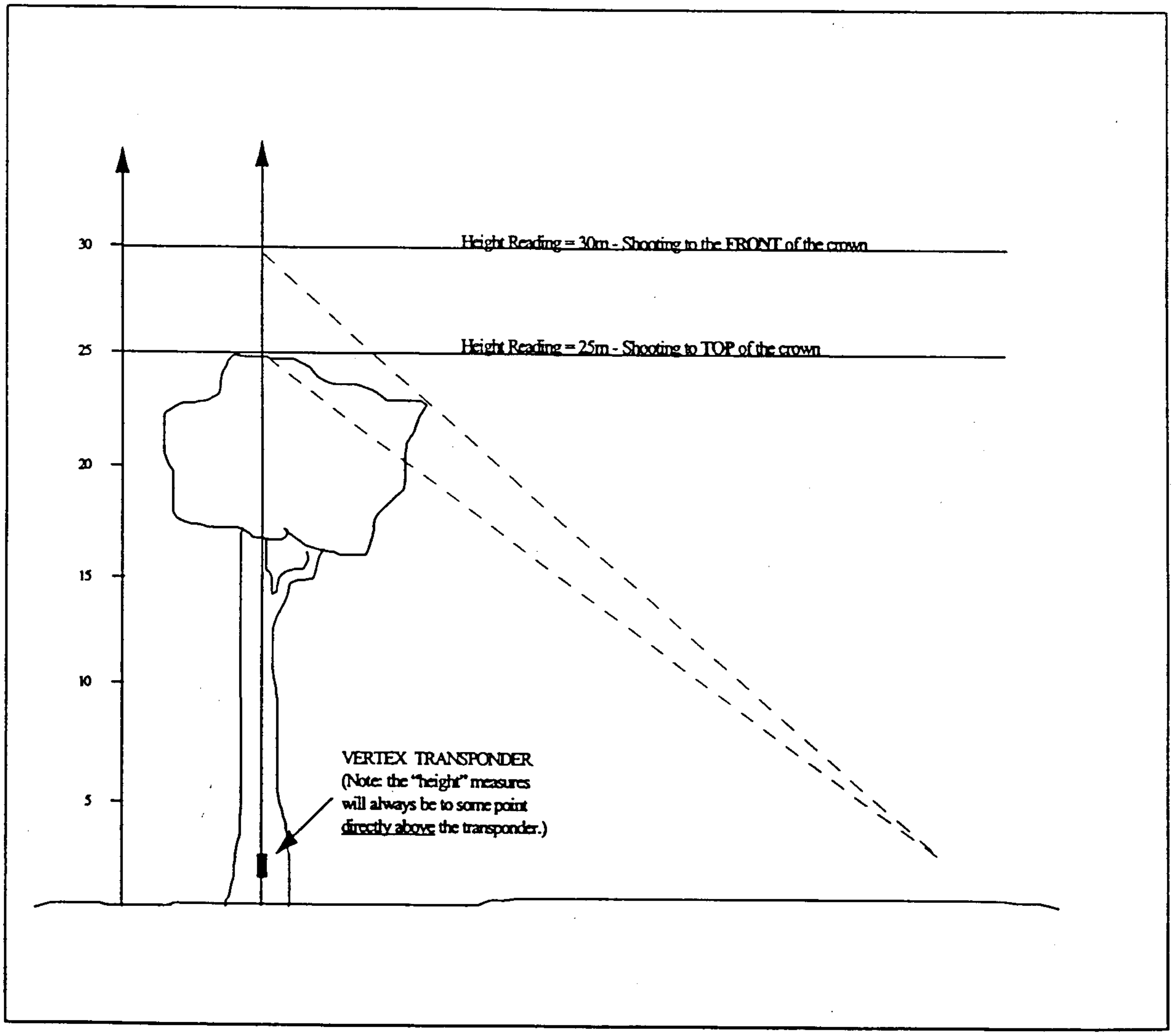
The main thing to keep in mind when heighting eucalypts is the shape of the tree crown. Figure 2 on Page 11 illustrates what can go wrong when a height reading is taken to the front of the tree crown instead of to the top of the crown.

Site Height
What we mean by "site height" is the maximum height trees could possibly reach in the area within and surrounding the plot. In other words, "what height would an undisturbed stand of trees reach?".

The procedure for collecting this bit of information varies according to the nature of the trees which are actually **in** the plot. In most cases the plot will probably contain at least three trees which are representative of this "maximum" height. In these situations all you need to do is calculate the average height of these trees and enter the average into the Site Height field.

If there are taller trees outside the plot (especially if the plot is in a patch of young regeneration or some other type of "gap") then the tallest three of those trees should be estimated for total height and that figure used to determine the plot's site height.

Figure 2: Heighting Eucalypts.


30
25
20
15
10
5
Height Reading = 30m - Shooting to the FRONT of the crown
Height Reading = 25m - Shooting to TOP of the crown
VERTEX TRANSPONDER
(Note: the "height" measures
will always be to some point
directly above the transponder.)

6. ASSESSING TREES

This part of the manual has six main sections. Sections 6.1, 6.2, 6.3 and 6.4 cover Crown Condition, Dominance, Hollow Status and Logging Impediment respectively. Sections 6.5 and 6.6 are titled Stem Quality Codes and Stem Structural Codes respectively and between them cover MARVL tree descriptions.

6.1 Crown Condition

Each tree in the plot is assessed for it's Crown Condition. The definitions of the Crown Condition classes are the same as for State Forest's P.G.P. system:

1 = Good - leafy vigorous crown
2 = Fair - average size and vigour
3 = Poor - senescent, diseased or damaged

6.2 Dominance Class

Each tree in the plot is assessed for it's Dominance Class. The definitions of the Dominance Classes are the same as for State Forest's P.G.P. system:

1 = Dominant - trees with crowns extending above the general canopy, receiving full light from above & partly from the sides
2 = Co-dominant - crown forms part of the general canopy, receives full light from above and little from the sides
3 = Sub-dominant - shorter than 1 & 2, crown extends into general canopy, receives a little light from above but none from the sides
4 = Suppressed - crown entirely below canopy, receives no direct light from above or sides

6.3 Hollow Status

Each tree in the plot must be assessed for it's hollow status. The codes are as follows:

0	Tree considered unlikely to contain hollows
1	Tree considered likely to contain hollows
2	Hollows suitable for animal or bird nesting visible

All trees in the plot must be assessed individually, regardless of how many trees in the plot have already been identified as having hollows. Do not attempt to record only enough "habitat trees" to meet a certain stocking rate (eg: 5 habitat trees per hectare), book all trees according to how they meet the definitions.

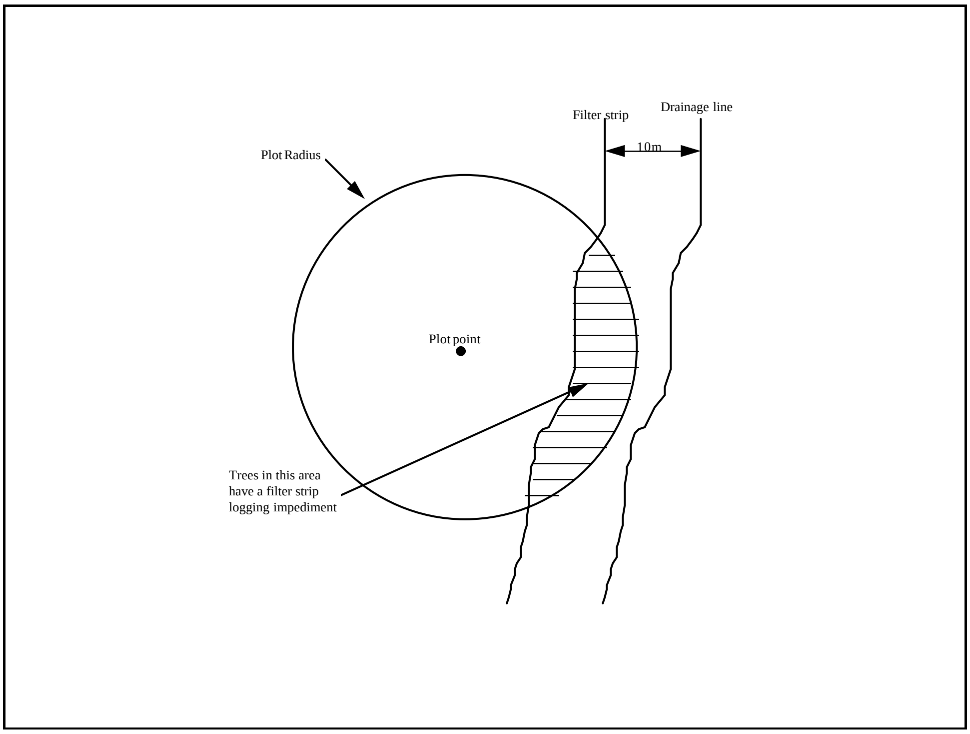
6.4 Logging Impediment

"Logging Impediment" is supposed to describe physical or filter strip impediments to a tree being harvested during a routine harvesting operation.

