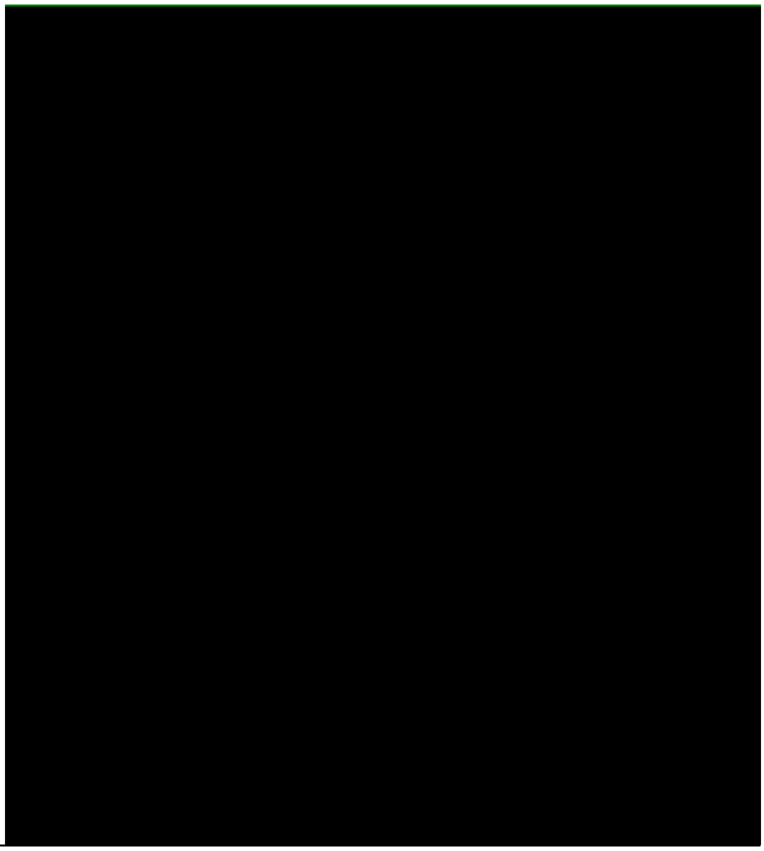
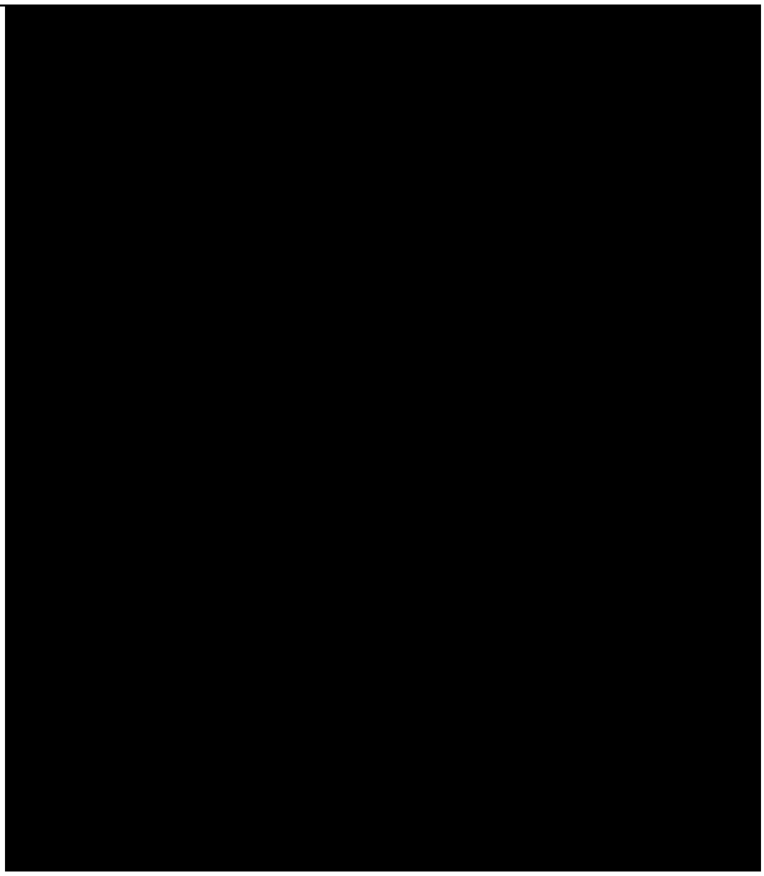


Strategic Inventory – Southern Region

A project undertaken as part of the NSW Comprehensive Regional Assessments
December 2000



STRATEGIC INVENTORY REPORT

SOUTHERN REGION

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

The project has been overseen and the methodology has been developed through the Forest Resource and Management Evaluation System (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 stratum 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 Southern CRA Regions. 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. 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

Target accuracy (PLE of +30% at 95% confidence level) for total volume in the South Coast Sub Region has been met in 13 out of the 20 strata, or 87% of total standing volume. The relationship between probable limit of error (PLE) and the number of sample points shows that target accuracy can be met by measuring 15 - 20 plots. However none of the strata meet the target accuracy for the estimation of high value products. 3 of the strata, representing 41% of the total standing high value volume is within +40% PLE.

The relationship between PLE and number of points shows that something in excess of 80 sample points would be required in each stratum to achieve the target accuracy. The reasons for this disparity are unknown at this stage

In the Tumut Sub Region target accuracy for total volume has been met in 4 out of 5 strata, whilst target accuracy for high value products was met in only 2 out of the 5 strata. There are too few points to be certain, but it appears that target accuracy for high value products can be met with a sample of around 30 points.

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

1. INTRODUCTION

The purpose of this report is to document the procedures used in the strategic inventory of all native forests within that region of NSW defined for the Southern Comprehensive Regional Assessment (CRA), and to present results of the inventory in terms of the stated objectives.

Inventory techniques used in the Southern CRA were fundamentally the same as those used for the strategic inventory component of the Upper North East (UNE) and Lower North East (LNE) CRAs. An overview of these techniques will be presented which should enable readers who are unfamiliar with the UNE and LNE inventories to understand the data presented. Procedures and techniques used in UNE and LNE are described in full in RACD (1999). Procedures and techniques used in the Southern CRA are described in detail in separate reports, all of which are appended to this report. The individual reports are:

- Strategic Inventory Southern CRA - Field Manual (Appendix A)
- MARVL system analysis (Appendix B)

2. INVENTORY PROCEDURES

2.1 OBJECTIVES OF THE INVENTORY

The objectives of the strategic inventory, as stated in the approved 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; and
4. to provide a spatial linkages for forest attribute and inventory data.

The accuracy target for the strategic inventory is specified as follows. 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 reasonably 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 be redesigned to somehow account for, and measure, within-compartment variation. Given the large number of compartments in the CRA area, 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

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

- Threatened Species Licence (NPWS) conditions such as
  - riparian buffers
  - rainforest, wetlands, heath, rocky outcrops
  - rare and non-commercial forest types
  - species specific habitat exclusions

- Pollution Control Licence (EPA) conditions such as
  - Stream filter strips
  - Hazard class 4 areas

- Forest management exclusions (SFNSW)
  - Forest Management Intent (FMI) exclusion categories
  - Non commercial forest types
  - Non forest
  - Areas of >30deg slope

The sample population so described uses an overestimate of the actual net area as the unmapped exclusions are included in the sample population. The estimate of the true net harvestable area used in yield calculations is a product in the Net Harvest Area Query Database. This estimate was neither available at the time nor applicable to the inventory net area.

Reference: For more detail please refer to the CRA report - 'NA57/ESFM - Application of the Protective Measures and Forest Practices into a Quantitative Database'.

2.3 DATA TO BE COLLECTED

The variables measured at each plot 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)

2.4 METHODS OF MEASUREMENT

Plot measurement methods are described in the "Strategic Inventory Southern CRA - Field Manual" (refer Appendix A).

A brief summary of the measurement procedure for each plot is as follows. Sample point locations were selected as described in Section 2.5.2; transect bearings and distances were calculated from identifiable take-off points to each sample point. A hip chain and compass, or a GPS unit, was used to locate each point. A 0.1ha plot (which has a horizontal radius of 17.84m) 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. The same size plot was used for all strata so that restratification could be easily accomplished.

All trees with an overbark diameter at breast height (DBHOB) equal to or greater than 10.0cm, were measured in the inventory. The State Forest standard for breast height is 1.3m; this point was marked on each tree. The variables listed in Section 2.3 were recorded for each tree. Measurement of these variables is described in "Strategic Inventory Southern CRA - Field Manual" (Appendix A). 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.

2.5 SELECTION OF THE SAMPLE

2.5.1 Stratification

Sampling in the Southern CRA was a stratified design. Strata were based on matrices of structure class by yield association group. Separate yield associations were defined for South Coast and Tumut Sub Regions. Yield associations for both Sub Regions are shown in Table 1. Structure codes for South Coast were derived from the interaction of yield association and CRAFTI structure code; the derivation of structure classes is shown in Table 2. Strata for South Coast and Tumut are shown in Table 3.

TABLE 1. SOUTH COAST AND TUMUT SUB REGION YIELD ASSOCIATIONS

Region	Yield association code	Description
South Coast	1	Blackbutt
	2	Sydney Blue Gum
	3	Spotted Gum
	4	Silvertop Ash
	5	Stringybark
	6	Coast Grey Box/Forest Red Gum/Woollybutt
	7	Apples
	8	Alpine Ash
	9	Brown Barrel/Messmate
	10	Gum
	11	Peppermint/Scribbly Gum
	12	Western Box
	13	Snow Gum
	14	Rainforest
	15	Cypress Pine
	16	Non Eucalypt Forest
	17	Non Forest
Tumut		Alpine ash
		Hardwoods
		All non-merchantable types

TABLE 2. SOUTH COAST SUB REGION YIELD ASSOCIATION/STRUCTURE CODE MATRIX

Yield association	Valid CRAFTI structure codes	Stratum
9	SA??2/3/4; TA???	1
1, 2	SA???; SC???; TA???; TB??4	2
3	SC1M3/4; SC1P?; SCNN3/4; TA???; TB??4	3
4	SA??2/3/4; SB???; SC1J?; SC1M?; SCNN1/2/3; TB??4	4
5, 6	SA1M3/4; SA1P3/4; SANN3/4; SB1M4; SB1P2/3/4; SBNN4; TB??1/2/3	5
9	SB1J4; SB1M3/4; SB1P3/4; SBNN3/4; SC1M3/4; SC1P3/4; TB???; TC??4	6
10	SA??4; SC1J3/4; SC1M2/3/4; SC1M2/3/4; SCNN2/3/4; TA???; TC???	7
1, 2	SB???; TB?N1/2/3; TC???	8
3	SA1?2/3/4; SB1J3/4; SB1M?; SB1P?; SBNN?; SC1J2/3/4; TB??1/2/3; TC??3/4	9
4	SC1P?; SCNN4; TA???; TB??1/2; TC???	10
5, 6	SAIJ2/3/4; SA1M2; SA1P2; SANN2; SB1J2/3/4; SB1M2/3; SBNN2/3; SC???; TA???; TB??4; TC???	11
9	SB1J1/2/3; SB1M1/2; SB1P1/2; SBNN2; SC1J?; SC1M1/2; SC1P1/2; SCNN?; TC??1/2/3	12
10	SA??2/3; SB???; SC1J1/2; SC1M1; SC1P1; SCNN1; TB???	13
1, 2	D????; F????; G????	14
3	D????; E????; F????; G????; SB1J1/2; SC1M1/2; TC??1/2	15
4	D????; E????; F????; G????	16
5, 6	D????; E????; F????; G????	17
9	D????; E????; F????; G????	19
10	D????; E????; F????; G????	19
7, 11	All, **except** SA1J1; SA1M1; SA1P1; SB1J4; SB1M1	20

