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THE DEPARTMENT OF CONSERVATION & LAND MANAGEMENT WESTERN AUSTRALIA

PREDICTING IMPACT IN THE SOUTHERN JARRAH FOREST

by

M Grant and P Blankendaal

Dieback disease caused by P.cinnamomi is widespread in the Southern Jarrah forests. The report examined seventy four (74) sites, forty two (42) with high impact and thirty two (32) with low impact, in terms of landform, soils, Southern Jarrah forest site type (SJFST) and vegetation.

High and low impact sites occurred in recognizable clusters. Dominant SJFST on high impact sites were P, sP, pS and S. Dominant SJFST on low impact sites were T, sT, tS, S and K.

The Dwellingup, Trent, Ellis, Mungardup and Caldyanup landform units occurred predominantly in the high impact class, whereas the Crowea, Bevan and Valley units were exclusively low impact. Both high and low impact occurred on the Hester, Collis, Mattaband, Keystone and Stream landform units.

High impact occurred most commonly on sandy-textured surface horizons and shallower lateritic soils (<50 cm), over a lateritic duricrust or clay subsoil. Windblown trees were common on high impact sites.

The use of plant indicator species was attempted but accuracy of prediction is less than fifty per cent at this stage. More work is required before this can be used as a predictive tool.

Listed below are the landform units described by the C.S.I.R.O. in their System 6 Study and in the maps of landform and soils:- Northcliffe to Manypeaks.

HESTER:-

Recorded Southern Jarrah Forest Site Types (SJKST) P, R and S. Consists of shallow sandy loam over laterite duricrust uplands, resulting in localised patches of poor drainage. Impact varied from low in some S SJFST to high in P, R and other S SJFST. Therefore, predicted impact on P and R sites will be high, while S sites may be variable.

DWELLINGUP:-

Recorded SJFST P and S. Consists of shallow sandy loam over laterite duricrust uplands, resulting in localised patches of poor drainage. Only high impact sites were observed in the survey. However, low impact S SJFST can be found on the Dwellingup landform unit. Predicted impact on P SJFST is high while S SJFST may be variable.

MUNGARDUP:-

Recorded SJFST A and B. Consists of sandy soils over clay subsoil drainage lines. Sites are infertile and observed impact was high. Predicted impact for this unit is high.

ELLIS:-

Recorded SJFST P. Consists of very shallow sands over laterite duricrust resulting in a poorly drained site. Impact observed in the survey was always high on this landform unit. Predicted impact is high to very high for this unit.

CALDYANUP:-

Recorded SJFST F, B and R. Consists of poorly drained infertile sandy plains and drainage floors. Impact observed in the survey was always high on this landform unit. Therefore, predicted impact will also be high for this landform unit.

TRENT:-

Recorded SJFST P. Consists of gravelly yellow duplex soils with some gravelly sand and scattered occurrence of lateritic duricrust. Poor drainage was observed on the high impact P SJFS type. Predicted impact on this landform unit is high when associated with the P type.

CROWEA:-

Recorded SJFST T, S, and P. Dissected uplands resulting in fertile slopes and narrow laterite crests. Only low impact sites were observed on this landform unit. Predicted impact will generally be low on this landform unit, although high impact may occur on shallow-soiled lateritic crests.

COLLIS:-

Recorded SJFST T, S, I, P, and N. Consists of duplex yellow brown soils with scattered occurrences of shallow sandy soils over laterite duricrust. High and low impact were observed on this landform unit. Predicted impact varies from low, on the fertile well drained sites, to high on the infertile poorly drained sites.

MAJOR VALLEY UNITS (V2 and V3):-

Recorded SJFST S and K. Consists of well drained, yellow duplex and deep loamy fertile soils. Impact observed was low throughout the survey, therefore predicted impact on this unit will be low.

MATTABAND:-

Recorded SJFST S and P. Consists of yellow duplex soils over clay subsoils. High and low impact were observed on this unit. Predicted impact is variable on this landform unit.

KEYSTONE:-

Recorded SJFST P and K. Consists of brown yellow duplex soils with scattered occurences of lateritic duricrust on upper slope and crests. Low impact was observed on the fertile soils of this unit. However, high impact was observed on the laterite crests. Predicted impact will be low in fertile areas and high in lateritic uplands of this landform unit.

STREAM:-

Recorded SJFST S and P. Consists of gravelly yellow duplex soils and occasional occurrences of brown duplex soils. Observed impact varied from low to high. Therefore predicted impact is also variable.

BEVAN:-

Recorded SJFST is K. Duplex soils consisting of sandy loams over clayey B horizon. Observed impact and predicted impact is low.