The sorts of things we mean by physical impediments are slopes greater than 30^o and rocky patches, in other words is there any "barrier" which would prevent you from being able to get to a tree.

Where a plot point falls close enough to a drainage line (regardless of whether the drainage line is mapped or unmapped) for some part of the plot to be within **10 metres** of the bank, any tree within that 10 metre strip is considered to have a logging impediment. Figure 3 shows how the filter strip logging impediment works.

Figure 3: Filter strip based logging impediment.



The codes are:

0	No impediment to harvesting
1	Physical impediment to harvesting
2	Impediment due to filter strip prescription

6.5 Stem Quality Codes

Trees in these plots are assessed for wood quality characteristics - not products. The assessor should not attempt to break the tree up into "logs" according to current specifications. In general each tree should be viewed overall and then assessed for wood quality on "sectional" basis. The series of alphabetic stem quality codes (along with the stem structural codes) are called a Dictionary. The Dictionary which is used in this inventory is shown in Appendix 6 on page 13.

An important point to note is that **stem size** makes no difference to **wood quality**. A section of stem which is only 20 centimetres in diameter but is straight and seemingly defect free should be described as being high quality (coded as "A").

Each tree's description will start with a section of waste (coded as "W") which represents both the stump height of the tree and any additional "butting" of the first log which may be necessary. If the whole tree is entirely unmerchantable then the waste section should continue up to the top height of the tree.

For trees of any species listed in Appendix 4 (on page 26) as being non-commercial, the whole tree is described as waste. Similarly, trees of any species listed in Appendix 5 (on page 27) as being suitable for pulp only, the whole tree is described as pulp. The lists shown in Appendices 4 and 5 are to be adhered to regardless of current local market conditions or the nature of any individual tree being assessed.

For trees of commercial species (ie: not listed in either Appendix 4 or 5) which contain some potentially merchantable material (including pulp) then the merchantable sections should be measured for length with the Vertex and given the appropriate quality code ("A", "B", "P" or "W"). This process continues right the way up the stem from the stump to the "stem deterioration point". From the "stem deterioration point" to the top of the tree crown should be given the code "T". If sections of waste occur between the merchantable sections then they should be included in the tree description in the same way as for merchantable sections.

All of the wood quality codes can be used more than once in any tree, and there is no reason why you cannot revert to a higher quality code once a section of low quality or waste has been described.

All tree descriptions must be booked in a cumulative way. By this we mean that if a tree has a five metre waste ("W") section at the stump, then ten metres of high quality ("A") material, then ten metres of low quality material ("B") up to the crown base (Stem Deterioration Point) and a top height ("T") of 40 metres, the tree description should look like this:

Tree No.	Spp Code	DBH (mm)	Harvesting Status	Crown Cond	Domin Class	Habitat Status	MARVL Tree Description
1	BBT	750	A	2	1		W5 A15 B25 T40

Trees of non-commercial species (NCO) should be given a tree description of waste ("W") to the top height of the tree as in the example below.

Tree No.	Spp Code	DBH (mm)	Harvesting Status	Crown Cond	Domin Class	Habitat Status	MARVL Tree Description

2	NCO	148	E	3	4		W10

If a section of a tree borders between two codes always describe the section as being the poorer of the two choices.

Viewing each tree from several angles definitely helps the assessor to pick up all the key features of the tree. Except in the case of very simple trees, all trees should be assessed from more than one perspective.

6.6 Stem Structural Codes

MARVL has a series of “built in” stem structural codes which are available in every type of Inventory State Forests undertakes. These codes are used to describe changes in the *shape or structure* of the stem rather than changes in the *quality* of the stem (although sometimes both shape/structure and quality are changed by a single feature of the stem, such as a fork).

Each of the stem structural codes has it’s own symbol (and associated information) which must be included in the tree description in a very specific way in order for MARVL to correctly interpret the code. An example of each code follows.

6.6.1 Dead (or broken) top (*)

This code is used to represent a tree which does not have a normal crown or stem, and is usually applied to trees which have been quite seriously damaged by harvesting or wind.

The code is inserted at the end of the tree description and must follow a feature height. The DEAD TOP code tells MARVL that the top height of that tree is not “normal” (so MARVL will not use the diameter and height of this tree to contribute to the formation of a diameter/height curve) and that any material above that point on the stem is dead and therefore not merchantable.

An example of the DEAD TOP structural code is shown below.

Tree No.	Spp Code	DBH (mm)	MARVL Tree Description	Crown Cond	Domin Class	Hollow Status	Logging Imped
1	WMY	541	W0.4 B25 T30 *	3	2	0	0

6.6.2 Fork (<)

This code is used to represent a tree which has a fork in the stem, and is applied when each of the leaders contains some merchantable material. The FORK code basically tells MARVL that the original tree has “ended” and that “new” trees now occur above the fork.

The double-heart section of the fork is never utilised. Because of this, that section of the tree is always described as waste ("W"). The most common situation is to describe one metre of waste at the top of the main stem of the tree (as in the example). If, however, a tree has a very acute fork, or the tree is very large, then the section of waste may be longer than one metre.

Because the FORK code represents a new leader (which MARVL treats just like a new tree) we need to provide a diameter for the leader. This is done by estimating the diameter of the leader 1.3 metres above the crutch of the fork. (To help you with the diameter estimate it is useful to look around for a tree of similar size to the leader and measure that tree to put your estimate "in the ball park".) The diameter estimate is then followed by the description of the leader, which is done in the same manner as for a tree right through to the tip of the leader. The process is repeated for the other leader(s), and this information is inserted directly beneath the first leader.

An example of the FORK structural code is shown below.

Tree No.	Spp Code	DBH (mm)	MARVL Tree Description	Crown Cond	Domin Class	Hollow Status	Logging Imped
1	TWD	683	W1 A8 W9 <300 B20 T35	1	2	2	0
			<280 B17 T31				

Note that only one "Crown Condition" and "Dominance Class" is given for the tree. These codes should take all leaders into consideration when classifying forked trees.

6.6.3 Diameter reduction (>)

This code is used to represent a tree which has a clearly identifiable point where the diameter of the stem reduces at a rate much faster than normal tree taper. The DIAMETER REDUCTION code is similar to the FORK code in that MARVL requires a new diameter estimate to be attached to the code.

Use of the DIAMETER REDUCTION code is relatively rare and is applied in situations such as a sucker growing off an old stump, or where the bottom section of a tree is swollen as a result of insect damage. This code should **not** be applied to the buttressing which occurs normally in trees, especially species like Brush Box.

An example of the DIAMETER REDUCTION code is shown below.

Tree No.	Spp Code	DBH (mm)	MARVL Tree Description	Crown Cond	Domin Class	Hollow Status	Logging Imped
1	SPG	683	W2>350 B21 T33	2	1	4	1

6.6.4 Forced cut (%)

This code is used in circumstances where the stem has a defect which could be removed from the tree in log servicing by a single saw cut but no waste section needs to be removed.

Virtually the only instances where this occurs is when a stem has a sharp change of direction over a distance of no more than 20 cm. In this case it is possible to have high quality wood right up to the change of direction, and more high quality wood immediately above the change of direction but because of the change of direction it would not be possible to have a single high quality log running through that point.

Note that a FORCED CUT should **not** be inserted simply because of a change of stem *quality.*

An example of the FORCED CUT code is shown below.