TABLE 3. SOUTH COAST AND TUMUT SUB REGION INVENTORY STRATA

Region	Stratum code	Yield association code	Structure class
South Coast	1	9	Late Mature
	2	1, 2	Mixed Age Mature
	3	3	Mixed Age Mature
	4	4	Mixed Age Mature
	5	5, 6	Mixed Age Mature
	6	9	Mixed Age Mature
	7	10	Mixed Age Mature
	8	1, 2	Mixed Age Young
	9	3	Mixed Age Young
	10	4	Mixed Age Young
	11	5, 6	Mixed Age Young
	12	9	Mixed Age Young
	13	10	Mixed Age Young
	14	1, 2	Regrowth Dominant
	15	3	Regrowth Dominant
	16	4	Regrowth Dominant
	17	5, 6	Regrowth Dominant
	18	9	Regrowth Dominant
	19	10	Regrowth Dominant
	20	7, 11	Regrowth Dominant
Tumut	1	Alpine ash	Mixed Age Young (Bago)
	2	Alpine ash	Mixed Age Mature (Maragle)
	3	Hardwoods	Mixed Age Mature(Bago/Maragle)
	4	Hardwoods	Mixed Age Young (Tumut)
	5	Hardwoods	Mixed Age Mature (Tumut)

2.5.2 Plot selection

Initial plot allocation was by stratum and proportional to net area. Supplementary allocation of plots per stratum was done to bring strata of smaller area up to a minimum of plots necessary to achieve desired precision.

Plots were selected randomly, according to the ratios described above, from the set of possible plot points derived by the intersection of the net area and a 1.5 km arbitrarily generated grid across the region.

2.6 FIELD WORK

Plot measurement was conducted in accordance with the guidelines set in the "Strategic Inventory Southern CRA - Field Manual" (Appendix A). Each inventory crew had at least 1 member experienced in marketing to assist with tree classification. All crews received training prior to commencement and were regularly monitored by supervisory staff.

2.7 DATA AUDIT

The audit team checked a percentage of all plots established by each measuring crew. The main objective of the audit process was to provide a quantitative measure of the accuracy of data collected by field crews and to ensure that data was of a satisfactory standard.

2.8 DATA INPUT

Data collected using the methods described above were entered into the computer using the software package MARVLDE3. MARVLDE3 was used for both “traditional” data entry, where plot data are recorded onto a paper plot sheet and later entered into a computer in the office, and for field data entry, where data are entered directly into a portable computer. 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 4. 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 4. MARVLDE3 RANGE SETTINGS

RangeChecks				
Diam Range	60	100	1500	4000
Height Range	0	0	50	70
Age Range	2	10	50	100
Plot Area Range	0.01	0.02	0.1	1
BAF Range	1	2	4	25
Slope Range	-40	-30	30	40
Tally Range	0	2	25	50
Length Range	1	5	60	200
Stratum Area Range	0.01	0.02	10000	99999
Plots In Group	0	5	1000	0
Group PLEBA	0	0	30	100
Group PLESPH	0	0	30	100
Diam Tolerance	1.05			
Height Tolerance	0.5	1.5		

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.

2.9 DATA PROCESSING

2.9.1 The MARVL method

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,
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 Cutting strategy

A "cutting strategy" is a list of rules used for the conversion of quality codes into products. Cutting strategies used for the conversion of quality codes to products for each sub region are shown in Tables 5 (South Coast) and 6 (Tumut).

TABLE 5. SOUTH COAST SUB REGION CUTTING STRATEGY

Product	Acceptable qualities	Minimum SED	Maximum SED	Maximum LED	Minimum length	Maximum length	Acceptable species
Large high value1	AE	380	1000	2999	3.6	15.4	ASB,BAN,BBG,BBT,BSB,CBX, FAS,FRG,GBX,GIB,GPM,GYG, IBK,MAG,MDG,MKG,MMT,NPM,RBW,RIB,RMY,RPM,RSB,SBG,SHG,SPG,SPM,STA,TRP, WBT,WHA,WSB,YER,YSB
Large high value2	AE	375	1000	2999	5.0	15.4	(as above)
Large high value3	AE	365	1000	2999	7.0	15.4	(as above)
Large high value4	AE	355	1000	2999	9.0	15.4	(as above)
Large high value5	AE	345	1000	2999	11.0	15.4	(as above)
Small high value	AE	250	380	500	3.6	15.4	ASB,BAN,BBG,BBT,BSB,CBX, FAS,FRG,GBX,GIB,GPM,GYG, IBK,MAG,MDG,MKG,MMT,NPM,OCE,RBW,RIB,RMY,RPM,RSB,SBG,SHG,SPG,SPM,STA,TRP,WBT,WHA,WSB,YER,YSB
Low value	BAE	300	1000	2999	2.4	15.4	ABX,ASB,BAN,BBG,BBT,BPM, BSB,CBX,FAS,FRG,GBX,GIB, GPM,GYG,IBK,MAG,MDG,MKG,MMT,MTG,NPM,OCE,PPM,RAP,RBW,RIB,RMY,RPM,RSB,SAP,SBG,SHG,SPG,SPM,STA,TBX,TRP,WBT,WHA,WSB,YER, YSB
Pulp	PBAE	100	1000	2999	3.0	15.4	ABX,ASB,BBG,BBT,BPM,BSA, BSB,CBX,FAS,GPM,MAG,MDG,MKG,MMG,MMT,MTG,NPM, PPM,RPM,RSB,SHG,SNG,SPG,SPM,STA,WHA,WSB,YER,YSB

TABLE 6. TUMUT SUB REGION CUTTING STRATEGY

Product	Acceptable qualities	Minimum SED	Maximum SED	Maximum LED	Minimum length	Maximum length	Acceptable species
Large high value1	AE	380	1000	2999	3.6	15.4	ALA,BPM,EUR,FAS,MAG,MMT,MTG,NPM
Large high value2	AE	375	1000	2999	5.0	15.4	(as above)
Large high value3	AE	365	1000	2999	7.0	15.4	(as above)
Large high value4	AE	355	1000	2999	9.0	15.4	(as above)
Large high value5	AE	345	1000	2999	11.0	15.4	(as above)
Small high value	AE	250	380	500	3.6	15.4	(as above)
Low value	BAE	250	700	2999	3.6	15.4	(as above)
Pulp	PBAE	100	700	2999	3.6	15.4	ALA,BPM,EUR,FAS,MAG,MMT,MTG,NPM,RSB,SBK,SNG

2.9.3 Taper and volume functions

Individual taper and volume functions were used for this analysis are listed in Table 7. Forms listed as "Muhairwe" are described in Muhairwe (1995; 1999); forms listed as "Bi" have been described in a single document by Carter (1998); forms listed a "Gordon" were described by Gordon (1983)

TABLE 7. LIST OF TAPER FUNCTIONS USED IN MARVL

Species	Form of volume and taper function used
Alpine ash	Gordon
Blackbutt	Muhairwe
Blue gum	Bi
Brown barrel	Bi
Messmate	Bi
Silvertop ash	Gordon
Spotted gum	Bi
Yellow stringybark	Gordon
All other species	Muhairwe

2.9.4 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 were accumulated into a single MDI file.
- A program was written to convert this file 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 with MARVL in the usual way.

2.9.5 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

An audit was carried out on the measured plots in accordance with the strategic inventory audit methodology as used in UNE and LNE CRA regions. The audit involved the random selection of measured plots, random selection of trees within plots, remeasurement of plot and tree parameters by a crew independent of the inventory crews, enabling checks between the two measures.

Auditing was ongoing through the first inventory field measurement stage. It resulted in some minor adjustments to individual crew measurement/assessment, however all factors audited were within acceptable limits.

3.2 STRATUM STATISTICS

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

Results for this inventory, by stratum, are shown in Section 4, Tables 8 - 19. All volumes quoted in these tables are in m3/ha. The tables show statistics for:

8 South Coast Sub Region, total standing volume (all products)
9 South Coast Sub Region, total merchantable standing volume
10 South Coast Sub Region, total volume of large high value products
11 South Coast Sub Region, for total volume of all high value products
12 South Coast Sub Region, total volume of low value products
13 South Coast Sub Region, total volume of pulp
14 Tumut Sub Region, total standing volume (all products)
15 Tumut Sub Region, total merchantable standing volume
16 Tumut Sub Region, total volume of large high value products
17 Tumut Sub Region, total volume of all high value products
18 Tumut Sub Region, total volume of low value products
19 Tumut Sub Region, total volume of pulp

The project proposal specifies that total volume and the volume of all high value products are to be estimated to within 30% of the true value, at the 95% confidence level. Tables of relevance to these targets are 8 and 11 for South Coast Sub Region, and 14 and 17 for Tumut Sub Region.

Table 8 shows that target accuracy for total volume in the South Coast Sub Region has been met in 13 out of the 20 strata; the relationship between probable limit of error (PLE) and the number of sample points is shown in Figure 1, which shows that target accuracy can be met by measuring 15 - 20 plots. Note that the point for stratum 20, 2 sample points only, is not shown in this figure.

Table 11 shows that none of the strata meet the target accuracy for the estimation of high value products. The relationship between PLE and number of points shows that something in excess of 80 sample points would be required in each stratum to achieve the target accuracy.

Factors used for stratification in the South Coast Sub Region have failed to adequately account for variation in estimates of the volume of high value products in the sample population. Fundamental reasons for this are not immediately apparent; the problem could be addressed in a separate study in the future.

Table 14 shows that target accuracy has been met, in the Tumut Sub Region, in 4 out of 5 strata. The data is shown graphically in Figure 3; there are barely enough points on this graph to see a trend, but it seems fairly certain that target accuracy can be met when the number of sample points is greater than 24.

Table 17 shows that target accuracy for high value products was met in only 2 out of the 5 strata. Again, there are too few points on the graph (Figure 4) to be certain, but it appears that target accuracy for these products can be met with a sample of around 30 points.