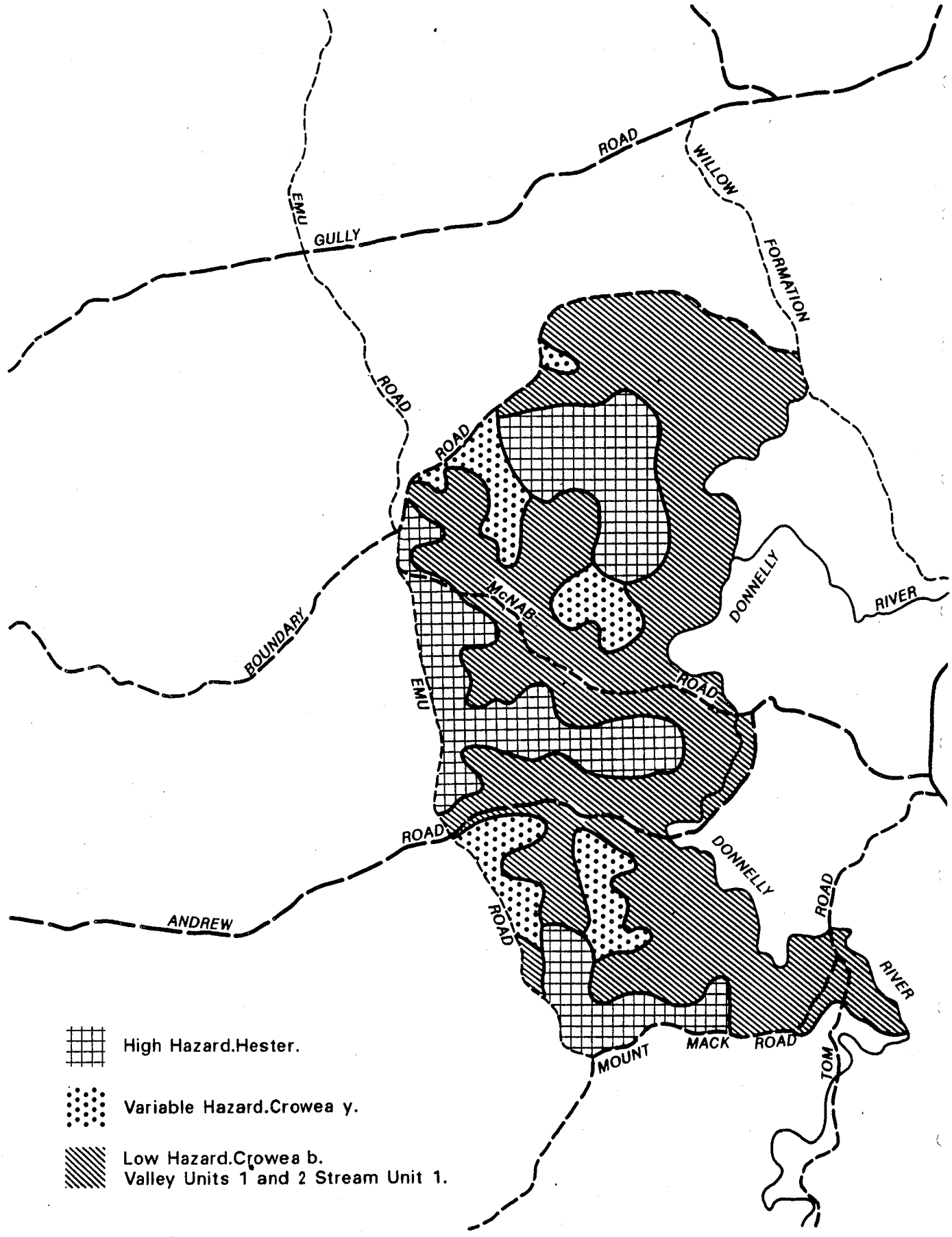
Dieback areas were not found on some of the landform units during this survey. It is not yet possible to predict impact on these sites.

Predicted impact maps for some forest blocks have been prepared to assist in planning forest operations. An example for Mack block is attached. However, landform mapping is not yet available over the whole Southern Forest (Appendix 2).

This report and survey should be regarded as an interim document. As more sites are found and described, the data base and the impact predictions will improve.

MACK BLOCK

Hazard Classes



REPORT

PREDICTING THE IMPACT OF *PHYTOPTHORA CINNAMONI* IN SOUTHERN JARRAH FOREST

by

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P. Blankendaal

PREDICTING IMPACT IN SOUTHERN JARRAH FOREST

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1. INTRODUCTION

Predicted Impact Mapping recognises that areas of forest vary in necrotic susceptibility to the *Phytophthora cinnamomi* fungus.

The Central Forest Region has been using Predicted Impact maps to assist in managing logging operations since 1984. Forest site types based on vegetation (Havel 1975 p 94-112) and landform (Atlas of Natural Resources 1980) are used to predict the impact of *Phytophthora cinnnamomi*.

The Southern Forest Region has, until recently, been without the information required for successful predicted impact mapping. However, a study of Southern Jarrah Forest Site Types (SJFST) was completed by G. Strelein in 1986, describing 17 different Southern Jarrah Forest Site Types. Also, Landform and Soil maps for the South Coast and hinterland were issued by the C.S.I.R.O. Division of Ground Water Research, Floreat,in January 1987.

These separate studies have provided a significant base on which to initiate development of a method of predicting impact in the Southern Forest Region.

A project was then designed to examine 3 methods of predicting *Phytophthora cinnamomi* impact;

1. Prediction by use of plant indicator species.
2. Prediction by use of vegetation site types (Southern Jarrah Forest Site Type; SJFST).
3. Prediction by use of landform and soil types.

To test each method of prediction, vegetation and soil data was collected from 74 plots (32 from current low impact forest and 42 from current high impact forest).

By comparing site types with the surveyed vegetation and soil information, common factors may be found that indicate the level of potential impact for a forest area. With this information a priority ranking order may be given to areas of forest for *Phytophthora cinnamomi* mapping.

3. METHOD

3.1 Selecting Sites for Survey

3.1.1 *Selecting High Impact Sites*

Areas nominated by Southern Forest Districts in combination with a survey of jarrah crown deaths by G.H. Heberle (1975-79), provided a base for selection of sites in this survey. However, some of the nominated sites were not included in the final population. These sites were generally considered not infected by *P.c.* upon field inspection. This subjective selection was based on definitions of impact categories as described in the 'Dieback Procedures Manual' 1986.

Viz. Low Impact: Some susceptible plants in the understorey killed by *Phytophthora cinnamomi*.

Moderate Impact: Many susceptible plants in the understorey killed by *Phytophthora cinnamomi* with less than 10 percent of overstorey dead or dying.

High Impact: Many susceptible plants in the understorey killed by *Phytophthora cinnamomi* with greater than 10 percent but less than 50 percent of the overstorey dead or dying.

Very High Impact: Most susceptible plants in the understorey killed by *Phytophthora cinnamomi* with greater than 50 percent of the overstorey dead or dying.

Sites were selected from low, high and very high impact categories.

3.1.2 *Selecting Low Impact Sites*

Selection of low impact sites was based on 3 criteria;

- Minimum age;
  Infections known to be less than 5 years old were not included in the survey. In this way it was certain that the pathogen had at least 5 years to reach its full destructive potential.

- Minimum size;
  Sites of less than 1 ha (approx.) were not included in the low impact survey.

- Low impact by definition;
  Only sites defined as low impact (see 3.1.1) were included in the low impact survey.

Low impact plots were located from 1978 dieback plans and plans produced from 70mm colour photography that were greater than five years old so that the minimum age criterion could be met.