Tree No.	Spp Code	DBH (mm)	MARVL Tree Description	Crown Cond	Domin Class	Hollow Status	Logging Imped
1	NEB	489	W0.3 A5 % A12 B20 T29	1	2	3	2

6.6.5 Merchantable branch (+)

This code is used when a tree has one (or more) limbs of sufficient size and quality to contain merchantable material. The main difference between a MERCHANTABLE BRANCH and a FORK is that with a MERCHANTABLE BRANCH the main stem of the tree can be serviced as a single log by using a chamfer cut on the branch and not cross-cutting the stem, whereas a FORK requires cross-cutting to remove the double-heart section of stem.

Like FORKS, MERCHANTABLE BRANCHES require a new diameter (1.3 metres from the base of the branch) and then a description as though they were a normal tree. The symbol (+) is used to start a second line of tree description where the diameter and quality information is placed.

An example of the MERCHANTABLE BRANCH code is shown below.

Tree No.	Spp Code	DBH (mm)	MARVL Tree Description	Crown Cond	Domin Class	Hollow Status	Logging Imped
1	SBG	631	W0.5 B25 T34	2	2	1	0
			+ 300P10 T18				

7. APPENDICES

Appendix 1: Plot Slope Correction Table

Average	Plot Size	
Slope	0.05ha	0.1ha
5	12.64	17.88
6	12.65	17.89
7	12.66	17.91
8	12.68	17.93
9	12.69	17.95
10	12.71	17.98
11	12.73	18.01
12	12.76	18.04
13	12.78	18.07
14	12.81	18.11
15	12.84	18.15
16	12.87	18.20
17	12.90	18.24
18	12.94	18.29
19	12.97	18.35
20	13.01	18.40
21	13.06	18.46
22	13.10	18.53
23	13.15	18.60
24	13.20	18.67
25	13.25	18.74
26	13.31	18.82
27	13.37	18.90
28	13.43	18.99
29	13.49	19.08
30	13.56	19.17
31	13.63	19.27
32	13.70	19.37
33	13.78	19.48
34	13.86	19.59
35	13.94	19.71
36	14.03	19.84
37	14.12	19.96
38	14.21	20.10
39	14.31	20.24
40	14.41	20.38
41	14.52	20.54
42	14.63	20.70
43	14.75	20.96
44	14.87	21.04
45	15.00	21.22

Appendix 2: Vertex Hypsometer User Notes

General

The Vertex uses ultrasonic pulses to determine the distance between the hypsometer and the transponder, the speed of these pulses varies with temperature and therefore the Vertex should only be used when it has reached a stable temperature.

To check the stability of the temperature of the Vertex press the ON/OFF button while holding down the STEP button. If the temperature displayed is steadily moving up or down then place the Vertex in the shade and wait until the temperature is stable (normally 5-10 minutes).

Instrument Set-up

The Vertex has two settings which must be checked before use, they are the "Pivot offset" and the "TRP height". To check these settings press the ON/OFF button and read the display on the side of the instrument. The "Pivot offset" should be set at 0.3 and the "TRP height" should be set at 1.3. If either of these settings are different then follow the routine described in the box below.

The "Pivot offset" is an allowance for the fact that when the operator tips their head back to look up to the top of a tree the angle they generate is created some distance behind the Vertex, usually about 0.3 metres. The "TRP height" is the height above the ground at which the transponder is held, in our case that height will always be 1.3 metres.

Vertex Set-up Procedure

1. Press ON/OFF while holding UNDO.
2. Press the orange button once.
3. Press the STEP button three times.
4. Press the orange button once.
5. Press the STEP button once.
6. Press the orange button once.
7. Press the STEP button three times.
8. Press the ON/OFF button once.

Calibration

To check if the Vertex needs calibration measure out exactly 10.00 metres between the centre of the transponder and the front of the hypsometer, turn the transponder on and hold the ON/OFF button down until the display shows an "Auto distance". If this "Auto distance" is between 9.98 and 10.02 then the instrument is ready for use, if not then it needs to be calibrated.

Vertex Calibration Procedure

1. Measure 20.00 metres between the transponder and the front of the hypsometer
2. Press and hold down the ON/OFF button.
3. Wait until the Vertex displays an "Auto dist".
4. While the ON/OFF button is still being pressed, press UNDO until the display shows 20.00.
5. Turn the Hypsometer off by Releasing the ON/OFF button and pressing it once more

The Vertex has now been calibrated for the **current temperature**. If the temperature changes by more than 5^o Celsius during the day then you should repeat the calibration process.

Temperature sensitivity

Because the Vertex is very temperature sensitive it should not be carried close to your body as your body heat will warm the hypsometer up. The hypsometer should never be placed in the sun and you should avoid touching the temperature sensor (the small steel circle on the front of the instrument) or aiming the hypsometer at the sun when heighting a tree.

Appendix 3: MARVL Tree Species Codes

Common Name	Botanical Name	Species Code
Apple, Roughbarked	Angophora floribunda	RAP
Apple, Smoothbarked	Angophora costata	SAP
Ash, Alpine	Eucalyptus delegatensis	ALA
Ash, Black	Eucalyptus sieberi	STA
Ash, Blue mountain	Eucalyptus oreades	BMA
Ash, Coast	Eucalyptus sieberi	STA
Ash, Silvertop	Eucalyptus sieberi	STA
Ash, White	Eucalyptus fraxinoides	WHA
Bangalay	Eucalyptus botryoides	BAN
Belah	Casuarina cristata	BLH
Blackbutt	Eucalyptus pilularis	BBT
Blackbutt, Largefruited	Eucalyptus pyrocarpa	PYR
Blackbutt, New England	Eucalyptus campanulata	NEB
Bloodwood group	Corymbia spp.	BLW
Bloodwood, Brown	Corymbia trachyphloia	BBW
Bloodwood, Pink	Corymbia intermedia	PBW
Bloodwood, Red	Corymbia gummifera	RBW
Bloodwood, Yellow	Corymbia eximia	YBW
Box, Apple	Eucalyptus bridgesiana	ABX
Box, Appletopped	Eucalyptus angophoroides	TBX
Box, Bimble	Eucalyptus populnea	PBX
Box, Brush	Lophostemon confertus	BBX
Box, Coast grey	Eucalyptus bosistoana	CBX
Box, Craven grey	Eucalyptus largeana	VBX?
Box, Fuzzy	Eucalyptus conica	FBX
Box, Grey	Eucalyptus moluccana	GBX
Box, Grey	Eucalyptus dawsonii	GBX
Box, Pilliga	Eucalyptus pilligaensis	LBX
Box, Red	Eucalyptus polyanthemos	RBX
Box, Rudders	Eucalyptus rudderi	UBX
Box, Steel	Eucalyptus rummeryi	SBX
Box, Swamp	Lophostemon suaveolens	LSU
Box, Western grey	Eucalyptus woollsiana ssp. microcarpa	MBX
Box, Western red	Eucalyptus intertexta	IBX
Box, White	Eucalyptus albens	WBX
Box, Whitetopped	Eucalyptus quadrangulata	QBX
Box, Yellow	Eucalyptus melliodora	YBX
Broombush	Melaleuca uncinata	BRO
Brown Barrel	Eucalyptus fastigata	FAS
Brushwood group	(Various)	BWD
Budda	Eremophila mitchellii	BUD
Candlebark	Eucalyptus rubida	CBK
Carbeen	Eucalyptus tessellaris	CAR