FIGURE1. SOUTH COAST SUB REGION - RELATIONSHIP BETWEEN PLE AND NUMBER OF SAMPLE POINTS, HIGH VALUE VOLUME

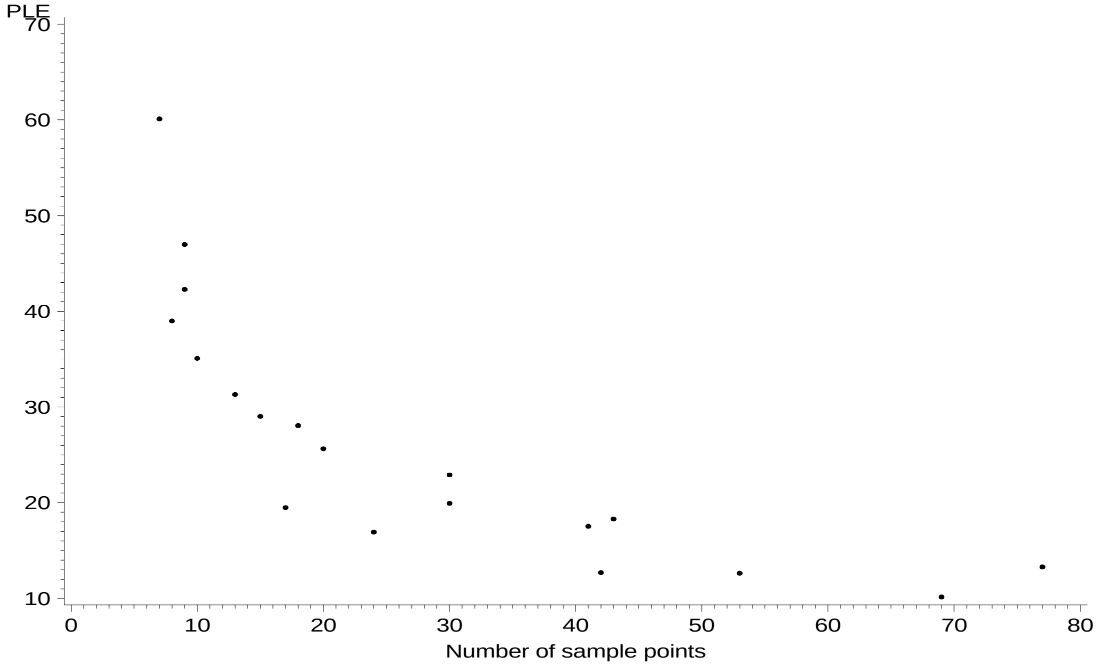


FIGURE 2. SOUTH COAST SUB REGION - RELATIONSHIP BETWEEN PLE AND NUMBER OF SAMPLE POINTS, HIGH VALUE VOLUME

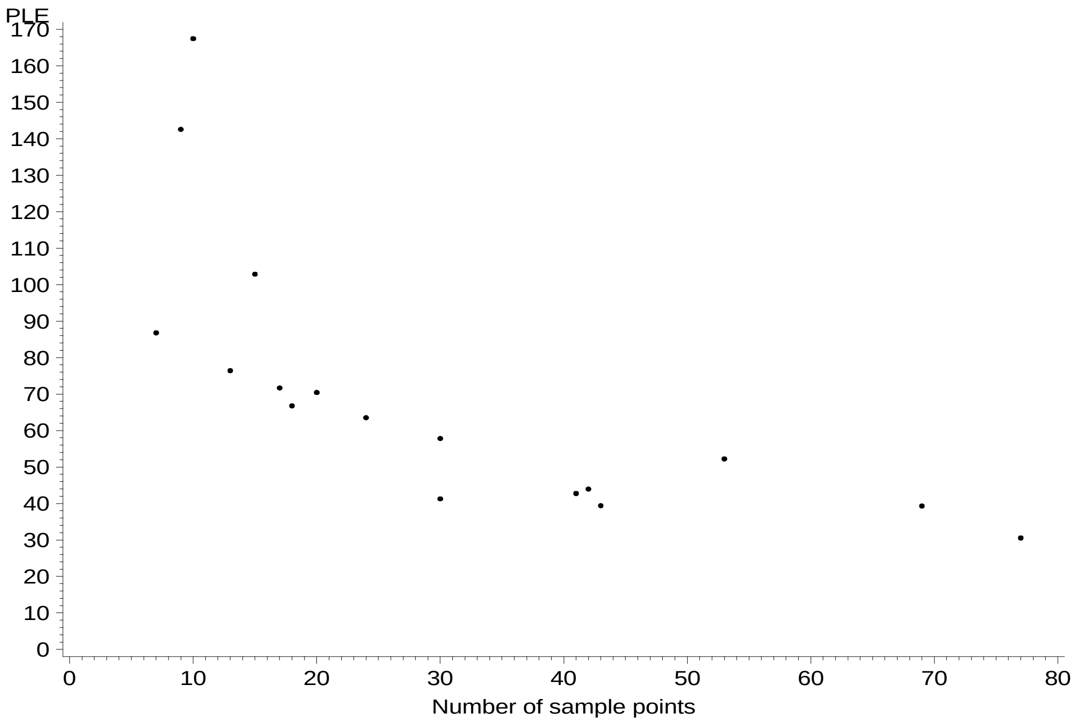


FIGURE 3. TUMUT SUB REGION - RELATIONSHIP BETWEEN PLE AND NUMBER OF SAMPLE POINTS, TOTAL VOLUME

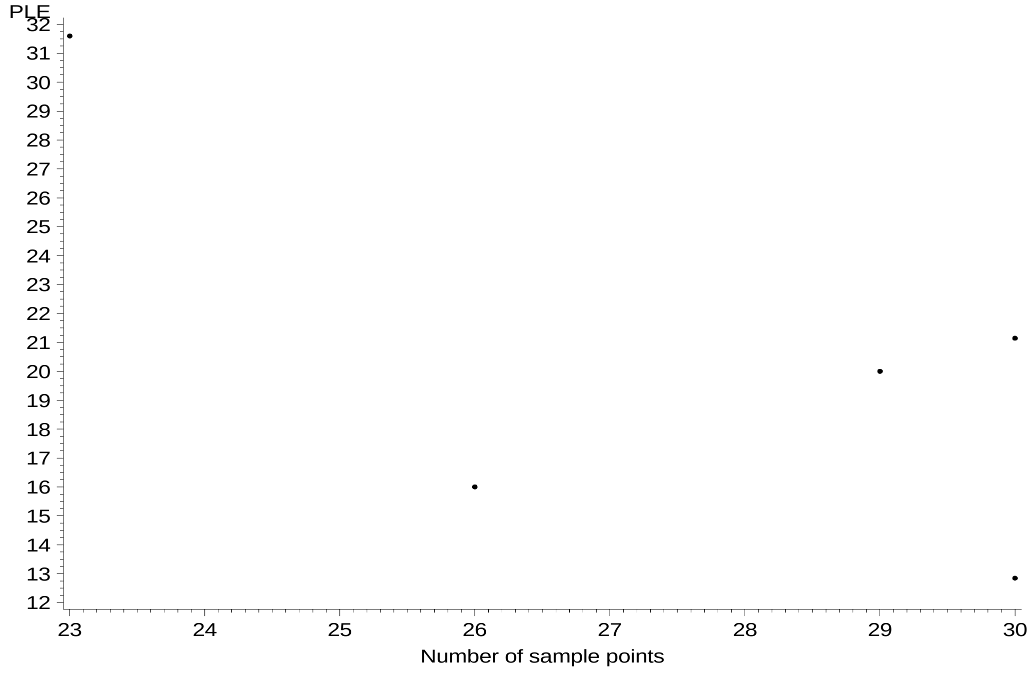
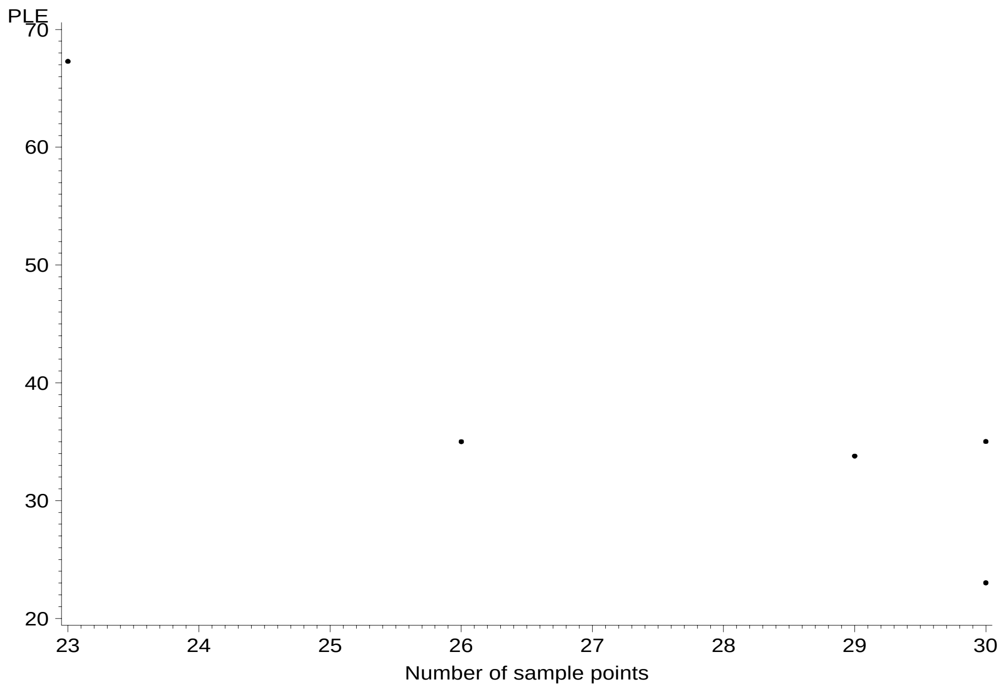


FIGURE 4. TUMUT SUB REGION - RELATIONSHIP BETWEEN PLE AND NUMBER OF SAMPLE POINTS, HIGH VALUE VOLUME



3.3 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.

3.4 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.

3.5 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
Mean	Arithmetic mean value for the parameter (m3/ha)
Max	Maximum observed value for the parameter (m3/ha)
Min	Minimum observed value for the parameter (m3/ha)
CI	Confidence interval (m3/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 8. SOUTH COAST SUB REGION - STATISTICS FOR TOTAL STANDING VOLUME (M^3/HA)

Stratum	N	MEAN	MAX	MIN	CI	PLE
1	18	320.3	652.7	38.3	89.9	28.1
2	9	399.9	773.1	107.0	187.9	47.0
3	30	284.0	697.1	58.4	65.1	22.9
4	41	282.8	701.6	69.6	49.6	17.5
5	15	251.3	544.1	109.2	72.9	29.0
6	53	355.6	900.4	82.3	44.9	12.6
7	30	232.9	574.9	37.1	46.4	19.9
8	13	302.2	627.4	91.2	94.6	31.3
9	77	239.9	903.9	42.9	31.9	13.3
10	17	189.4	351.8	80.2	36.9	19.5
11	69	220.7	641.3	83.3	22.4	10.1
12	10	238.5	464.5	77.9	83.7	35.1
13	42	250.1	507.8	70.1	31.7	12.7
14	8	178.2	285.0	73.1	69.5	39.0
15	43	214.5	652.3	38.4	39.2	18.3
16	24	237.5	447.0	75.6	40.2	16.9
17	20	181.8	428.1	62.4	46.6	25.6
18	9	338.9	702.9	111.4	143.3	42.3
19	7	201.5	436.7	66.1	121.1	60.1
20	2	138.5	165.2	111.7	339.9	245.5

TABLE 9. SOUTH COAST SUB REGION - STATISTICS FOR TOTAL MERCHANTABLE STANDING VOLUME (M^3/HA)

Stratum	N	MEAN	MAX	MIN	CI	PLE
1	18	241.9	642.6	0.0	86.7	35.8
2	9	211.4	446.0	37.3	121.5	57.5
3	30	198.6	444.1	27.3	41.8	21.1
4	41	192.9	490.6	32.0	39.7	20.6
5	15	175.1	407.6	49.7	61.8	35.3
6	53	294.4	900.4	51.3	46.4	15.8
7	30	153.4	469.1	3.4	42.3	27.6
8	13	202.1	427.6	43.5	76.3	37.8
9	77	183.9	684.1	0.0	27.3	14.9
10	17	140.8	272.1	30.7	37.9	26.9
11	69	132.6	543.1	0.0	19.3	14.5
12	10	204.9	459.0	34.3	93.7	45.8
13	42	179.4	488.0	28.3	31.9	17.8
14	8	82.9	165.7	11.3	43.8	52.8
15	43	168.9	646.9	24.3	39.7	23.5
16	24	154.3	266.6	4.3	34.8	22.5
17	20	94.1	270.5	13.7	29.8	31.7
18	9	232.2	674.0	49.8	139.7	60.2
19	7	162.9	421.9	20.3	130.6	80.2
20	2	31.5	48.2	14.7	212.8	676.7

TABLE 10. SOUTH COAST SUB REGION - STATISTICS FOR TOTAL VOLUME OF LARGE HIGH VALUE PRODUCTS (M^3/HA)

Stratum	N	MEAN	MAX	MIN	CI	PLE
1	18	25.7	95.0	0.0	17.8	69.2
2	9	20.9	113.5	0.0	30.2	144.3
3	30	24.7	112.0	0.0	11.2	45.5
4	41	12.0	83.6	0.0	6.2	51.7
5	15	6.9	54.2	0.0	8.3	119.4
6	53	32.3	439.0	0.0	18.3	56.8
7	30	8.3	63.1	0.0	6.4	77.5
8	13	25.0	105.2	0.0	22.1	88.3
9	77	25.1	184.5	0.0	9.0	35.9
10	17	2.8	15.0	0.0	2.5	87.0
11	69	9.9	93.5	0.0	4.7	47.8
12	10	23.2	203.4	0.0	45.7	197.6
13	42	9.6	85.9	0.0	6.3	65.1
14	8	0.7	5.8	0.0	1.7	236.5
15	43	14.8	114.3	0.0	7.5	51.0
16	24	6.0	38.3	0.0	4.5	74.3
17	20	1.0	12.8	0.0	1.5	149.4
18	9	2.4	21.3	0.0	5.5	230.6
19	7	11.7	34.9	0.0	13.0	110.6
20	2	0.0	0.0	0.0	.	.