3.2 Recording Techniques

Recording techniques were standard for all sites surveyed.

3.2.1 *Vegetation*

Vegetation assessment of high impact areas was done to the method described by J. Havel (1975).

"Ratings of Trees (1 to 5) were drawn from an area of 40m radius from an observation point chosen from the centre of the area of *P.c.* impact:

0 Absent

1 One or two trees

2 Three to five trees

3 More than five trees, but contributing less than one third of total stand.

4 Between one third and one half of the total stand.

5 More than one half of the total stand.

Ratings of undergrowth species were based on an area of 20 metres radius from the observation point:

0 Absent

1 Very rare; seen only after careful search.

2 Present, observable but in small numbers only.

3 Common locally, but not uniformly over the whole area.

4 Common over the whole area.

5 Completely dominating undergrowth.

The ratings do not conform to any standard vegetation parameters, such as cover density, frequency or abundance. They were devised to give rapid estimates of relative importance of species at observation point:" (p 70)

(J. Havel Bulletin 86 1975a)

Vegetation assessment sheets as used by G. Strelein in his study of site types in Southern Jarrah Forest were used to tabulate this data.(App.1)

3.2.2 *Soil*

A full soil profile description of each site was given using Northcotes system of soil description. The colour of the soil profiles were described using the standard soil colour charts (Munsell).

All soil colours can be measured by 3 attributes;

Hue, which represents the dominant spectral colour e.g. red, yellow, green, blue etc,
Value, which represents the relative lightness of colour,
and Chroma, which represents the relative purity or strength of the spectral colour.

eg. 10yr 5 / 6
hue value chroma

Test holes were excavated to a depth of 1 metre or to an impervious layer (laterite or clay hardpan).

3.3 Allocation of Site Types to Surveyed Plots

3.3.1 *Southern Jarrah Forest Type*

Given a vegetation abundance list and a soil description of each plot, a Southern Jarrah Forest type was described using "The Handbook for identification of Southern Jarrah Forest Types" by G.J. Strelein 1986.

3.3.2 *C.S.I.R.O. Landform and Soil Units*

Landform units were located and read from maps compiled by Dr M. Churchward of C.S.I.R.O. Division of Groundwater Research Floreat.

Although the maps represent most of the Southern Region (Refer app. II) the northern section has only been completed to first draft stage. Field assistance from Dr M. Churchward was acquired to interpret information from these draft maps.

In the same way a landform and soils category was given to plots covered by the "Atlas of Natural Resources Darling System of Western Australia" 1980.

4 RESULTS

4.1 Distribution of Impact Plots Throughout the Southern Region

The geographic distribution of high and low impact plot clusters,within the Region, is shown in Appendix III.

4.1.1 *Clusters of High Impact Sites*

Five main clusters were recognised,namely;-

a.Nº.1 Vasse Highway, Barlee and Easter forest block.

b.Nº.2 East of Donnelly River Mill, Carter, Alco, Mack and Netic forest blocks.

c.Nº.3 Cleave and Flybrook forest blocks.

d.Nº.4 Frankland and Collis forest blocks.

e.Nº.5 North of Denmark in Denmark, Harewood and Powley forest blocks.

4.1.2 *Clusters of Low Impact Sites*

Four main clusters are recognised;

f.Nº.6 West of the Donnelly River in Lewin, Easter and Andrew Forest Blocks.

g.Nº.7 Strickland and Carey Forest Blocks.

h.Nº.8 Bevan and Mattaband Forest Blocks.

i.Nº.9 Wye and Deep Forest Blocks.

These clusters are displayed in App.III.

4.2 Summary of Site Types Found Throughout the Survey

4.2.1 *Southern Jarrah Forest Site Types (SJFST)*

The range of discrete Southern Jarrah Forest (SJFST) site types, from a total of 42 high impact plots was as follows;

(Descriptions of each site type Alpha Code is given in app.IV).

TABLE 4.2a

SJFST	P	S	R	B	F	N	A
Frequency	20	11	4	4	1	1	1

The range of discrete SJFST types, from a total of 32 low impact sites was as follows;

TABLE 4.2b

SJSFT	T	S	K	P	I	V
Frequency	9	11	5	5	1	1

Table 4.2a and 4.2b display discrete site types. This has been done to create greater segregation between the types. However, discrete site types occurred naturally only as a small percentage of the total sites surveyed.

Admixtures of site types are combinations of two types with a dominant and influencing component e.g. sT signifies T as dominant and s as the influencing type. Table 4.2c and 4.2d list the admixture types found throughout the high and low impact survey.

TABLE 4.2c HIGH IMPACT ADMIXTURES

SJFST	S	pS	tS	rS	P	sP	rP	aP	yP
Frequency	4	5	1	1	8	6	2	1	1

SJFST	iP	xP	R	aR	sR	pR	B	aB	bA	F	N
Frequency	1	1	1	1	1	1	3	1	1	1	1

TABLE 4.2d LOW IMPACT ADMIXTURES

SJFST	T	uT	sT	K	sK	S	tS	pS
Frequency	5	1	3	3	2	4	5	2

SJFST	tV	nI	P	rP	sP	kP
Frequency	1	1	1	2	1	1

4.2.2 Variation in C.S.I.R.O. Landform and Soil Categories Throughout the Survey

The following tables (4.2 e & f) show a frequency of occurrence of C.S.I.R.O. landforms and soils types found in the survey

TABLE 4.2e HIGH IMPACT

Landform & Soils Type	DW	H	E	Ca	Mp	Tr	Co	MT	CM	K	QN	A	W	S_1
Frequency	9	7	5	3	3	2	2	3	1	2	1	1	1	2

TABLE 4.2f LOW IMPACT

Landform & Soils Type	Cr	Co	Be	H	K	Mt	V_2	V_3	S_1
Frequency	14	3	2	2	1	2	1	1	1

There are only twenty seven (27) plots recorded in table 4.2f. This was due to five (5) plots occuring in areas of forest without landform map coverage.(refer App. II)

As for Southern Jarrah Forest Types the landform and soil types are also listed as discrete types to enable greater segregation. However in the following section, Discussion 5, some land form units are subdivided on the basis of the following variations in soils, indicated by the classes b (brown), y (yellow), d (duplex sands), p (shallow),l (laterite). (Churchward, 1982 p 25).