Common Name	Botanical Name	Species Code
Cherry, Native	Exocarpus cupressiformis	NCH
Cuttail	Eucalyptus fastigata	FAS
Cypress pine, Black	Callitris endlicheri	BCP
Cypress pine, White	Callitris glaucophylla	WCP
Emu Bush	Eremophila longifolia	EMU
Eucalyptus spp.	Eucalyptus spp.	EUC
Eurabbie	Eucalyptus bicostata	EUR
Gum, Bancroft's Red	Eucalyptus bancroftii	ARG?
Gum, Blakelys red	Eucalyptus blakelyi	BRG
Gum, Blue	Eucalyptus saligna	SBG
Gum, Cabbage	Eucalyptus amplifolia	CGG
Gum, Dunn's white	Eucalyptus dunnii	DWG
Gum, Dwyers red	Eucalyptus dwyeri	DRG
Gum, Flooded	Eucalyptus grandis	FLG
Gum, Forest red	Eucalyptus tereticornis	FRG
Gum, Grey	Eucalyptus propinqua	GYG
Gum, Grey	Eucalyptus punctata	GYG
Gum, Grey	Eucalyptus canaliculata	GYG
Gum, Gully	Eucalyptus smithii	GPM
Gum, Maidens	Eucalyptus globulus ssp. maidenii	MDG
Gum, Manna	Eucalyptus viminalis	MAG
Gum, Monkey	Eucalyptus cypellocarpa	MKG
Gum, Mountain	Eucalyptus dalrympleana	MTG
Gum, Mountain grey	Eucalyptus cypellocarpa	MKG
Gum, Narrowleaved red	Eucalyptus seeana	NRG?
Gum, Red (group)	Eucalyptus spp.	RDG?
Gum, Ribbon	Eucalyptus viminalis	MAG
Gum, River red	Eucalyptus camaldulensis	RRG
Gum, Roundleaved	Eucalyptus deanei	RLG
Gum, Scribbly	Eucalyptus haemastoma	SCG
Gum, Scribbly	Eucalyptus racemosa	SCG
Gum, Scribbly	Eucalyptus rossii	SCG
Gum, Scribbly	Eucalyptus sclerophylla	SCG
Gum, Scribbly	Eucalyptus signata	SCG
Gum, Shining	Eucalyptus nitens	SHG
Gum, Snow	Eucalyptus pauciflora	SNG
Gum, Spotted	Corymbia maculata or C. variegata	SPG
Gum, Large-leaved Spotted	Corymbia henryi	LSG?
Gum, Sydney blue	Eucalyptus saligna	SBG
Gum, Tumbledown red	Eucalyptus dealbata	TRG
Gum, White	Eucalyptus dunnii	DWG
Ironbark group	Eucalyptus spp.	IBK
Ironbark, Blueleaved	Eucalyptus fibrosa ssp. nubila	BIB

Common Name	Botanical Name	Species Code
Ironbark, Broadleaved	Eucalyptus fibrosa	FIB
Ironbark, Grey	Eucalyptus siderophloia	GIB
Ironbark, Grey	Eucalyptus paniculata	GIB
Ironbark, Mugga	Eucalyptus sideroxylon	RIB
Ironbark, Narrowleaved	Eucalyptus crebra	NIB
Ironbark, Red	Eucalyptus sideroxylon	RIB
Ironbark, Silverleaved	Eucalyptus melanophloia	SIB
Mahogany, Blue Mountains	Eucalyptus notabilis	MMY?
Mahogany, Broadleaved white	Eucalyptus umbra ssp. carnea	BMY
Mahogany, Narrowleaved white	Eucalyptus acmenioides	NMY
Mahogany, Red	Eucalyptus resinifera	RMY
Mahogany, Red	Eucalyptus scias (syn. pellita)	RMY
Mahogany, Swamp	Eucalyptus robusta	SMY
Mahogany, white (group)	Eucalyptus acmenoides or E. umbra	WMY
Mallee group	Eucalyptus spp.	MAL
Messmate	Eucalyptus obliqua	MMT
Non-commercial Eucalypts	Eucalyptus spp	NCE
Non-commercial others	(Various)	NCO
Oak group	(Various)	OAK
Oak, Bull	Allocasuarina leuhmanii	BOK
Oak, Forest	Allocasuarina torulosa	FOK
Other commercial Eucalypt	Eucalyptus spp	OCE
Palm, Cabbage tree	Livistona australis	CTP
Peppermint group	Eucalyptus spp.	PPM
Peppermint, Broadleaved	Eucalyptus dives	BPM
Peppermint, Gully	Eucalyptus smithii	GPM
Peppermint, Narrowleaved	Eucalyptus radiata	NPM
Peppermint, New England	Eucalyptus nova-anglica	EPM
Peppermint, River	Eucalyptus elata	RPM
Peppermint, Sydney	Eucalyptus piperita	SPM
Pine, Hoop	Araucaria cunninghamii	HPP
Quandong	Santalum acuminatum	QUA
Rosewood, Western	Heterodendron oleifolium	ROS
Sallee, Black	Eucalyptus stellulata	BSA
Sallee, White	Eucalyptus pauciflora	SNG
Stringybark group	Eucalyptus spp.	SBK
Stringybark, Baileys	Eucalyptus baileyana	LSB
Stringybark, Bloodwood	Eucalyptus baileyana	LSB
Stringybark, Blueleaved	Eucalyptus agglomerata	ASB

Common Name	Botanical Name	Species Code
Stringybark, Brown	Eucalyptus capitellata	BSB
Stringybark, Diehard	Eucalyptus cameronii	DSB
Stringybark, Narrowleaved	Eucalyptus oblonga	OSB
Stringybark, Needlebark	Eucalyptus planchoniana	NSB
Stringybark, New England	Eucalyptus caliginosa	ESB
Stringybark, Red	Eucalyptus macrorhyncha	RSB
Stringybark, Silvertop	Eucalyptus laevopinea	SSB
Stringybark, White	Eucalyptus globoidea	WSB
Stringybark, Yellow	Eucalyptus muelleriana	YSB
Stringybark, Youmans	Eucalyptus youmanii	USB
Tallowwood	Eucalyptus microcorys	TWD
Turpentine	Syncarpia glomulifera	TRP
Wattle group	Acacia spp.	WAT
Wilga	Geijera parviflora	WIL
Woollybutt	Eucalyptus longifolia	WBT
Yertchuk	Eucalyptus consideniana	YER
Scaly Bark	Eucalyptus squamosa	SCB?

Appendix 4: Non-commercial Species List

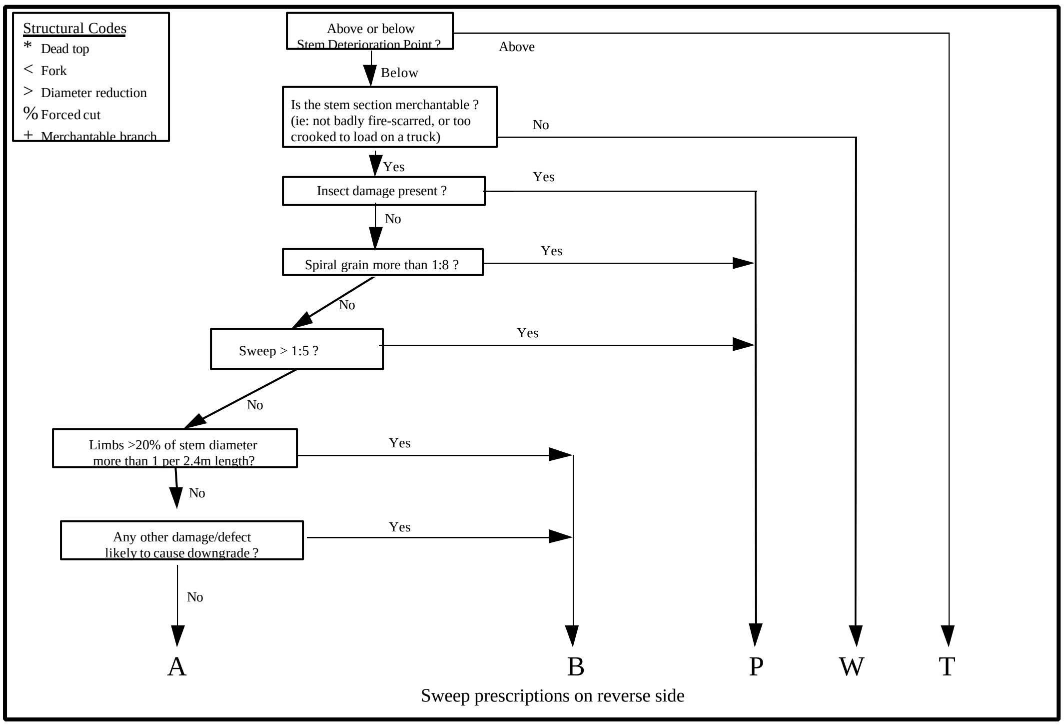
Common Name	Botanical Name	Species Code
Ash, Blue mountain	Eucalyptus oreades	BMA
Belah	Casuarina cristata	BLH
Bloodwood, Brown	Corymbia trachyphloia	BBW
Bloodwood, Yellow	Corymbia eximia	YBW
Box, Swamp	Lophostemon suaveolens	LSU
Broombush	Melaleuca uncinata	BRO
Brushwood group	(Various)	BWD
Budda	Eremophila mitchellii	BUD
Cherry, Native	Exocarpus cupressiformis	NCH
Cypress pine, Black	Callitris endlicheri	BCP
Cypress pine, White	Callitris glaucophylla	WCP
Emu Bush	Eremophila longifolia	EMU
Eucalyptus spp.	Eucalyptus spp.	EUC
Mahogany, Blue Mountains	Eucalyptus notabilis	MMY?
Mallee group	Eucalyptus spp.	MAL
Non-commercial Eucalypts	Eucalyptus spp	NCE
Non-commercial others	(Various)	NCO
Oak group	(Various)	OAK
Oak, Bull	Allocasuarina leuhmanii	BOK
Oak, Forest	Allocasuarina torulosa	FOK
Palm, Cabbage tree	Livistona australis	CTP
Quandong	Santalum acuminatum	QUA
Rosewood, Western	Heterodendron oleifolium	ROS
Wattle group	Acacia spp.	WAT
Wilga	Geijera parviflora	WIL
Scaly Bark	Eucalyptus squamosa	SCB?