TABLE 11. SOUTH COAST SUB REGION - STATISTICS FOR TOTAL VOLUME OF ALL HIGH VALUE PRODUCTS (M^3/HA)

Stratum	N	MEAN	MAX	MIN	CI	PLE
1	18	28.1	102.2	0.0	18.8	66.7
2	9	21.5	116.2	0.0	30.7	142.6
3	30	29.2	117.6	0.0	12.0	41.3
4	41	15.8	83.6	0.0	6.8	42.8
5	15	7.9	54.2	0.0	8.1	102.9
6	53	36.4	439.0	0.0	19.0	52.2
7	30	11.4	63.1	0.0	6.6	57.8
8	13	31.7	120.3	0.0	24.2	76.4
9	77	31.5	200.2	0.0	9.6	30.6
10	17	7.6	30.4	0.0	5.4	71.6
11	69	14.5	117.1	0.0	5.7	39.3
12	10	26.9	203.4	0.0	45.1	167.4
13	42	14.5	85.9	0.0	6.4	44.0
14	8	1.9	14.8	0.0	4.4	236.5
15	43	22.4	141.0	0.0	8.8	39.4
16	24	12.3	75.4	0.0	7.8	63.5
17	20	3.6	18.6	0.0	2.5	70.4
18	9	10.6	95.7	0.0	24.5	230.6
19	7	15.7	34.9	0.0	13.6	86.8
20	2	0.0	0.0	0.0	.	.

TABLE 12. SOUTH COAST SUB REGION - STATISTICS FOR TOTAL VOLUME OF LOW VALUE PRODUCTS (M^3/HA)

Stratum	N	MEAN	MAX	MIN	CI	PLE
1	18	36.3	194.6	0.0	24.0	66.1
2	9	50.0	139.2	0.0	34.1	68.2
3	30	27.0	95.6	0.0	9.2	34.2
4	41	26.5	112.9	0.0	8.9	33.6
5	15	37.3	140.4	0.0	20.3	54.4
6	53	28.6	132.5	0.0	7.7	27.0
7	30	14.7	55.7	0.0	5.8	39.2
8	13	37.2	95.9	0.0	20.2	54.3
9	77	25.7	118.1	0.0	6.1	23.6
10	17	14.7	41.1	0.0	6.0	41.2
11	69	18.0	164.8	0.0	5.5	30.8
12	10	20.8	69.8	0.0	14.5	69.6
13	42	29.1	115.8	0.0	9.2	31.6
14	8	13.4	34.0	0.0	11.2	83.6
15	43	25.3	169.1	0.0	9.7	38.2
16	24	10.7	49.0	0.0	5.8	54.0
17	20	11.4	67.1	0.0	8.1	70.9
18	9	16.3	41.8	0.0	13.3	81.5
19	7	15.6	58.1	0.0	18.9	120.9
20	2	5.7	7.9	3.5	28.0	490.4

TABLE 13. SOUTH COAST SUB REGION - STATISTICS FOR TOTAL VOLUME OF PULP (M^3/HA)

Stratum	N	MEAN	MAX	MIN	CI	PLE
1	18	90.4	220.2	0.0	32.8	36.3
2	9	47.4	145.6	0.0	37.0	78.1
3	30	71.7	182.7	9.2	18.4	25.7
4	41	79.5	256.9	6.5	18.3	23.0
5	15	68.5	253.3	6.4	36.5	53.3
6	53	127.3	350.8	14.9	20.4	16.0
7	30	62.5	217.2	2.4	19.6	31.3
8	13	62.0	129.3	0.0	24.7	39.8
9	77	60.4	264.9	0.0	9.1	15.0
10	17	61.1	131.9	17.0	19.8	32.5
11	69	50.8	201.7	0.0	8.2	16.1
12	10	90.2	223.5	6.6	43.1	47.8
13	42	66.9	218.3	0.0	13.9	20.8
14	8	45.0	105.0	0.0	31.9	70.9
15	43	67.5	219.1	6.6	14.1	20.9
16	24	80.3	165.8	2.9	18.1	22.5
17	20	44.3	126.2	4.8	15.2	34.2
18	9	127.4	391.8	29.6	82.2	64.5
19	7	69.2	134.6	4.6	45.9	66.3
20	2	14.6	26.1	3.1	146.1	1000.8

TABLE 14. TUMUT SUB REGION - STATISTICS FOR TOTAL STANDING VOLUME (M^3/HA)

Stratum	N	MEAN	MAX	MIN	CI	PLE
1	30	326.4	871.7	83.7	69.0	21.1
2	23	328.8	1249.0	115.1	103.9	31.6
3	29	343.0	921.1	96.3	68.6	20.0
4	30	408.2	765.4	158.8	52.4	12.8
5	26	350.1	682.7	126.9	56.0	16.0

TABLE 15. TUMUT SUB REGION - STATISTICS FOR TOTAL MERCHANTABLE STANDING VOLUME (M^3/HA)

Stratum	N	MEAN	MAX	MIN	CI	PLE
1	30	275.0	865.0	21.9	64.3	23.4
2	23	261.3	1200.4	36.1	100.4	38.4
3	29	202.4	425.5	63.4	41.4	20.4
4	30	284.7	505.0	93.7	42.1	14.8
5	26	215.8	461.9	43.8	53.7	24.9

TABLE 16. TUMUT SUB REGION - STATISTICS FOR TOTAL VOLUME OF LARGE HIGH VALUE PRODUCTS (M^3/HA)

Stratum	N	MEAN	MAX	MIN	CI	PLE
1	30	105.5	520.4	0.0	43.4	41.2
2	23	68.5	690.5	0.0	66.2	96.6
3	29	52.5	215.1	0.0	20.7	39.4
4	30	101.9	272.6	5.4	28.0	27.5
5	26	60.4	212.7	0.0	24.4	40.5

TABLE 17. TUMUT SUB REGION - STATISTICS FOR TOTAL VOLUME OF ALL HIGH VALUE PRODUCTS (M^3/HA)

Stratum	N	MEAN	MAX	MIN	CI	PLE
1	30	131.8	551.9	0.0	46.2	35.0
2	23	95.8	690.5	0.0	64.5	67.3
3	29	61.4	224.9	0.0	20.8	33.8
4	30	114.8	277.1	7.3	26.4	23.0
5	26	77.6	252.4	0.0	27.2	35.0

TABLE 18. TUMUT SUB REGION - STATISTICS FOR TOTAL VOLUME OF LOW VALUE PRODUCTS (M^3/HA)

Stratum	N	MEAN	MAX	MIN	CI	PLE
1	30	27.8	69.7	0.0	7.4	26.7
2	23	20.3	187.2	0.0	17.0	83.7
3	29	24.6	106.5	0.0	10.3	41.7
4	30	28.5	70.8	0.0	6.6	23.3
5	26	24.1	76.3	0.0	8.6	35.6

TABLE 19. TUMUT SUB REGION - STATISTICS FOR TOTAL VOLUME OF PULP (M^3/HA)

Stratum	N	MEAN	MAX	MIN	CI	PLE
1	30	40.6	160.4	0.0	11.7	28.8
2	23	69.3	181.2	4.0	20.6	29.7
3	29	56.9	239.5	4.2	20.1	35.3
4	30	42.1	123.1	0.0	11.5	27.3
5	26	31.6	79.9	2.3	8.2	25.9

5. REFERENCES

Cater, Phil (1998). *Taper and volume functions for MARVL*. State Forests of NSW, Internal report.

Gordon, A, (1983). "Comparison of compatible polynomial taper equations." New Zealand Journal of Forestry Science 13: 146-155.

Lawrence, M.E. (1986). The MARVL pre-harvest inventory procedure. Proceedings, "Harvesting whole trees with processing and log allocation in the forest to conventional and energy products" Conference, Rotorua, Forest Research Institute, Rotorua, New Zealand.

Muhairwe, Charles K. (1995). *Taper study for* Eucalyptus grandis. State Forests of NSW, Unpublished report.

Muhairwe, Charles K. (1999). "Taper equations for *Eucalyptus pilularis* and *E. grandis* for the north coast in New South Wales, Australia". Forest Ecology and Management 113: 251-269.

NZFRI (1995a). *Guide to using MARVL data capture 3*. New Zealand Forest Research Institute Limited, NZ FRI.

NZFRI (1995b). *Guide to using MARVL V3*. New Zealand Forest Research Institute Limited, NZ FRI Software Series.

SFNSW (1999). *Strategic Inventory. Upper North East and Lower North East CRA Regions*. A project undertaken for the Joint Commonwealth NSW Regional Forest Agreement Steering Committee as part of the NSW Comprehensive Regional Assessments. Project No. NA04/FRA.

Vanclay, Jerome K. (1994) "Modelling Forest Growth and Yield". CAB International, Wallingford, UK.

APPENDIX A - STRATEGIC INVENTORY SOUTHERN CRA - FIELD MANUAL

Strategic inventory - Southern CRA

Field manual

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.

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 supervisor.

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

Plot sheets (keep a good supply)

Booking board

Pencil & eraser (including spare leads)

Spare folders for storing finished plot sheets

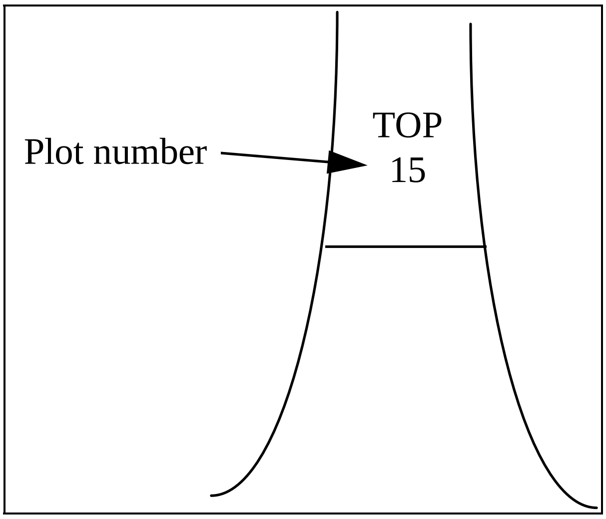
Set of field notes (you’re reading them now!)