4.2.3 *C.S.I.R.O. landform and soils type and associated Southern Jarrah Forest Site Types*

TABLE 4.2g HIGH IMPACT

Hester		P(2)	S(4)	R(1)	
Dwellingup		P(5)	S(4)		
Ellis		P(4)	S(1)		
Mungardup				B(2)	A(1)
Caldyanup	F(1)			B(1)	R(1)
Trent		P(2)			
Collis p			N(1)		
Collis y		P(1)			
Mattaband y		P(1)	S(1)		
Mattaband b		P(1)			
Keystone b		P(1)			
Keystone y		P(1)			
Camballup		P(1)			
Quindabellup					R(1)
Angove				B(1)	
Wilga					R(1)
Stream$_1$			S(2)		

TABLE 4.2h LOW IMPACT

LANDFORM		SJFST		
Crowea 1		S(3)		
Crowea b		S(2)	T(2)	
Crowea y		S(2)	T(4)	
Crowea d		S(1)		
Collis y	I(1)	S(1)	T(1)	
Bevan y				K(1)
Bevan b				K(1)
Hester		S(2)		
Keystone				K(1)
Mattaband	P(2)			
Valley 3				K(1)
Valley 2		S(1)		
Stream	P(1)			

By comparing tables 4.2g and 4.2h some landform units are occurring solely in one of the impact categories or in both of the impact categories.

The Dwellingup, Ellis, Mungardup and Caldyanup units have occurred predominantly in the High Impact table 4.2g.

The Mattaband, Collis, Keystone, Hester and Stream have occurred in both high and low impact tables (4.2 g and h).

However, Crowea, Bevan and $Valley_2$ and $Valley_3$ have occurred exclusively in the low impact table 4.2h.

Some landform units occurred only once throughout the survey (Cambellup, Quindabellup, Angove and Wilga). These units were exclusively associated with high impact P.c. sites.

4.3 Soils

4.3.1 *Soil Type*

Tables 4.3a and 4.3b show a graduation of soil textures, as described in "*The Factual Key for the Recognition of Australian Soils*" (K.H. Northcote, 1960) found throughout the high and low impact sites. Soil textures were read from the full profile of the test hole, with some sites having two or three horizons.

The following table (4.3a) shows seven (7) soil textures grades reduced from nineteen (19) grades described in *Northcote's Key* ,this was done to provide better discrimination between the grades.

TABLE 4.3a HIGH IMPACT

Soil Texture	Frequency of Occurrence	Percentage of Total
Sand	2	4
Loamy sand	31	54
Clay sand	9	16
Sandy loam	3	5
Loam	0	0
Clay loam	2	4
Sand clay	10	17

On the high impact sites the sandy textures (sand, loamy sand, clay sand) represented 74% of soil types found. The loam textures (sandy loam, clay loam, loam) represented 9% of the soil types found. Sandy clay textures were 17% of the total variation in soil textures.

TABLE 4.3b LOW IMPACT

Soil Texture	Frequency of Occurrence	Percentage of Total
Sand	1	2
Loamy sand	15	26
Clay sand	8	14
Sandy loam	4	7
Loam	0	0
Clay loam	6	11
Sandy clay	15	26
Clay	8	14

On the low impact sites the sandy textures (sand, loamy sand and clay sand) represented 42% of soil types found. The loamy textures (sandy loam, clay loam, loam) represented 18% of soil types found. Sandy clay and clay textures represented 40% of the total variation in soil textures.

TABLE 4.3c COMPARISON

	High Impact %	Low Impact %
Sand	74%	42%
Loam	9%	18%
Clay	17%	40%

From the results in the comparison table (4.3c) the sand texture group has decreased in total frequency from 74% to 42%. The loam texture group has risen from 9% in the high impact plots to 18% in the low. Whilst the clay texture group has risen from 17% in high impact plots, to 40% in the low impact plots.

4.3.2 *Soil Depth*

The soil profiles of the 42 high impact sites revealed 31 with lateritic duricrusts, 10 with clay subsoils which were impenetrable to the probe. One plot contained deep sands to a depth of 120cms which was penetrable to the probe.

The average depth of soils with laterite duricrusts was 44cm. However, the average depth of soil profiles with impervious clay layers was 52cm. The modal class for high impact soil profiles was from 30 - 60cm.

Windblown trees occurred consistently on very shallow lateritic soils (less than 50cm), revealing duricrust and lateritic boulders. Windblown trees were also observed on one high impact site revealing an impervious clay layer.

In comparison the soil profiles of the 32 low impact sites revealed 21 plots with clay subsoils, 3 plots contained horizons impenetrable to the probe due to large amounts of gravel and rubble. Two plots had lateritic duricrusts impenetrable to the probe whilst the remaining 6 had horizons of variable soil structure.

The average depth of soil profile holes was 75cm. Whilst the modal class for low impact soil profiles was from 60 - 100cm. There were also large amounts of root material (trees and understorey) observed in the test hole excavation.

4.3.3 *Soil Colour*

Hue, value and chroma ratings were described for each horizon in the soil profile of a test plot. Results ranged through 8 hues (2.5 yr, 5 yr, 7.5 yr, 10 yr and 2.5 y, 5 y, 7.5 y, 10 y).

Tables 4.3 d - g show the value/chroma ratings of the A_1 soil horizons associated with various soil types and impervious layers.

TABLE 4.3 d ; A_1 HORIZON VALUE/CHROMA RATINGS FOR HIGH IMPACT SITES WITH LATERITIC DURICRUST.