Appendix 5: "Pulp Only" Species List

Common Name	Botanical Name	Species Code
Apple, Roughbarked	Angophora floribunda	RAP
Apple, Smoothbarked	Angophora costata	SAP
Box, Apple	Eucalyptus bridgesiana	ABX
Box, Appletopped	Eucalyptus angophoroides	TBX
Box, Bimble	Eucalyptus populnea	PBX
Box, Fuzzy	Eucalyptus conica	FBX
Gum, Bancroft's Red	Eucalyptus bancroftii	ARG?
Gum, Cabbage	Eucalyptus amplifolia	CGG
Gum, Dwyers red	Eucalyptus dwyeri	DRG
Gum, Forest red	Eucalyptus tereticornis	FRG
Gum, Narrowleaved red	Eucalyptus seeana	NRG?
Gum, Red (group)	Eucalyptus spp.	RDG?
Gum, Scribbly	Eucalyptus haemastoma	SCG
Gum, Scribbly	Eucalyptus racemosa	SCG
Gum, Scribbly	Eucalyptus rossii	SCG
Gum, Scribbly	Eucalyptus sclerophylla	SCG
Gum, Scribbly	Eucalyptus signata	SCG
Gum, Snow	Eucalyptus pauciflora	SNG
Gum, Tumbledown red	Eucalyptus dealbata	TRG
Other commercial Eucalypt	Eucalyptus spp	OCE
Peppermint, Sydney	Eucalyptus piperita	SPM
Stringybark, Needlebark	Eucalyptus planchoniana	NSB

Appendix 6: Dictionary

Northern Region Native Forest MARVL Dictionary



Developed by Northern Region Inventory Unit, 1996.

Allowable Sweep Table

Section Length	Mid Diam of Sect (cm)									
	5	10	15	20	25	30	35	40	45	50
1.0	0.4	0.8	1.3	1.7	2.1	2.5	2.9	3.3	3.8	4.2
2.0	0.6	1.3	1.9	2.5	3.1	3.8	4.4	5.0	5.6	6.3
3.0	0.8	1.7	2.5	3.3	4.2	5.0	5.8	6.7	7.5	8.3
4.0	1.0	2.1	3.1	4.2	5.2	6.3	7.3	8.3	9.4	10.4
5.0	1.3	2.5	3.8	5.0	6.3	7.5	8.8	10.0	11.3	12.5
6.0	1.5	2.9	4.4	5.8	7.3	8.8	10.2	11.7	13.1	14.6
7.0	1.7	3.3	5.0	6.7	8.3	10.0	11.7	13.3	15.0	16.7
8.0	1.9	3.8	5.6	7.5	9.4	11.3	13.1	15.0	16.9	18.8
9.0	2.1	4.2	6.3	8.3	10.4	12.5	14.6	16.7	18.8	20.8
10.0	2.3	4.6	6.9	9.2	11.5	13.8	16.0	18.3	20.6	22.9
11.0	2.5	5.0	7.5	10.0	12.5	15.0	17.5	20.0	22.5	25.0
12.0	2.7	5.4	8.1	10.8	13.5	16.3	19.0	21.7	24.4	27.1
13.0	2.9	5.8	8.8	11.7	14.6	17.5	20.4	23.3	26.3	29.2
14.0	3.1	6.3	9.4	12.5	15.6	18.8	21.9	25.0	28.1	31.3
15.0	3.3	6.7	10.0	13.3	16.7	20.0	23.3	26.7	30.0	33.3

Strategic Inventory Project

Auditing Methodology Outline

(as at May 13th, 1997)

1.0 Objectives.

The objectives of the Strategic Inventory Audit Program are to place State Forests in a position where it is able to:

- have confidence in the quality of data collected,
- demonstrate the validity of the data collected, and
- provide additional training and supervision for field crews where a need for such work is identified.

2.0 Auditing Structure.

For each field crew working on the Strategic Inventory Project a proportion of plots will be audited for correct procedures and accurate measurements. The benchmark sampling intensity of plots for auditing will be 5% of plots measured.

Within the Upper and Lower North-East CRA regions the audits will be carried out by two audit field crews working under the supervision of the Northern Quality Control Forester.

Plots will be selected for audit on the basis of the field crew which measured the plot. Audit plots will be selected once a fortnight and will draw from all plots completed by the field crew in the last 10 working days. Sampling of plots for audit will be without replacement.

2.1 Reporting.

There will be two standard reports produced by the Quality Control Forester, they are the Detailed Report and the Summary Report. The Detailed Report will contain all the information about the plot and the values of all parameters measured/assessed. It will also contain all differences between crew and audit values as well as demerit points accrued for that plot. The Summary Report will only contain information about which crew was audited and the demerit points accrued for that plot. *(The exact format and structure of the reports has not been finalised as they are still in the development stage - also, I need to see some **final** document which described the inventory attributes, etc.)*

Reports on the results of all audits will be provided (ASAP) to the Supervising Forester of the crew being audited. Reports of audit activities will also be provided to the Project Manager and Northern Division Co-ordinator on request.

3.0 Audit Attributes.

The attributes which will be audited fall into two categories, plot attributes and tree attributes. Following is a brief description of each audit attribute and how it will be checked.

3.1 Plot Attributes.

3.1.1 *Audit Crew ID:* The initials of the audit crew leader. If the Northern Quality Control Forester forms part of the audit crew then their initials will be used, otherwise, the initials of the audit FA leading the audit crew. Format: ABC.

3.1.2 *Audit Date:* The date on which the plot was audited. Format: dd-mmm-yy.

3.1.3 *Inventory ID:* Unique identifier for the inventory from which a sample plot has been drawn. Each inventory unit (be they old Districts, Management Areas, etc) will be assigned a number from 1 to how ever many inventories are specified. No leading zeros will be applied. Format: 12.

3.1.4 *Plot ID:* Unique identifier for each plot in the Strategic Inventory Project. Format: IISSPP. Where "II" is the *Inventory ID*, "SS" is a two digit stratum identifier (with leading zero) and "PP" is a two digit plot number (also with leading zero). **Note:** this attribute is the database field which links plot and tree attributes.

3.1.5 *Crew ID:* The initials of the field crew leader. Format: ABC.

3.1.6 *TOP:* Take-Off-Point. Is the TOP for the audit plot correctly located and marked? **Note:** for plots which are located in a compound traverse (ie: plots which have been located from another plot rather than a nominated roadside point) this attribute will not apply. Format: Yes/No.

3.1.7 *Location:* Has the plot been located correctly? (ie: Is the plot point within 10% of the traverse distance of where it should be?) Format: Yes/No.