Scientific calculator

3. LOCATING PLOT POINTS

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

Figure 1: Marking the TOP 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 (how to locate the TOP and the magnetic bearing and slope distance from the TOP to the plot point) must be recorded in the “comments” section of the plot sheet.

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 plot sheet. **THE PLOT SHOULD <u>NOT</u> BE MOVED FROM THIS SPOT UNLESS YOU ARE <u>SURE</u> 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 plots. The size of the plot will be shown on the plot location information given to you by your supervisor. The plot point mark on the ground is the centre of the plot and the horizontal radius of the plot is 17.84m for a 0.1ha hectare plot.

4.2 Marking the Plot Boundary

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

One person should hold the transponder 1.3m directly above the plot point while another person sweeps around the plot perimeter measuring the **horizontal** 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 1.3m when measuring distances. While most trees will be clearly in or out, any trees about which there is some doubt will need to be checked exactly using the slope correction method described below.

Once the boundary of the plot has been determined, **all** trees with a diameter at breast height (1.3m) of 100mm or more are to be recorded. No palms or ferns should be included.

All sample 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 1.3m was measured.

4.3 Slope Correction

When looked at from directly above, strategic inventory plots are circular in shape. Plots set out on sloping ground will not be circular, they will be more or less oval in shape, with the long axis running up and down the slope. The procedure for allowing for slope is done on an individual tree basis. In other words, trees about which there is some doubt as to whether they are sample trees or not must be checked to determine whether the horizontal distance is less than or greater than the plot specification.

For such 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 1.3m. To do this, one person should hold the end of the 30 or 50m tape 1.3m 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 1.3m. At all times the tape should be held tight, straight (no bending around trees, branches etc.) and parallel to the ground.

[§] For details on use of the Vertex see “Vertex Hypsometer User Notes” in Appendix 2.

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

Please take care when checking trees near the boundary because one tree in or out of a plot can make a difference of several hundred cubic metres.

4.4 Information to be recorded on the plot sheet

Pieces of information which needs to be recorded for each plot and each tree on the plot are listed in the Table 1, below. The column headed "MARVL variable" identifies default MARVL variables, the column headed "User defined variable" identifies those variables which we have defined for the purposes of this inventory. The following sections contain a description of what each variable means and how it is recorded.

Table 1. List of variables to be recorded

Level	MARVL variable	User defined variable
Inventory	Inventory name	
	Description (optional)	
Plot	Plot number	Aspect code
	Stratum	Filter strip distance
	Description (optional)	Site height
	Measure date	Easting
	Plot area	Northing
	Slope	Map zone
	Dictionary	Years since logging
Tree	Tree number	Crown condition
	Species code	Dominance
	DBHOB	Hollow status
	Quality, structure description	Logging impediment

4.4.1 Inventory level

Inventory name. In the "Inventory name" field of the plot sheet record the standard identifier for the plot you are measuring. This name will be provided to you with all the plot location information by your supervisor. The format of the Inventory name is a character string of maximum length 20 characters.

Inventory description. This field is optional. Format is a character string, maximum length 40.

4.4.2 Plot level

Plot number. Plot numbers in the strategic inventory are 4 or 5 digits numbers which consist of 2 parts. the first 1 or 2 digits are the standard Management Area (MA) code; the second 3 digits are a sequential plot number within the MA. Plot number is therefore guaranteed of being unique in NSW.

In the "Plot number" field of the plot sheet record the record the 4 or 5 three digit plot number shown on the plot location information page.

Stratum. In the "Stratum" field of the plot sheet 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 supervisor. The format of the Stratum ID is a 1 or 2 digit number.

Description. A 40 character description of the plot may be entered (optional).

Plot area. In the "Plot area" field of the plot sheet record the size of the plot, in hectares. Plot area is always 0.1ha.

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

Slope. In the "Slope" field of the plot sheet record the slope, to the nearest degree, of the plot you are measuring.

Dictionary. Record the quality code dictionary that you are using for this plot. This will normally not change for the entire inventory.

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

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

Filter strip distance. In the "Filter Strip Distance" field of the plot sheet 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, record 99.

Site height. In the "Site Height" field of the Plot Header record the Site Height of the plot you are measuring.

Easting Record the 6 digit easting in this field. This information will be provided by your supervisor

Northing. Record the 7 digit northing in this field. This information will be provided by your supervisor

Map zone. Record the 2 digit map zone in this field. This information will be provided by your supervisor

Years since logging. Record a 1 or 2 digit number, which is an estimate of the number of years since the plot was logged. If this estimate is greater than 10, record 99.

4.4.3 Tree level

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 sheet, 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.

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.

Note that the MARVL computer system only recognises the standard codes shown in Appendix 3. If you think you need a new code, contact Phil Carter.

DBHOB. In the "DBH" column record the diameter of the tree you are measuring in millimetres.

Quality, structure 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 Section 6.

Crown condition. In the column "Crown Condition" record the 1 digit Crown Condition code for the tree you are measuring.

Dominance. In the column "Dominance" record the 1 digit Dominance code for the tree you are measuring.

Hollow status. In the column "Hollow Status" record the 1 digit Hollow Status code for the tree you are measuring.

Logging impediment. In the column "Logging Imped" record the 1 digit Logging Impediment code for the tree you are measuring.

5. MEASURING AND ASSESSING PLOTS AND TREES

This section gives details, where necessary, of the measurement or assessment procedure for variables listed in the previous Section 4 (above). MARVL tree description is outlined in the Section 6

5.1 Plot data

5.1.1 Plot slope

The slope of the plot is measured by standing at the plot point and measuring the slope 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.

Remember, when taking slope readings with the clino you should "shoot" to something at he same height as your eye level, **not** to the ground level.

5.1.2. Site height

What we mean by "site height" is the maximum height that the tallest trees could possibly reach in the area within and surrounding the plot.

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 site height.

5.2. Tree data

5.2.1. DBHOB

DBHOB (diameter at breast height over bark) is measured according to a standard set of rules. 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 <u>uphill side</u> of the tree. Where the tree is on a lean, 1.3m is measured on the <u>underside</u> 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 <u>averaged</u> 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, the most convenient method is to use a 1.3m stick.

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

The measuring tape should be placed around the tree 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.

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

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 more different trees.

5.2.2. Tree height

Five trees per plot of commercial species are to be measured for total height. These heights will normally be obtained as part of the MARVL tree description. The procedure described in this section is to be followed in obtaining these heights.

The height information from measured trees is used to predict the heights of trees which are not measured for height. The five trees selected for measurement should cover the DBHOB size of the plot and preferably be fairly evenly distributed throughout the size range. All height trees must be “normal” in terms of 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 range, then the five trees should span that range.

The Forestor “Vertex” hypsometer is the preferred instrument for height measurement. Details of the use of the Vertex can be found in the manual; a brief outline is provided here.

The Vertex should be calibrated before use. See Vertex User notes in Appendix 2 for more details.

The procedure for measuring tree height is described below.

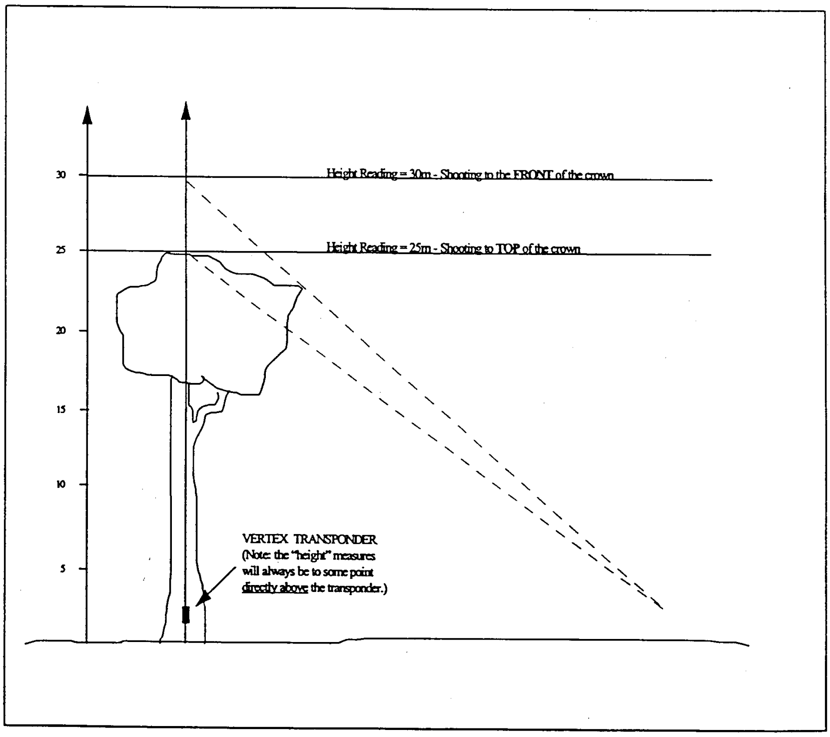
Turn the transponder on and place it at the middle of the side of the tree at 1.3m. The person with the hypsometer should place themselves about as far away from the tree as the tree is tall and in a position where they can see both the transponder and the top of the tree.

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.

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.)

5.2.3. Quality, structure description

Tree description in terms of MARVL structural and quality codes is outlined in the Section 6.

5.2.4. Crown condition

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

1	Good crown
2	Fair crown
3	Poor crown.

Definitions of these classes are:

Good crown
Well-shaped, vigorous crown; obviously expanding, mainly primary crown; few, if any, dead branches and no mistletoe.

Fair crown
Crown neither well-shaped nor vigorous, nor could it be called deformed or badly balanced. Mainly primary crown, not vigorous in appearance, but with crown expansion taking place. Some dead branches, or branchlets, and a minor incidence of mistletoe mat be accepted.

Poor crown
A deformed or unbalanced crown; low crown density and not vigorous; not expanding and apparently incapable of expansion. Mainly secondary crown; dead branches common; mistletoe mat be present.

5.2.5. Dominance

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

1	dominant
2	codominant
3	subdominant
4	suppressed

Definitions of these classes are:

Dominant
Tree with a crown extending above the general canopy, receiving full light from above and partly from the sides; a larger than average tree in the stand.

Codominant
Tree with crown forming part of the general canopy, receiving full light from above but comparatively little from the sides

Subdominant
Tree shorter than the previous classes, but with a crown extending into the canopy formed by those classes, receiving little light from above but none from the sides.

Suppressed
Tree with a crown entirely below canopy, receives no direct light from above or from the sides

5.2.6. Hollow status
Each tree in the plot must be assessed for its hollow status. The codes are as follows:

0	No hollows visible
1	Tree likely to have hollows, but hollows not visible
2	Tree has visible hollows.

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.