	YR				Y			
HUE	2.5	5	7.5	10	2.5	5	7.5	10
	5/1 LIGHT RED	-	6/8 REDDISH YELLOW	6/4 (2) LIGHT YELLOW BROWN	8/3 PALE	8/1 PALE	6/1 LIGHT	6/1 LIGHT
	5/2	-	7/2 (2)	6/6 (4)	8/4 YELLOW	8/3 YELLOW	8/1 GREY	8/1 GREY
	7/5 PALE RED	-	7/3 (2) PINKISH GREY	7/1	-	-	-	-
	-	-	-	7/6 (5)	-	-	-	-
	-	-	-	7/8	-	-	-	-
	-	-	-	8/2	-	-	-	-
	-	-	-	8/4 VERY PALE BROWN	-	-	-	-

TABLE 4.3 e ; A_1 HORIZON VALUE/CHROMA RATINGS FOR HIGH IMPACT SITES WITH CLAY LAYERS.

	YR				Y			
HUE	2.5	5	7.5	10	2.5	5	7.5	10
	-	-	5/6 STRONG BROWN	6/6 (2) BROWNISH YELLOW	6/2 LIGHT BROWN GREY	8/1 LIGHT GREY	6/1 GREY	6/1 (2) GREY
	-	-	-	-	7/3 PALE YELLOW	-	-	-
	-	-	-	-	8/3 (2)	-	-	-

TABLE 4.3 f ; A_1 HORIZON VALUE/CHROMA RATINGS FOR LOW IMPACT SITES WITH LATERIC DURICRUST.

	YR				Y			
HUE	2.5	5	7.5	10	2.5	5	7.5	10
	-	-	5/8	5/6	-	-	-	-

TABLE 4.3 g ; A_x VALUE/CHROMA RATINGS FOR LOW IMPACT SITES WITH SANDY PROFILES AND CLAY LAYERS.

	YR				Y			
HUE	2.5	5	7.5	10	2.5	5	7.5	10
	–	5/8(2)	6/8(2)	5/6	–	–	–	–
	–	–	–	5.8(2)	–	–	–	–
	–	–	–	6/6(3)	–	–	–	–
	–	–	–	6/8	–	–	–	–
	–	–	–	7/6(2)	–	–	–	–
	–	–	–	7/8(4)	–	–	–	–
	–	–	–	8/5	–	–	–	–
	–	–	–	8.6	–	–	–	–

The high impact tables (d and e) are distinguished by lateritic and clay impervious layers. Table d (ratings for lateritic duricrust) shows a concentration of sites around the 10 yr hue with value/chroma ratings ranging from 6.4 to 7.4. This may be considered insignificant because the low impact tables (f and g) also concentrate around this hue. However, the 2.5 yr hue only occurred in the high impact lateritic duricrust table (4.3 d), which may be a direct result of the high iron content in the soil and indicative of lateritic floaters and a lateritic duricrust. All three sites with the 2.5 yr hue were considered to have had very high impact on the forest overstorey (*E. marginata, Allocasuarina fraseriana*) due to *Phytophthora cinnamomi*.

4.4 Vegetation

One hundred and thirty four (134) different plant species were identified from 74 high and low impact plots and treated to discriminant analysis to derive linear discriminant functions for each defined species (Fisher 1936). Fisher's linear discriminant functions are designed to maximise the separation between the species and provide a base to allocate species into two linear discriminant functions (high and low impact). Of the 134 species originally sampled, 57 were isolated on the basis of their site fidelity expressed by variance ratios.

The sum of the variance ratios (B) of species present on a site may be compared as Z scores between the linear discriminant functions. The discriminant function with the highest Z score is the applicable function for the site.

$$\text{i.e.} \quad Z = A + B_1S_1 \ldots\ldots\ldots B_nS_n$$

Vegetation abundance was recorded on a further 6 *P. cinnamomi* test sites (4 low and 2 high). Only 1 out of 4 low impact sites had a corresponding low impact Z score, but both high impact sites had accurate Z scores.

With further sampling it is hoped to increase the accuracy of this method of predicting *P. cinnamomi* impact.

5 DISCUSSION

5.1 Distribution of Impact Plots

Cluster position of high and low impact plots as described in section 4.1 of Results may be explained by the following geological characteristics (refer App.III).

Clusters 1 and 2 (high impact) may be associated with the remnant laterite duricrust (McArthur and Clifton,1975,p 7) present in the Dwellingup, Hester and Ellis Creek landforms of the Darling Plateau.

Cluster 3 (high impact) is also associated with remnant laterite duricrust but situated on the low plateau.(McArthur and Clifton 1975 p 7.)

Cluster 4 (high impact) is also part of the Great Plateau (Jutson 1934) containing remnant pockets of duricrust as part of the Beardmore ridge (Churchward *et al.*,1982,p 13).

Cluster 5 (high impact) plots found in this area were associated with shallow soils overlying heavy clays and laterite duricrusts. There is no text to support the reason for a cluster of high impact *P. cinnamomi* sites in this area.

Clusters 6 and 7 (low impact) are associated with the dissected Darling Plateau formed by the Donnelly River. Soils in this landform increase in fertility towards the valley bottom (McArthur and Clifton,1975,p 14).

Clusters 8 and 9 (low impact) are formed as a result of predominant red and yellow podzols through these areas. Red earths, often referred to as karri loams make up significant ports of the Crowea, Keystone, Mattaband and V_1 units. Yellow earths have slightly shallower surface horizons and make up major proportions of the Bevan, Crowea, Mattaband, Collis and Keystone units (Churchward *et al.* 1982 p 22).

5.2 Vegetation

Vegetation analysis is still incomplete at this stage. Further field and computer analysis of all data is required to test the accuracy of the linear discriminants. The sample size will be increased with further field investigation and from this a test for accuracy may be developed.

5.3 Soils

Soil texture, colour and depth all varied through the range of high and low impact *P. cinnamomi* sites surveyed. Soil colour had little observable variation, whereas soil texture and depth had distinct variations between impact categories.

From the results 4.3.1, the sand texture grade changes to greater proportions of clay and loam textures from the high to the low impact sites.(Table 4.3 a,b,c).

This change can be related to the landforms associated with the high and low impact *P. cinnamomi* plots. The sandy textures occurring on the lateritic uplands and seasonally wet flats and drainage lines. The loam and clay textures occurring with the more dissected landforms associated with the low impact *P. cinnamomi* plots.