3.1.8 *Layout:* Is the plot centre marked clearly (if no wire peg has been used crews will have to re-mark the plot centre on completion of the plot if the point becomes scuffled during measurement), and has the plot number been painted on the nearest "in" tree? Format: Yes/No.

3.1.9 *Crew Filter Strip distance (F/S distance):* Distance from the plot point to the centre of the nearest drainage line **if** the drainage line is within 50 metres of the plot point measured by the crew(otherwise blank). Format: 12.

3.1.10 *Audit Filter Strip distance (F/S distance):* Distance from the plot point to the centre of the nearest drainage line **if** the drainage line is within 50 metres of the plot point measured in the audit (otherwise blank). Format: 12.

3.1.11 *Crew Slope:* Average plot slope measurement as recorded by the field crew, in degrees. Format: 12.

3.1.12 *Audit Slope:* Average plot slope measurement as recorded by the audit crew, in degrees. Format: 12.

3.1.13 *Crew Tree Count:* Total number of trees counted as "in" the plot by the field crew. Format: 123.

3.1.14 *Audit Tree Count:* Total number of trees counted as "in" the plot by the audit crew. Format: 123.

3.2 Tree Attributes.

3.2.1 *Plot ID:* Unique identifier for each plot in the Strategic Inventory Project. Format: IISSPP. Where "II" is the *Inventory ID*, "SS" is a two digit stratum identifier (with leading zeros) and "PP" is a two digit plot number (also with leading zeros).

3.2.2 *Tree No.:* The tree number (as designated by the field crew) for the sample tree. Format: 123.

3.2.3 *Crew Species:* Crew's species code for the sample tree (standard State Forests three character codes). Format: ABC.

3.2.4 *Audit Species:* Audit species code for the sample tree (standard State Forests three character codes). Format: ABC.

3.2.5 *Crew Diam:* Crew's measurement of DBHob for the sample tree (in millimetres). Format: 1234.

3.2.6 *Audit Diam:* Audit measurement of DBHob for the sample tree (in millimetres). Format: 1234.

3.2.7 *Crew Description:* Crew's MARVL description for sample tree (alphanumeric string). Format: A1 B2 C3...

3.2.8 *Audit Description:* Audit MARVL description for sample tree (alphanumeric string). Format: A1 B2 C3...

3.2.9 *Crew Height:* Crew's measurement of total height for sample tree (in metres, 1 decimal place). Format 12.3.

3.2.10 *Audit Height:* Audit measurement of total height for sample tree (in metres, 1 decimal place). Format 12.3.

3.2.11 *Crew Crown Condition:* Crew's crown condition score for the sample tree (ordinal scale from 1 to 3). Format: 1.

3.2.12 *Audit Crown Condition:* Audit crown condition score for the sample tree (ordinal scale from 1 to 3). Format: 1.

3.2.13 *Crew Dominance:* Crew's dominance score for the sample tree (ordinal scale from 1 to 4). Format: 1.

3.2.14 *Audit Dominance:* Audit dominance score for the sample tree (ordinal scale from 1 to 4). Format: 1.

3.2.15 *Crew Hollow:* Crew's Hollow Status code for the sample tree (ordinal scale from 0 to 1). Format: 1.

3.2.16 *Audit Hollow:* Audit Hollow Status code for the sample tree (ordinal scale from 0 to 1). Format: 1.

3.2.17 *Crew Logging Impediment:* Crew's Logging Impediment code for the sample tree (ordinal scale from 0 to 2). Format: 1.

3.2.18 *Audit Logging Impediment:* Audit Logging Impediment code for the sample tree (ordinal scale from 0 to 2). Format: 1.

4.0 Sampling Intensity.

The sampling intensity of this audit program has two components. The first is the plot level sampling intensity, ie: what number or proportion of plots will be re-visited? The second is the tree level sampling intensity, ie: once you are at the plot, how many trees will you sample?

Given the relatively equal importance of all plot attributes combined and all tree attributes combined, it is logical that the two levels of auditing be roughly equal. If one particular attribute was considered to be far more important than any other, then the sampling intensity for that attribute should reflect it's importance.

4.1 Plot Level Sampling Intensity.

The plot level sampling intensity will be on a sliding scale depending on the results of previous audits. Protocols for acting on the detection of substandard work are detailed in Section 5.5 "Substandard Work." on page ????

The benchmark sampling intensity will be 5% of plots measured. In any case where auditing reveals substandard work the sampling intensity for that crew will be raised to 10% for 4 weeks (ie: the next two audits). If any substandard work (either the same problem or any "new" problems) is detected during the 4 week period of 10% sampling then the sampling intensity will be raised to 15% for a 4 week period. If no substandard work is detected during a period of raised sampling intensity (either 10 or 15%) then the sampling intensity will revert to a lower level.

4.1.1 Selection of Sample Plots.

Upon receipt of the fortnightly list of plots measured by a crew, each plot in the list will be given a sequential number starting from 1. (Note: this number is used solely for selecting sample plots and is discarded after the selection process is complete.) The required number of sample plots will be calculated, based on the *current* sampling intensity for that crew, and a random number generator will be used to select the required number of sample plots.

For example: Crew A completed 15 plots in the last fortnight and their current sampling intensity is 15%. The plots will be numbered from 1 through to 15 and two (15% of 15 is 2.25, fractions below 0.5 will be rounded down - 0.5 and greater will be rounded up) random numbers between 1 and 15 will be generated to select the sample plots. If any random numbers are duplicated in the generation process, the random number generator will be re-run until a set of unique numbers is produced.

4.2 Tree Level Sampling Intensity.

Tree level sampling intensity will be a sliding scale based on the number of trees in the sample plot. Table 1 shows the sampling intensity for tree level attributes.

Table 1: Tree level sampling intensity.

Tree Count of Sample Plot (by audit)	Audit Sample
<6 trees	100 % sample
6-20 trees	6 sample trees
21-30 trees	7 sample trees
31-40 trees	8 sample trees
41-50 trees	9 sample trees
51 +	10 sample trees

4.2.1 Selection of Sample Trees.

Once a plot has been selected for auditing the Tree Number list from the plot will form the basis of sample tree selection. The required number of sample trees will be calculated, based on Table 1, and a random number generator will be used to select the required number of trees.

For example: Plot 23 contains 43 trees and so requires the selection of 9 sample trees. The random number generator will generate 9 numbers between 1 and 43 to select the sample trees. If any random numbers are duplicated in the generation process, the random number generator will be re-run until a set of unique numbers is produced.

5.0 Acceptable Limits.

For all attributes being audited an acceptable limit range must be determined. Measured attributes are relatively easy to attach such limits to, but estimated attributes present a far less clear picture in terms of determining what represents an acceptable value and what doesn't.

This is particularly pertinent in regard to the tree descriptions which, due to the "unknown" nature of internal defect and general vagaries of external appearance, will be based primarily on the opinion of the marketing foreman in each crew.

Acceptable limits for plot attributes are dealt with in Section 5.1, general tree attributes are in Section 5.2 and tree descriptions are in Section 5.3.

5.1 Plot Attributes.

Table 2 shows the acceptable limits for plot attributes.

Table 2: Acceptable limits for plot attributes.

Attribute	Units	Acceptable range	Comments
Audit Crew ID	N/A	N/A	
Audit Date	N/A	N/A	
Inventory ID	Ordinal No.	1-20	
Plot ID	Numeric code	10101-202050	
Crew ID	N/A	N/A	
TOP	location in metres, no units for marking	10% of traverse distance for location	
Location	metres	10% of traverse distance	
Layout	N/A	N/A	
Filter Strip distance	metres	±5	
Crew Slope	degrees	±2	
Crew Tree Count	tally of "in" trees	0	Critical attribute

5.2 General Tree Attributes.

Table 3 shows the acceptable limits for tree attributes.

Table 3: Acceptable limits for tree attributes.

Attribute	Units	Acceptable range	Comments
Plot ID	N/A	N/A	
Tree No.	N/A	N/A	
Tree Species	N/A	N/A	
Crew Diam	millimetres	±1% - DBHob <600mm ±2% - DBHob >599mm	More tolerance for larger trees. 600mm used as cutoff because trees <600mm can be reached around, trees >599 can't
Crew height	metres	±1m - height <20m ±2m - height 20-35m ±5m - height>35m	More tolerance for larger trees.
Crew Crown Condition	Ordinal scale	±1	
Crew Dominance	Ordinal scale	±1	
Crew Hollow	Ordinal scale	N/A	
Crew Logging Impediment	Ordinal scale	±1m for trees coded as 2	

5.3 Tree Descriptions.

As mentioned in Section 5.0, tree descriptions pose a unique problem in terms of determining acceptable limits for accuracy.