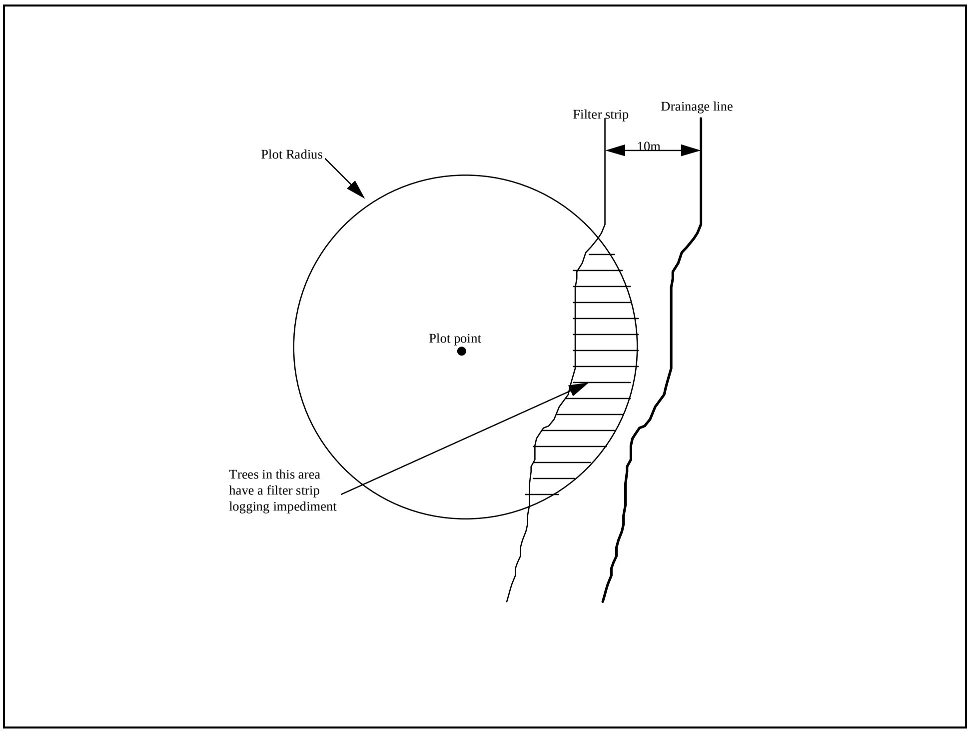
5.2.7. Logging impediment
“Logging Impediment” describes physical or filter strip impediments to a tree being harvested during a routine harvesting operation. The codes are:

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

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, or all, of the plot to fall within the filter strip, trees within the filter strip should be coded as 2. Figure 3 shows how the filter strip logging impediment works.

Figure 3: Filter strip based logging impediment.



6. MARVL TREE DESCRIPTION

6.1 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 is called a Quality Code Dictionary. Quality codes used for this inventory are shown in the table below:

Code	Description
E	“elite” quality, pole, pile or girder quality
A	high value product, includes quota sawlogs, small graded logs, sleeper logs and veneer logs
B	low value product, includes salvage logs, mining timber
P	pulp
W	waste
T	top of tree, special case of waste

In very brief outline, the stem of each sample tree is divided into sections, a MARVL tree description is a sequence of quality code and height for each tree section. Structural codes permit the form of the tree, things such as forks and broken tops, to be recorded.

An important point to note is that **stem size** makes no difference to **wood quality**. A section of stem which is only 150mm in diameter but is dead straight, perfectly round and seemingly defect free should be described as being elite quality (coded as “E”).

The description of each tree will start with a section of waste (coded as “W”), of minimum length 0.3m, which represents both the stump and any additional “butting” of the first log which may be necessary. If the whole tree is entirely unmerchantable then it is only necessary to code the tree as a “W”. The sequence of quality code plus height is repeated up the tree as many times as necessary. Structural codes are interposed as necessary.

There in no strict minimum length for a stem section, although lengths of merchantable sections less than 2m would not normally be recorded. Section heights should be recorded with the Vertex hypsometer.

Quality codes should be assessed without regard to species. It is often the case, for example, that a given species might be locally unsaleable, either generally, or for a particular product. The MARVL system will allow us to take account of species characteristics with a “cutting strategy”, which is a set of rules, including permissible species, governing the conversion of quality codes into products.

All 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 10m of high quality ("A") material, then 10m of low quality material ("B") and a total height ("T") of 40 metres, the tree description would look like this:

W5 A15 B25 T40

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.

6.2 Stem Structural Codes

MARVL has a series of "built in" stem structural codes which may be used to describe changes in the structure of the stem. A list of available structural codes is shown in Table 2. A description of each follows.

Table 2. MARVL structural codes

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

6.2.1 Broken or dead top (*)

This code is used to represent a tree which has sustained damage serious enough to affect the relationship between its height and DBHOB.

The code is inserted at the end of the tree description and must follow a feature height. The code tells MARVL that the recorded height for that tree is abnormal. MARVL will not use the diameter and height of this tree in the fitting a diameter/height curve.

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

W0.4 B5*

6.2.2 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 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 1.3m 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.

W1 A8 W9 <300 B20 T35
              <280 B17

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

6.2.3 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.

W2>350 B21 T33

6.2.4 Forced cut (%)
This code is used in circumstances where a cut is essential, but there is no change in taper, a kink, for example.

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.

W0.3 A5 % A12 B20 T29

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.

W0.5 B25 T34
+ 300 P10

Appendix 1: Slope Correction Table

Slope (°)	Slope distance 0.1ha plot
1	17.84
2	17.85
3	17.86
4	17.88
5	17.91
6	17.94
7	17.97
8	18.02
9	18.06
10	18.12
11	18.17
12	18.24
13	18.31
14	18.39
15	18.47
16	18.56
17	18.66
18	18.76
19	18.87
20	18.98
21	19.11
22	19.24
23	19.38
24	19.53
25	19.68
26	19.85
27	20.02
28	20.21
29	20.40
30	20.60
31	20.81
32	21.04
33	21.27
34	21.52
35	21.78
36	22.05
37	22.34
38	22.64
39	22.96
40	23.29
41	23.64
42	24.01
43	24.39
44	24.80
45	25.23

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: Standard tree species codes

Common name	Botanical name	Code
	Eucalyptus olida	OLI
Alpine Ash	Eucalyptus delegatensis	ALA
Apple Box	Eucalyptus bridgesiana	ABX
Appletopped Box	Eucalyptus angophoroides	TBX
Baileys Stringybark	Eucalyptus baileyana	LSB
Bangalay	Eucalyptus botryoides	BAN
Belah	Casuarina cristata	BLH
Big Badja Gum	Eucalyptus badjensis	BBG
Bimble Box	Eucalyptus populnea ssp. populnea	PBX
Black Ash	Eucalyptus sieberi	STA
Black Box	Eucalyptus largiflorens	BLX
Black Cypress pine	Callitris endlicheri	BCP
Black Gum	Eycalyptus aggregata	BKG
Black Sallee	Eucalyptus stellulata	BSA
Blackbutt	Eucalyptus pilularis	BBT
Blakelys red Gum	Eucalyptus blakelyi	BRG
Bloodwood group	Eucalyptus spp.	BLW
Bloodwood Stringybark	Eucalyptus baileyana	LSB
Blue Gum	Eucalyptus saligna	SBG
Blue mountain Ash	Eucalyptus oreades	BMA
Blueleaved Ironbark	Eucalyptus fibrosa ssp. nubila	BIB
Blueleaved Stringybark	Eucalyptus agglomerata	ASB
Brittle Gum	Eucalyptus mannifera ssp. maculosa	MMG
Broadleaved Ironbark	Eucalyptus fibrosa ssp. fibrosa	FIB
Broadleaved Peppermint	Eucalyptus dives	BPM
Broadleaved white Mahogany	Eucalyptus umbra ssp. carnea	BMY
Broombush	Melaleuca uncinata	BRO
Brown barrel	Eucalyptus fastigata	FAS
Brown Bloodwood	Eucalyptus trachyphloia	BBW
Brown Stringybark	Eucalyptus capitellata	BSB
Brush Box	Lophostemon confertus	BBX
Brushwood group	(Various)	BWD
Budda	Eremophila mitchellii	BUD
Bull Oak	Allocasuarina leuhmanii	BOK
Butterbush	Pittosporum phylliraeoides	BUT
Cabbage Gum	Eucalyptus amplifolia	CGG
Cabbage tree Palm	Livistona australis	CTP
Candlebark	Eucalyptus rubida	CBK
Carbeen	Eucalyptus tessellaris	CAR
Coast Ash	Eucalyptus sieberi	STA
Coast grey Box	Eucalyptus bosistoana	CBX
Coolibah	Eucalyptus microtheca	COO
Cuttail	Eucalyptus fastigata	FAS
Diehard Stringybark	Eucalyptus cameronii	DSB
Dwyers red Gum	Eucalyptus dwyeri	DRG
Emu bush	Eremophila longifolia	EMU
Eucalyptus spp.	Eucalyptus spp.	EUC

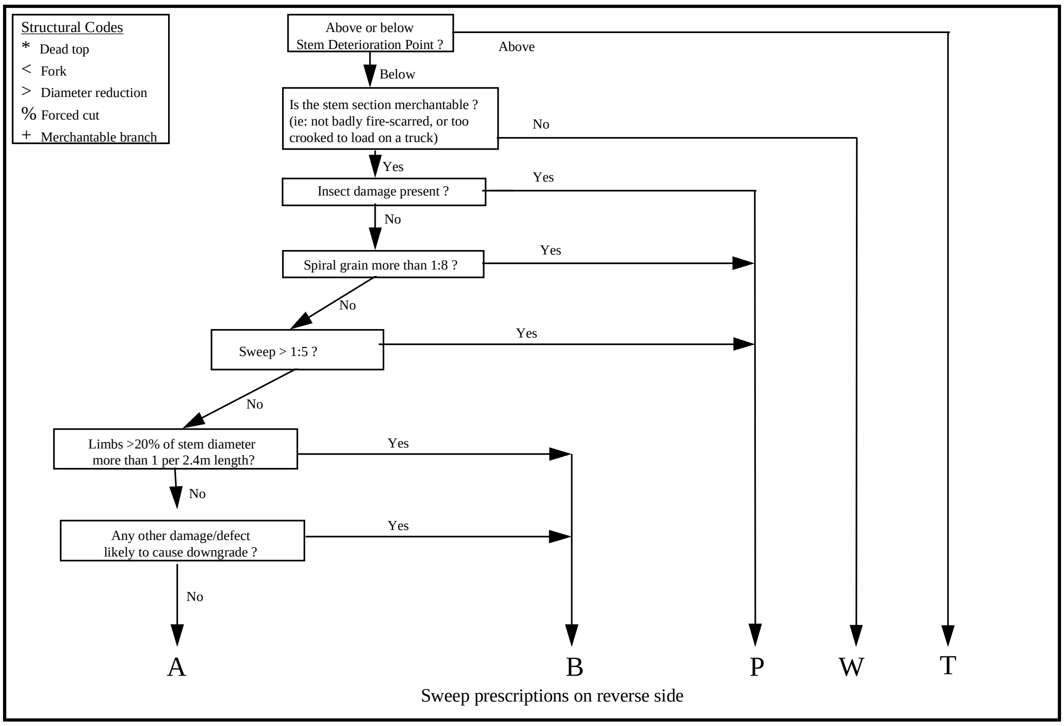
Common name	Botanical name	Code
Eurabbie	Eucalyptus globulus ssp. bicostata	EUR
Eurah	Eremophila bignoniflora	ERB
Flooded Gum	Eucalyptus grandis	FLG
Forest Oak	Allocasuarina torulosa	FOK
Forest red Gum	Eucalyptus tereticornis	FRG
Fuzzy Box	Eucalyptus conica	FBX
Grey Box	Eucalyptus moluccana	GBX
Grey Box	Eucalyptus dawsonii	GBX
Grey Gum	Eucalyptus propinqua	GYG
Grey Gum	Eucalyptus punctata	GYG
Grey Ironbark	Eucalyptus siderophloia	GIB
Grey Ironbark	Eucalyptus paniculata	GIB
Gully Peppermint	Eucalyptus smithii	GPM
Gympie messmate	Eucalyptus cloeziana	GMM
Hoop Pine	Araucaria cunninghamii	HPP
Ironbark group	Eucalyptus spp.	IBK
Kurrajong	Brachychiton populneus	KUR
Largefruited Blackbutt	Eucalyptus pyrocarpa	PYR
Maidens Gum	Eucalyptus globulus ssp. maidenii	MDG
Mallee Cypress pine	Callitris preissii	MCP
Mallee group	Eucalyptus spp.	MAL
Manna Gum	Eucalyptus viminalis	MAG
Messmate	Eucalyptus obliqua	MMT
Mixed species		MIX
Monkey Gum	Eucalyptus cypellocarpa	MKG
Mountain grey Gum	Eucalyptus cypellocarpa	MKG
Mountain Gum	Eucalyptus dalrympleana	MTG
Mugga Ironbark	Eucalyptus sideroxylon	RIB
Mulga	Acacia aneura	MUL
Myall	Acacia pendula	MYL
Narrowleaved Ironbark	Eucalyptus crebra	NIB
Narrowleaved Peppermint	Eucalyptus radiata	NPM
Narrowleaved Stringybark	Eucalyptus oblonga	OSB
Narrowleaved white Mahogany	Eucalyptus acmenioides	NMY
Native Cherry	Exocarpus cupressiformis	NCH
Needlebark Stringybark	Eucalyptus planchoniana	NSB
Needlewood	Hakea leucoptera	NCO
New England Blackbutt	Eucalyptus andrewsii ssp. Campanulata	NEB
New England Peppermint	Eucalyptus nova-anglica	EPM
New England Stringybark	Eucalyptus calignosa	ESB
Non-commercial Eucs	Eucalyptus spp	NCE
Non-commercial others	(Various)	NCO
Oak group	(Various)	OAK
Other commercial Eucalypt	Eucalyptus spp	OCE
Peppermint group	Eucalyptus spp.	PPM
Pilliga Box	Eucalyptus pilligaensis	LBX
Pink Bloodwood	Eucalyptus intermedia	PBW
Quandong	Santalum acuminatum	QUA