The soil depth also varied according to the landform and as a result impact categories changed. Shallow soils on the upland lateritic landforms were associated with the high impact plots and in some situations wind blown trees were observed. Soils of greater depth often occurred on the more dissected landforms (*e.g.*Donnelly, Crowea b, Valley landform units)

Poor drainage characteristics were observed on landforms associated with the high impact *P. cinnamomi* plots (*e.g.*concreted laterite,laterite floaters and plant species indicating poor drainage ,refer,"Handbook for identifying Southern Jarrah Forest Site Types"). Whilst fewer drainage problems were observed on the dissected landforms.

Soil colour had little variation, with the majority of soil colours occurring in the 10 yr hue (Table 4.3 d,e,f). However, one hue (Table 4.3 d),was found to be quite separate from the common percentage.

This group is in the 2.5 yr hue with value and chroma ratings of between 5.1 and 7.5. This soil colour was associated with plots occurring on very high impact *P. cinnamomi* infections.

5.4 LANDFORMS

The Following Extract from Churchward *et al.* (1982) Describes the Basis for his Allocation of Landform and Soils types of the South Coast and Hinterland, W.A., Northcliffe to Mt Many Peaks

"The study area, forming the southern fringe of the Great Plateau of Western Australia (Jutson 1934), is composed of precambrian crystalline rocks partially overlain by various consolidated and unconsolidated sediments. A deeply weathered mantle occurs extensively on both granitoid and sedimentary rocks. This mantle can have an upper horizon of sesquioxidic crusts and nodules over mottled and pallid kaolinised country rock, a sequence of horizons that is sometimes referred to as the laterite profile (Stephens 1946). There has been differential stripping of the mantle with subsequent exposure of the deeper horizons and of country rock while the resultant detritus has been transported down slope.

This old land surface has been subject to a long and complex history of events and processes which are expressed as variations in topography, soils and hydrology. These factors together with the nature of the rock types, form the basis for recognition and classification of mapping units.

Most of the units are grouped according to whether they are associated with extensive areas of unconsolidated surficial deposits. Division within these broad lithologic groups is based on local relief, slope and drainage patterns to give landform units which are

identified by a local name. Some units have fairly uniform soils but others, with definable variations, are subdivided. Major or minor valleys have been recognised, generally depending on whether the associated stream is permanent or seasonal."(p.11-25)

The following are landform units found in the survey.

5.4.1 *Hester Landform Unit*

The Hester landform often occurs as narrow ridge crest zones, with soils consisting of duricrust, gravels and sands. The gravelly duplex soils on the flanks of the crests possibly reflect greater stripping related to the deep dissection of the Blackwood River (Atlas of Natural Resources, 1982 p 28).

Southern Jarrah Forest Site Type (SJFST) P, S and R occurred consistently on the Hester landform (Table 4.2 g,h). This association of landform and SJFST is further emphasised by similar soil and vegetation characteristics as described in the "Atlas of Natural Resources"; 1980, and "Handbook for the Identification of Site Types in the Southern Jarrah Forest"; 1986.

Site types P and R were exclusively associated with high impact *P. cinnamomi* infections. This association of high impact with types P and R is also noted in the report "Site Classification in

the Southern Jarrah Forest" (Strelein, 1986). However site type S was associated four times with high impact *P. cinnamomi* infections and twice with a low impact *P. cinnamomi* infection (Table 4.2 g,h).

Conditions on site types P, R and S become seasonally favourable to the pathogen with higher moisture contents than other Southern Jarrah site types, as the relationships of site and soil moisture which favour activity of the fungus are improved (Shea, 1975 p.xx). In type S these conditions are more localised and patchy, being related to minor topography, drainage and geological features (Strelein, "Site classification",1986,p.47). These localised and patchy conditions combined with the broad category of the S Southern Jarrah Forest Site Type (Strelein, 1986 p 24) account for the variation of *P. cinnamomi* impacts displayed on the Hester unit. However, where the Hester unit contains P or R types then these types can be regarded as potential high impact sites.

5.4.2 *Dwellingup Landform Unit*

The Dwellingup landform occurs as broad upland crests, with soils dominated by duricrust, gravels and sands (Atlas of Natural Resources, 1982 p 28).

Southern Jarrah Forest Site Type P and S occurred consistently on the Dwellingup unit (Table 4.2 g) and were exclusively associated with high impact *P. cinnamomi* infections. The occurrence of P and S site types on the Dwellingup unit is again further emphasised by similar soil and vegetation characteristics as described in the "Atlas of Natural Resources"; (1980) and "Handbook for the Identification of Site Types in the Southern Jarrah Forest";(1986).

A relationship between Southern Jarrah Forest Site Type S and high impact *P. cinnamomi* infections has also already been shown in this report (refer 5.4.1). However, no low impact *P. cinnamomi* sites were recorded on the Dwellingup landform. This may be due to the small sample of high and low impact sites. However, it is safe to assume that a low impact S type may exist on the Dwellingup landform because of its association with the Hester landform as part of a common group known as the Dwellingup family (Churchward verbal communication 1987).

5.4.3 *Ellis Landform Unit*

This landform mapping unit was first observed with the preparation of a dieback map for the Ellis Creek forest block in the Nannup district (Helyar and Gillard, 1985). The Ellis unit is associated with Dwellingup Family of landform units (Churchward, 1987,verbal communication).

The unit occurred in sizes ranging from 1 hectare through to 25 hectares, because of this size the unit is not mapped on any large scale landform and soil maps available.

The unit is typically described as having concreted pisolitic laterite duricrust and very shallow A_1 horizon (5-30cm). The duricrust is frequently exposed to the surface and dark colouration (purple - black) of the pisolitic laterite may be observed. Surface gravel stones are quite abundant and are heavy due to an increased iron content. As a result of their shallow duricrust all Ellis units have impeded drainage and wind blown trees commonly occur.

The overstorey component of the unit is comprised of equal admixtures of *Eucalyptus marginata* and *E. calophylla*. A dense midstorey of *Banksia grandis* may occur on sites uninfected by *P. cinnamomi*. The shrub layer commonly consists of *Agonis parviceps, Bossiaea aquafolium, Hovea chorizemfolia, Leucopogon capitellatus, Patersonia umbrosa* and *Podocarpus drouyniana*. Less consistently occurring shrub species are *Adenanthos obovata, Bossiaea linophylla, Acacia pulchella, Leucopogon propinquus, Macrozamia reidleii* and *Xanthorrhoea gracilis*.