In relation to **quality** codes it is unrealistic to expect audit crew members to be in a position where they can determine how well a tree has been described (with the probable exception of small trees, which are generally less "deceptive" and simpler to describe). As such, only gross errors will be detectable by audit crews.

The application of **structural** codes will be far easier for audit crews to determine acceptable limits. Although there is some overlap between codes like *merchantable branch* and *fork*, audit crews will be able to record the occurrence of missed or over-used codes.

A five-point ordinal score will be used to measure the acceptability of tree descriptions, where:

1. Excellent tree description. All quality codes seem appropriate.
All structural codes are appropriate (including diameter estimates where required in cruising notation).
All feature heights are within the same error margins allowed for total height measurement. (Quality code changes not included.)
No other errors/omissions (eg: stump height allowances, waste sections, etc).

2. Good tree description. Only fails one of the above points.

3. Average tree description. Fails any two of the above points.

4. Poor tree description. Fails any three of the above points.

5. Shocker. Fails all of the above points.

Only trees which score 1 or 2 will be considered to be within acceptable limits.

5.4 Demerit Points.

All instances where a plot. general tree or tree description attribute falls outside the acceptable limits one demerit point will accrue for that plot. The only exception is where the Crew Tree Count is in error, in this case 6 demerit points *per tree* will be accrued.

A plot will be considered to have failed when it's total number of demerit points exceeds the maximum level accepted for a plot of the relevant tree count. Maximum demerit levels are prescribed in Table 4.

Table 4: Maximum demerit point table.

Tree Count (by audit)	Maximum demerit point total
<10 trees	10
11-20 trees	15
21-30 trees	18
>30 trees	25

5.5 Substandard Work.

In any case where substandard work is detected by the audit team courses of action will be set in motion. The first course of action is the change in audit sampling intensity described in Section 4.1 "Plot Level Sampling Intensity".
The second course of action will consist of:

- Advise the Division Co-ordinator of the problem.

- Discussion between the crew and their Field Supervisor (and the Quality Control Forester if appropriate). The substandard aspects of the crew's work should be raised in a positive manner and the crew given an opportunity to explain how the situation has arisen (after all, it may simply be a matter of misunderstanding or misinterpreting an instruction).

- If there is some dispute over the matter then the crew should be reminded of the aims of the inventory, the standards of work expected and the reasons why State Forests is insisting on such standards. Additional training and/or supervision (either from the Field Supervisor or the Quality Control Forester) should be arranged.

- Continued substandard work may necessitate a "re-shuffling" of crew members.

In cases where a plot has not "failed" but there are aspects of measurement which are below the specified standards these details will be presented to the Field Supervisor in the standard Detailed Report (see Section 2.1 "Reporting") for them to act on if they choose. The Quality Control Forester will be available to advise Field Supervisors in regard to action taken in response to substandard work.

6.0 System Development.

At this stage there is still quite a lot of system development work to do.

Northern Region CSO Steve Wright has indicated that he will be able to provide up to two day's assistance in database development. If further resources are required for systems development the Quality Control Forester will make arrangements with the Project Manager.

It is anticipated that the final audit database will be able to generate general reports by Inventory Crew, Inventory ID, Audit Crew, etc.

Other features should include a function to facilitate the production of Summary reports indicating results by attribute (eg: average diameter difference) for demerit points, or Detailed reports including tree level raw data and actual differences as well as processed demerit points and totals for all attributes.

Progress reports to the Project Manager will be made periodically.

Strategic Inventory Audit Report
(UNE and LNE)

State Forests of NSW
1998

Summary

The objectives of the audit process were:

1. In the native forest inventory, to provide a quantitative measure of the accuracy of data collected by field crews and to ensure that data was of a satisfactory standard.
2. In the hardwood plantation inventory, to ensure compliance with “standard of measurement” conditions of the contract between State Forests and the contractor.

To achieve these aims, a subsample of plots was measured in each type, native forest and plantation.

In native forest, 3 plots out of 249 audited plots (1.2%) failed audit. In plantation, no plots failed audit. These results are considered to be highly satisfactory, and indicate that field measurement practice was of a high standard.

1. Introduction

This reports presents the audit results for the FRAMES Strategic plot location and measurement in State Forests in the Upper North-East and Lower North-East regions.

The Strategic Inventory Audit Team had two main tasks:

1. In the native forest inventory, to provide a quantitative measure of the accuracy of data collected by field crews and to ensure that data was of a satisfactory standard[1].
2. In the hardwood plantation inventory, to ensure compliance with "standard of measurement" conditions of the contract between State Forests and the contractor.[2]

2. Methods

Data audited by the Strategic Inventory Audit Team was collected using methods described in the Strategic Inventory Field Manual[3]. Training of each crew by the Audit Team attempted to ensure continuity and consistency between crews.

The Strategic Inventory Auditing Methodology document approved by the Technical Committee served as the basis of the auditing process.

A Microsoft Access database was created to enter, store and report on Strategic Inventory audit data.

2.1. Determination of sampling intensities and allowable ranges

The final structure for plot level sampling intensity was:

- Standard sampling intensity of 5% of plots measured unless a plot was deemed to have failed the auditing process, in which case a higher sampling intensity, was applied for a minimum of 4 weeks to ensure future compliance was achieved.
- The tree level sampling intensity as stated in the Strategic Inventory Auditing Methodology aimed at producing an average of 10-20% sample of trees from within the plot.

3. Audit Results

3.1. Native Forests

3.1.1. Overview of plots audited per crew

The number of plots audited was 249 or 13% of plots measured. The number of trees audited was 3351. Only 3 plots failed audit.

[1] Refer to "Strategic Inventory Project Auditing Methodology", SFNSW 1997. Unpublished.
[2] Refer to "Agreement, specifications and general conditions for MARVL inventory of areas on State Forests", 1997. Contract between SFNSW and Forest Data. Unpublished.
[3] Refer to "Strategic Inventory Field Manual", SFNSW 1997. Unpublished.

Table 1: Number of plots measured and audited for native forest crews.

Crew	Number of plots measured	Number of plots audited	Audit sample %
1	143	20	14
2	68	18	29
3	175	15	9
4	121	14	12
5	129	18	16
6	71	7	10
7	117	26	20
8	144	23	15
9	105	18	18
10	187	21	7
11	133	13	9
12	161	13	7
13/14	165	17	10
15	112	17	12
16/20	80	9	9
Total	1911	249	13

*Crews 13 & 14 are the same crew with a different crew identifier when they moved from the Styx River MA to Walcha MA.

The auditing process was done as a progressive process, to monitor the performance of crews, rather than a final audit at the end of the process. As such, the audit percentage for plots checked was higher then the minimum audit level set out in the specifications.

3.1.2. Tree count data per plot

The tree count data for all crews, was found to come from a population with a normal distribution. In Table 2 the Chi-square test show there is no significant difference between the audit and crew values. The significance level (α) of the test is 0.05, or 5%.

Table 2: Chi-square analysis of tree count data .

Crew	Number of plots audited	Number of plots different	Chi-square of tree count	P
1	20	6	.1229	1
2	18	3	.2038	1
3	15	4	.4071	1
4	14	4	.2451	1
5	18	2	.1270	1
6	7	2	.2549	1
7	26	9	.4704	1
8	23	8	.1897	1
9	18	10	.9351	1
10	21	5	.2772	1
11	13	5	.1428	1
12	13	1	.0345	1
13/14	17	2	.2918	1
15	17	1	.0938	1
16-20	9	3	.0586	1
Total	249	65	3.8548	1

3.1.3. Diameter and height data

The main focus of diameter and height data analysis is differences between measurements made by the crews and the measurements made by the audit team. The differences between crew and audit diameter and height values were analysed for average difference and standard deviation of differences. The results are shown in Table 3.