Common name	Botanical name	Code
Red Bloodwood	Eucalyptus gummifera	RBW
Red Box	Eucalyptus polyanthemos	RBX
Red Ironbark	Eucalyptus sideroxylon	RIB
Red Mahogany	Eucalyptus resinifera	RMY
Red Mahogany	Eucalyptus pellita	RMY
Red Stringybark	Eucalyptus macrorhyncha	RSB
Ribbon Gum	Eucalyptus viminalis	MAG
River Oak	Casuarina cunninghamiana	ROK
River Peppermint	Eucalyptus elata	RPM
River red Gum	Eucalyptus camaldulensis	RRG
Rosewood	Heterodendron oleifolium	ROS
Roughbarked Apple	Angophora floribunda	RAP
Roundleaved Gum	Eucalyptus deanii	RLG
Rudders Box	Eucalyptus rudderi	UBX
Scribbly Gum	Eucalyptus haemastoma	SCG
Scribbly Gum	Eucalyptus racemosa	SCG
Scribbly Gum	Eucalyptus rossii	SCG
Scribbly Gum	Eucalyptus sclerophylla	SCG
Scribbly Gum	Eucalyptus signata	SCG
Shining Gum	Eucalyptus nitens	SHG
Silverleaved Ironbark	Eucalyptus melanophloia	SIB
Silvertop Ash	Eucalyptus sieberi	STA
Silvertop Stringybark	Eucalyptus laevopinea	SSB
Smoothbarked Apple	Angophora costata	SAP
Snow Gum	Eucalyptus pauciflora	SNG
Spotted Gum	Eucalyptus maculata	SPG
Steel Box	Eucalyptus rummeryi	SBX
Stringybark group	Eucalyptus spp.	SBK
Swamp Box	Lophostemon suaveolens	LSU
Swamp Mahogany	Eucalyptus robusta	SMY
Sydney blue Gum	Eucalyptus saligna	SBG
Sydney Peppermint	Eucalyptus piperita	SPM
Tallowwood	Eucalyptus microcorys	TWD
Tumbledown red Gum	Eucalyptus dealbata	TRG
Turpentine	Syncarpia glomulifera	TRP
Unknown species		UNK
Wattle group	Acacia spp.	WAT
Weeooka	Eremophila oppositifolia	WEE
Western Boobialla	Myoporum montanum	BOO
Western grey Box	Eucalyptus woollsiana ssp. Microcarpa	MBX
Western red Box	Eucalyptus intertexta	IBX
White Ash	Eucalyptus fraxinoides	WHA
White Box	Eucalyptus albens	WBX
White Cypress pine	Callitris glaucophylla	WCP
White Gum	Eucalyptus dunnii	DWG
White Mahogany	Eucalyptus acmenioides or E. umbra	WMY
White Sallee	Eucalyptus pauciflora	SNG
White Stringybark	Eucalyptus globoidea	WSB

Common name	Botanical name	Code
Whitetopped Box	Eucalyptus quadrangulata	QBX
Wilga	Geijera parviflora	WIL
Woollybutt	Eucalyptus longifolia	WBT
Yellow Bloodwood	Eucalyptus eximia	YBW
Yellow Box	Eucalyptus melliodora	YBX
Yellow Stringybark	Eucalyptus muelleriana	YSB
Yertchuk	Eucalyptus consideniana	YER
Youmans Stringybark	Eucalyptus youmanii	USB

Appendix 4: Sample 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

APPENDIX B - MARVL SYSTEM ANALYSIS

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.

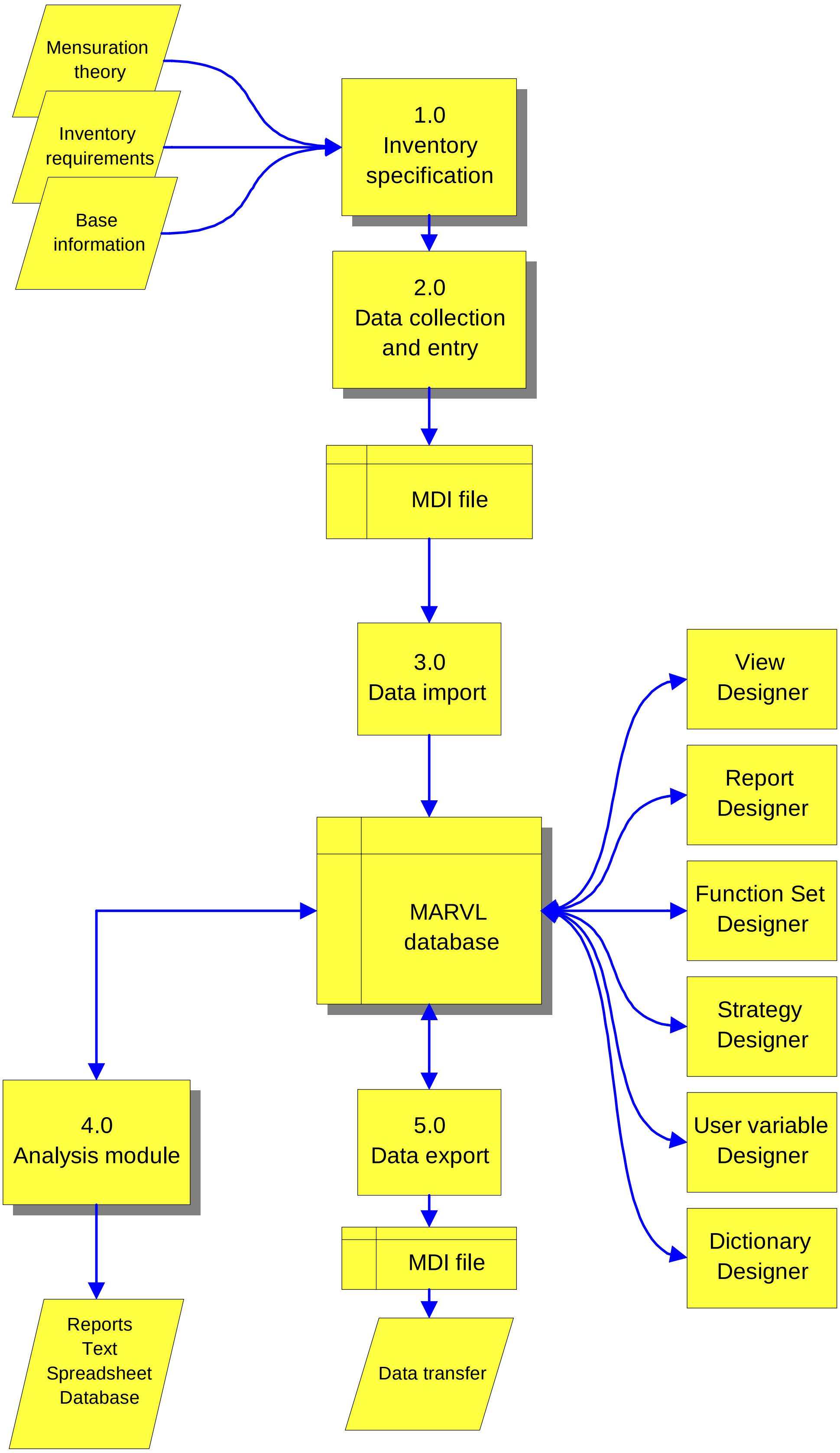
At step 1, MARVL supports the use of fixed area plots (“bounded” plots in MARVL literature), horizontal point and horizontal line samples, which may be used in simple or stratified designs. There is a “double sampling” option at the plot level.

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).