Southern Jarrah Forest Site Type P (Table 4.2 g) occurred consistently on this unit. The occurrence of P site types on the Ellis unit is supported by similar soil and vegetation

characteristics described in "The Handbook for Identification of Site Types in the Southern Jarrah Forest"; 1986 and from the results in this report.

As a result of this association, the Ellis unit can be regarded as a potential high impact unit.

5.4.4 *Mungardup Landform Unit*

This unit occurs as broad shallow depressions in the Blackwood Plateau. The Blackwood Plateau is a down faulted block of sedimentary rocks between the Darling Scarpe and the Naturaliste-Leeuwin Ridge (Atlas of Natural Resources). The Mungardup Landform supports a mixture of open forest of jarrah, marri and open woodland of *B. attenuata* and *B. ilicifolia*.

Of the 3 sites classified as Mungardup Landform units,one was given SJFS type A and two were classified as SJFS type B. These types are commonly poorly drained with clay subsoil.

This is the first evidence of *P. cinnamomi* high impact forest associated with SJFS Types A and B in this report. Both types are infertile with low growth potential and may be regarded as potential high impact sites in association with the Mungardup landform.

5.4.5 *Caldyanup Landform Unit*

This landform unit comprises of poorly drained plains and drainage floors with occasional low rises of sand or weathered country rock. A unique characteristic of this unit is a humus podsol layer found below the A_1 horizon (Churchward *et al.* 1982).

Southern Jarrah Forest Site Types F, B, and R occurred once each on the Caldyanup unit. Descriptions of SJFS Types F, B and R are consistent with the Caldyanup description (refer App.IV).

The Caldyanup landform can be used in conjunction with the three SJFS Types associated with it, to form a common group of site types characterised by open flats of low quality *E. marginata* over humic sands.

All three SJFS Types have low growth potential because of infertile soils, this in conjunction with poor drainage caused by the podsolic layer may result in high impact on the jarrah overstorey.

5.4.6 *Trent (Tr) Landform Unit*

The Trent landform unit is divided into two classes based on topography; Tr C - mainly on ridge crests with yellow duplex soils, some gravelly sand and some lateritic duricrust Tr S - Deep grey sands on slopes with some iron podsols (Churchward *et al.* 1982).

Two very high impact sites were found on the Tr C landform, both were given a SJFS Type P. The description of the Tr C unit is similar to the P type in soils but some differences exist between vegetation descriptions, in fact, the Tr S class is more suited to the SJFS Type P vegetation description. However, the mapping units on the 'Landform and Soils Maps, Northcliffe to Many Peaks' do not recognise the crest (C) and slope (S) classes of the Tr landform described in the manuscript (Churchward *et al.* 1982) and therefore the Tr unit in conjunction with SJFS type P must be regarded as having a potential high *P. cinnamomi* impact when referring to the mapping units.

5.4.7 *Bevan (BE) Landform Unit*

This unit is characterised by undulating plains with gentle slopes (<5°), with granitic rocks and sporadic occurrence of unconsolidated sandy deposits.

The Bevan landform unit is divided into two soil classes; BEy (yellow) and BEb (brown) both of which were found in the survey of low impact sites.

The BEy class has duplex soils with a grey brown sandy surface, an A_{2} horizon which is sometimes bleached and a clay B horizon variously mottled yellow, yellow-brown, light grey and reddish-brown. The B horizon has a hue of 10 yr and little structure.

The BEb class consists of light brown sandy loam surface and an unbleached A_{2} horizon, with a clay B horizon mottled yellow-brown and red-brown. The A_{1} horizon may be up to 1m thick and usually contains some gravel (Churchward *et al.* 1982). The results of this report show BEy and BEb occurring in association with K SJFS type (Table 4.2 h). The soil description of the K type in the 'Handbook for Identification of Site Types in the Southern Jarrah Forest', is similar to the BEy and BEb descriptions with the possible inclusion of quartz grit as well as lateritic gravel.

However, vegetation descriptions by the two manuscripts are markedly different between K type and Bevan, brown and yellow. Even so, Strelein does recognise that the K type can occur on the Bevan landform unit (Handbook p 28).

The results of this report show two low impact sites on the Bevan landform unit. It is difficult to draw conclusions from this small sample, but some relationship between Bevan and K is shown without reference to results. Strelein recognises that K type should display a low potential impact towards *P. cinnamomi* (Handbook for Identification of Southern Jarrah Forest Types p 27) and therefore Bevan landform unit could also show a tendency towards low potential impact.

5.4.8 *Crowea (CR) Landform Unit*

This landform occupies crests and upper slopes of spurs and ridges which is representative of the dissected Darling Plateau. The dissection has occurred forming local divides in the Warren and Donnelly River drainage systems.

The CR unit is divided into five soil classes as descibed in sect 4.2.2 of this report.

The Crowea yellow (CRy) class contains duplex soil profiles with pale grey-brown sand to sandy loam A horizon, 20 - 40cm thick. This A_1 horizon is over a yellow, yellow-brown and grey mottled clay B horizon, A_1 horizons may contain low to moderate amounts of lateritic gravel.

This yellow class supports a tall 30 - 40m, forest of *E. marginata* and *E. calophylla* with a scattered understorey of *Banksia grandis* and *Persoonia longifolia*. A dense shrub layer of *Bossiaea linophylla, Acacia myrtifolia, A. divergens, A. pulchella* may exist and in conjunction with creepers *Hardenbergia comptoniana* and *Kennedia* species (Churchward *et al.* 1982).

Southern Jarrah Forest Site Type T and S occurred on the Crowea yellow class 4 and 2 times respectively (Table 4.2 h) as low impact *P. cinnamomi* infections. The occurrence of the T and S SJFS types on the Crowea yellow class is supported by similar soil and vegetation characteristics described in the ' Handbook for identification of site types in the Southern Jarrah forest'. From these results the Crowea yellow landform unit may be recognized as having a low potential for P.cinnamomi impact.