Table 3: Analysis of diameter (DBHOB) and height (total height) measurements for all Native Forest Crews.

	Diameter difference		Height difference	
CREW	(mm) #	Std Dev (mm)	(m) #	Std Dev (m)
1	0.8	17.7	0	2.4
2	1.3	3.5	-0.7	2.1
3	1.4	9.8	0.0	2.1
4	-1.6	3.4	-0.3	2.2
5	-2.3	8.0	-0.4	2.1
6	-2.3	13.3	0.7	1.5
7	-0.2	3.5	-0.1	1.6
8	-0.9	8.6	0.0	1.5
9	1.2	20.2	-0.4	2.5
10	-2.0	30.9	0.4	2.6
11	-0.8	5.9	-0.6	1.8
12	-0.1	1.6	-0.2	1.5
13/14	-0.8	4.1	-0.3	1.3
15	1.1	15.7	0.2	2.2
16-20	-0.3	11.5	0.0	1.4
All	-0.4	13.9	-0.2	2.0

A negative value means that the audit value was greater than the crew value.

The descriptive statistics in Table 3 give an indication of the average difference in measurements. Table 4 shows the results of goodness of fit test, and the significance of differences between audit and crew measurements. Table 4 summarises the data into crews, which was useful for crew monitoring. However as no single crew measured all the plots in stratum, the combined result for all data is the most significant result.

Table 4. KS -goodness of fit analysis of height and diameter data.
α = 0.05 (95% confidence limit), degrees of freedom = (n-1).

	Height			Diameter		
Crew	Chi-square statistic	Observations (n)	alpha	Chi-square statistic	Observations (n)	alpha
1	16.1	89	1	132.0	175	0.99
2	15.3	92	1	9.8	150	1
3	14.1	75	1	49.7	119	1
4	8.1	50	1	3.3	80	1
5	15.9	90	1	33.3	153	1
6	4.2	29	1	60.3	58	0.35
7	12.3	127	1	8.4	230	1
8	10.7	115	1	66.3	206	1
9	19.1	87	1	151.6	146	0.34
10	12.2	105	1	249.8	183	.0006
10*				41.5	182	1
11	9.0	65	1	24.9	117	1
12	5.8	65	1	1.19	109	1
13/14	6.3	82	1	7.18	126	1
15	16.4	84	1	50.2	147	1
16-20	2.9	44	1	27.5	87	1
All	168.7	1199	1	875.5	2086	1

From Table 4 we can see that there is no difference between the crew and audit diameter measurements at the 5% significance level for all the height and diameter data collected. For individual crews it is noted that a recording error by crew 10 (where 1168 was recorded as 768), a significant difference in the chi-square statistic occurred. When this tree was removed in 10*, no significant difference then existed.

3.1.4. Ordinal data

These variables are subjectively-determined ordinal variables. Assessment of significant difference between the audit and crew measurement was conducted using a Kappa test (Cohen, 1960; Hudson and Ramm, 1987).

Crown Condition.

Crew coding	Audit coding			Total	% the same	Kappa	Variance	Z statistic
	1	2	3					
1	134	179	6	319	42			
2	63	794	224	1081	73			
3	2	164	558	724	77			
Total				2124	70	0.58	.00005	85.9

Over 70% of the classification by the two crews were the same. There is also no significant difference between the two assessments.

Dominance

Dominance was assessed into 4 classes. For the purposes of later model implementation, Classes 1 and 2 (Dominant and codominant) were amalgamated.

Crew coding	Audit coding			Total	% the same	Kappa	Variance	Z statistic
	1&2	3	4					
1&2	481	1	0	619	78			
3	78	743	178	999	74			
4	3	164	340	507	67			
Total				2129	73	0.69	.00005	31.2

Before dominant and codominant were combined, 70% of codes were the same. After amalgamation 73% were the same. There is no significant difference between audit and crew measurements.

Logging Impediment

Crew coding	Audit coding			Total	% the same	Kappa	Variance	Z statistic
	1	2	3					
1	1760	1	6	1767	99			
2	0	78	9	87	90			
3	11	10	248	269	92			
Total				2123	98	0.94	.00005	140.6

The agreement on logging impediment was 98%. There is no significant difference between crew and audit results

3.1.5. Tree description scores

Tree description data is a series of height-cumulative wood quality codes. Meaningful interpretation of the Strategic Inventory Dictionary requires an extensive knowledge of wood quality attributes of native forest tree species. A State Forests Marketing Foreman was generally included in each field crew.

Audit analysis of the tree descriptions is confined to determining the proportions of tree descriptions which scored 3, 4 or 5 differences. Table 6 summarises the proportion tree descriptions with greater than 3 differences for each crew.

Table 6: Frequency of tree descriptions that score >=3..

Crew	Total number of Tree Descriptions	Number of 3,4,5 Tree Descriptions	% of 3,4,5 Descriptions
1	171	7	4.0
2	150	13	8.7
3	119	9	7.6
4	80	2	2.5
5	153	5	3.3
6	58	1	1.7
7	230	9	3.9
8	206	14	6.8
9	146	17	11.6
10	183	3	1.6
11	117	8	6.8
12	109	1	0.9
13/14	126	1	0.8
15	147	8	5.4
16-20	87	1	1.0
All	2082	99	4.7

Only 4.7% of all trees described have significant differences in total tree code between the audit crew and the original measurers. The impact of the differences in stem description is more substantial in the upper portion of the tree. The coding in these sections is generally less important than the classification of the tree in the lower bole section.

3.2. Hardwood plantation

3.2.1. Overview of plots audited

A total of 979 plots were installed by the contractor. 50 plots were audited, giving an audit sampling intensity of 5%. No plots failed the auditing process, with the average demerit points for plots was 36% of the maximum allowable demerit points, before a plot is failed.

3.2.2. Tree count data per plot

A Chi-square analysis at 95% confidence, of the tree count data from 50 audited plots showed no significant difference.

3.2.3. Diameter and height data

The differences between crew and audit diameter and height values (Table 7) were analysed for average difference, standard deviation of differences and average difference as a percentage of the audit value.

Table 7: Analysis of diameter (DBHOB) and height (total height) measurements for the Hardwood Plantation Strategic Inventory.

Diameter Difference #		
(mm)	Standard Deviation (mm)	(% of Audit)
0.1	8.9	0
Height Difference #		
(m)	Standard Deviation (m)	(% of Audit)
-0.3	0.9	1

a negative difference means that the audit value was greater than the crew value.

Table 8 contains the results of a Chi-square test for significant differences between crew and audit values for diameter and height. (∝ = 0.05,).

	Diameter	Height
Observations (n)	290	243
Chi-square statistic	116.110	7.704
Critical Chi-square	329.649	279.288
Probability	P < 0.001	P < 0.001

3.2.4. Ordinal data

The Kolmogorov-Smirnov test for goodness of fit for ordinal data is used to determine if there is a significant difference between the crew and audit Crown Condition and Dominance scores (Table 9) .

Table 9: Kolmogorov-Smirnov test for goodness of fit for crew and audit Crown Condition and Dominance scores.

	Crown Condition	Dominance
Observations (n)	290	290
D-statistic	0.082	0.048
Critical D-statistic	0.071	0.071
Probability	*0.02>P(D=0.082)>0.01*	0.5>P(D=0.048)>0.2

The crew and audit Crown Condition scores are significantly different, while no significant difference is present for Dominance. Analysis of the distribution of demerit points over time indicate that the frequency of demerit points declines over time.

3.2.5. Tree description scores

The method for assessing the quality of a tree description is defined in Annexure B of the contract. It does not specify a threshold for a failed tree description, rather it specifies how demerit points may be accumulated for a tree description and then those demerit points contribute to the total demerit points for the plot. 74% of descriptions scored no demerit points and only 2% of descriptions scored more than 1 point. The overall demerit point average for all 290 trees audited of 0.2 points indicates which indicates that the tree descriptions are satisfactory.

4. References

Cohen, J. (1960). A coefficient of agreement for nominal scales. Education and Psychological Measurement **20**:1 37-46.

Hudson, Willian H., and Carl W. Ramm. (1987). Correct formulation of the kappa coefficient of agreement. Photogrammetric Engineering and Remote Sensing **53**:4 421-422.