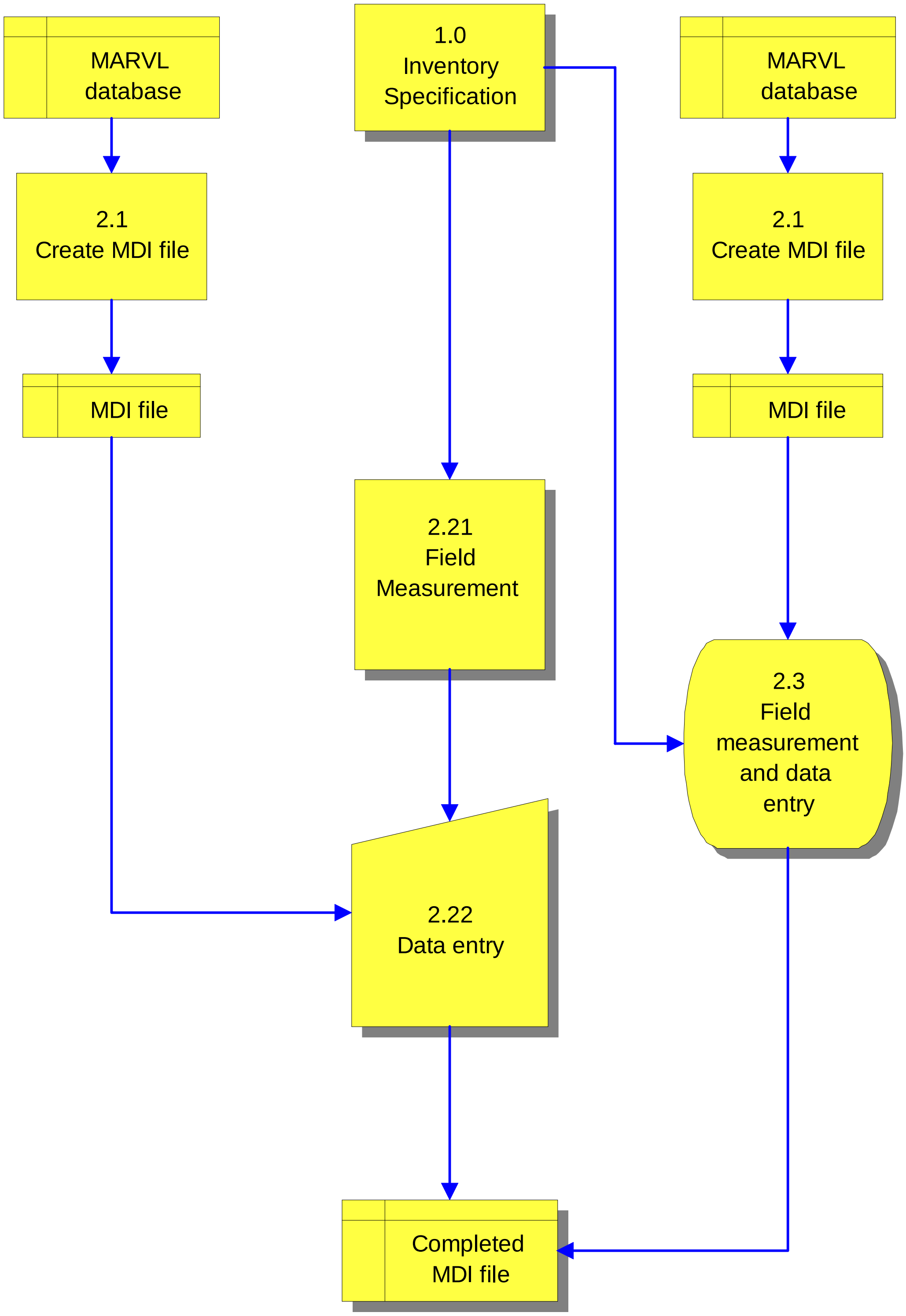
The MARVL data capture program MARVLDE3 is used to collect MARVL inventory data, either on a PC in the office, entering data from hand written plot sheets, or in the field, entering data directly into a DOS-based portable data recorder (PDR). A series of menus and data entry screens (forms) allows the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

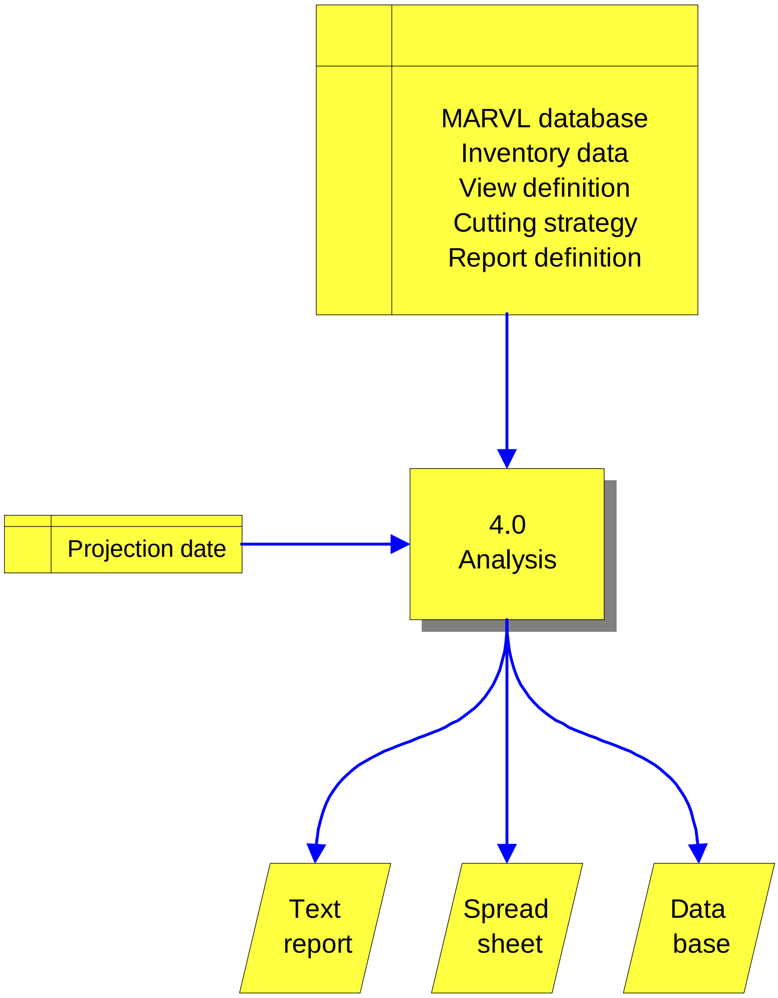
The Analyse module is the heart of MARVL. The analysis module uses data from the database to produce reports. This process is described in Figure 3, and represents item 8 in the Husch *et al*. (1982) list.

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

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.

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

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,

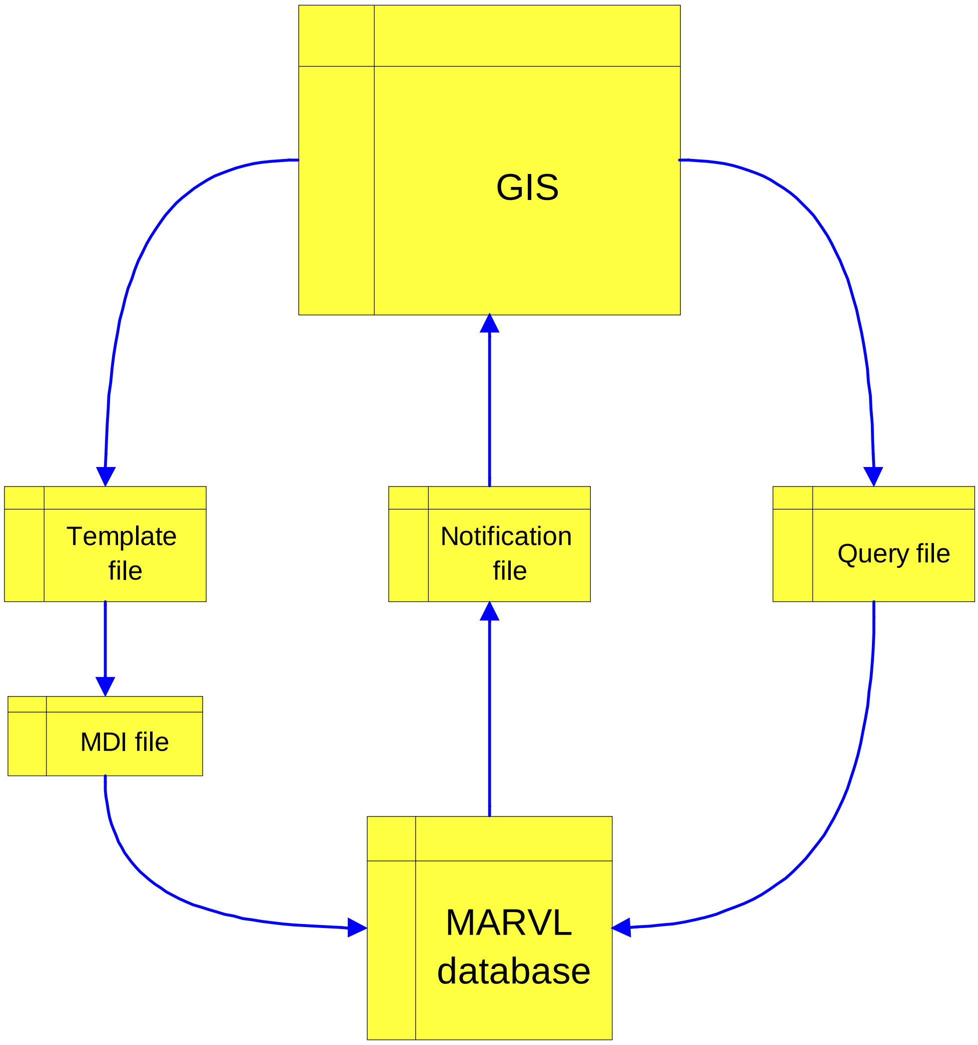
3. use the View Designer to assign function sets, validate and save the view,

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.



References

Anon (1990). MicroMARVL - versatile plantation inventory. NZ Forest Research Institute, What's new in Forest Research? Number 191

Cochran, William G. (1977). Sampling techniques. John Wiley and Sons.

De Vries, Pieter G. (1986). Sampling theory for forest inventory. Springer-Verlag.

Deadman, M.W. and C.J. Goulding (1978). “A method for assessment of recoverable volume by log types.” New Zealand Journal of Forestry Science **9**: 225-239.

Demaerschalk, J.P. (1972). “Converting volume equations to compatible taper equations.” Forest Science **18**: 241-245.

Gordon, A.D. and M.E. Lawrence (1995). External stem quality assessment - MARVL. In D. Hammond Ed. 1995 Forestry Handbook. New Zealand Institute of Forestry. 190-191.

Hock, Barbara (1996). Linking MARVL and the geographic information system Arc/Info. NZ Forest Research Institute, Unpublished Project Record Number 4996

Husch, Bertram, Charles I. Miller and Thomas W. Beers (1982). Forest Mensuration. Wiley.

Lawrence, M.E. (1986). The MARVL pre-harvest inventory procedure. Proceedings, “Harvesting whole trees with processing and log allocation in the forest to conventional and energy products” conference, Rotorua, Forest Research Institute, Rotorua, New Zealand.

Muhairwe, Charles K. (1995). Taper study for *Eucalyptus* species particularly blackbutt. State Forests of NSW, Unpublished report

NZFRI (1995). Guide to using MARVL V3. New Zealand Forest Research Institute Limited, NZ FRI Software Series Number ?

NZFRI (1997). Guide to using MARVL data capture 3. New Zealand Forest Research Institute, Number ?

Pnevmaticos, S.M. and S.H. Mann (1972). “Dynamic programming in tree bucking.” Forest Products Journal **22**: 26-30.

Vanclay, Jerome K. (1994). Modelling forest growth and yield. Applications to mixed tropical forests. CAB International.

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 *i*th tree
D_i	DOB, *i*th tree
d_i	DUB, *i*th tree
b_i	double bark thickness, D_i - d_i
H_i	height of *i*th tree
h_i	level above ground of a point on the stem, *i*th tree
l_i	distance from the top of the tree *i*th tree, H_i - h_i
R	l_i / H_i
g_i	basal area of *i*th tree
w_i	frequency of *i*th tree
X	per hectare characteristic
x_i	any characteristic of *i*th 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)

$w_i = 1000 \dfrac{\sqrt{F}}{D_{Bi} \, L}$ (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:

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

Pettersen 2:

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

Logarithmic:

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

Taper functions

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

Taper function 01:

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

$$\textit{where}\;\; d_i = DUB\,\textit{at length}\; l_i\;\textit{from tree tip}$$

Taper function 07:

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

Taper function 08:

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

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

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

Taper function 09:

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

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

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

Taper function 10:

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

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

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

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:

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

Volume table 03:

$$\log(V_i) = b_1 \log(D_{Bi}) + b_2 \log(H_i) + b_3 \frac{D_{Bi}^2}{10000} + b_4$$

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:

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

Volume tables 08 - 11

Integral of taper function types 08 - 11

Volume table 12:

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

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
```