The Crowea laterite (CR1) occurs on the crests and ridges of the dissected Darling plateau. Soils are composed of sand to sandy loam containing moderate to high amounts of lateritic gravels. lateritic duricrusts occur commonly on this class.

The Crowea laterite class supports a tall forest of *E. marginata* and *E. calophylla* with an understorey composed of *Banksia grandis* and *Persoonia longifolia*. The shrub layer is composed of *Bossiaea linophylla, Acacia pulchella, A. myrtifolia, Xanthorrhoea gracilis* and *X. preissii*.

Southern Jarrah Forest Site Type S occurred 3 times (Table 4.2 h) on the Crowea laterite as low impact *P. cinnamomi* sites. This evidence suggests that the Crowea laterite is a potential low impact class. However, the occurrence of the lateritic duricrust raises the possibilities of moderate to high impact *P. cinnamomi* impact sites occurring on the sites where the duricrust exists (as in type P).

The Crowea brown class (CRb) contains yellow duplex soils with brown gravelly A horizons, 5 - 100cm thick, over a brown yellow mottled clay subsoil. Red earths may be associated with the Crowea brown occurrence.

Crowea brown supports tall open forests of *E. diversicolor, E. calophylla* and *E. marginata*. An understorey of *Banksia grandis, Allocasuarina decussata* and *Persoonia longifolia* occurring with a dense shrub layer of *Acacia pentadenia, A. urophylla, Hovea elliptica*.

Southern Jarrah Forest Site Type T and S occurred on this Crowea class, twice each as low impact *P. cinnamomi* infections (Table 4.2 h). The occurrence of type T can be explained by similarities in the soil and vegetation descriptions of the Crowea brown and site type T. However, site type S is a broad category with variable understorey structure, site drainage and fertility (Strelein Handbook, 1986 p 24).

The two low impact plots occurred at the high fertility end of the S category with a range of high fertility indicator species occurring, *Pteridium esculentum, Hovea elliptica, Leucopogon verticillatus*,Strelein. Handbook, 1986 p43-50, on loamy clay soils.

Site type S and more commonly T occur on fertile well drained sites which have moderate to good growth potential (Strelein 1986 p 25,27). The Crowea brown class is a fertile well drained landform. As there are four low impact sites on this class the Crowea brown may then be considered to have a low potential *P. cinnamomi* impact.

Crowea sand (CRd) is characterised by duplex profiles with a grey sandy surface, strongly bleached A_2 horizon, and a pale yellow, brown and grey mottled subsoil. A dark brown organic horizon or ferruginous nodules are common at the interface between the A and B horizons. The A horizon ranges in depth from 20 to 40cm.

The forest on these sites is composed of tall open *E. marginata* and *E. calophylla*. There is an understorey of *Banksia grandis* and *Persoonia longifolia* with a shrub layer of *Acacia myrtifolia, Agonis parviceps, Kingia australis, Xanthorrhoea preissii, Podocarpus drouyniana* and *Macrozamia reidleii* (Churchward *et al.* 1982).

Southern Jarrah Forest Site Type S occurred on this class as a low impact *P. cinnamomi* infection (Table 4.2 h). Strelein in his Handbook, reports that Southern Jarrah Forest Site types N, I and P are the most likely site types to occur on the CRd (Strelein 1986 p 18). This low impact site was recorded as a pS admixture. The P influence is noted on this site. As mentioned in this report (5.4.1) from Strelein's study site type P is a potential moderate to high impact site.

As there is only one low impact occurring on this Crowea class there are no real conclusions to be drawn from these results. However, with the likely occurrence of P sites on the Crowea sand the Crowea sand may be recognised as a potential high impact class.

5.4.9 *Collis Landform Unit*

These are low hills or low hilly terrain with smooth flanking slopes and with less than 20m local relief. Soils are composed mainly from deeply weathered granitic rocks, with the occasional sparadic outcrop. Lateritic duricrust occurs sporadically and is overlain by shallow sands. Yellow duplex soils are dominant with four classes based on textures in the surface horizons and hue of the B horizon (Churchward *et al.* 1982).

Five plots occurred on the Collis unit, four on the Collis yellow class (COy) and one plot on the Collis shallow (COp) class.

Three of the four plots occurring on the yellow class were associated with low impact *P. cinnamomi* infections and the other with a high impact *P. cinnamomi* infection.

The Collis yellow has yellow duplex soils with gravelly pale grey-brown sand or loamy sand 25 - 35cm thick. The B horizon is composed of mottled yellow, grey and brown clay. Lateritic duricrust is sometimes present in this class. Collis yellow supports a tall *E. marginata* and *E. calophylla* forest with an understorey of scattered *Banksia grandis* and *Persoonia longifolia*. The shrub layer consists of *Bossiaea linophylla, Xanthosia rotundifolia, Acacia species, Hakea species* and creepers *Kennedia coccinea, Hardenbergia comptoniana* (Churchward *et al.* 1982).

The three low impact *P. cinnamomi* infections were of the I, S and T site types. The three types all have similar soil and vegetation descriptions as that of the Crowea yellow and according to Strelein (Handbook 1986 p 19,24,26) I, S and T may be found on the Collis yellow.

The final plot occurring on the Collis yellow was on a high *P. cinnamomi* impact infection. The Southern Jarrah Forest Site type associated with this category was an admixture of S and P (SP). The occurrence of P on the Crowea yellow is noted in Strelein's Handbook (p 16).

From these results on the Collis yellow class the Southern Jarrah Forest Site types I, S and T may be associated with low *P. cinnamomi* impact. However, site type I may possibly incur a greater *P. cinnamomi* impact when the forest stand is opened up or disturbed (Strelein 1986 p 20). P sites occurring on the Collis yellow however may be associated with high *P. cinnamomi* impact.

A single high impact plot occurred on the Collis shallow landform class. The associated SJFS type was an N. The N type corresponds to the soil description of the Collis shallow unit, consisting of shallow grey sands over clay. These sites support a Jarrah woodland with a dense low shrub layer of *Hibbertia, Xanthosia, Agonis and Isopogon* species. These characteristics suggest that the Collis shallow class may be a potential high impact class.

5.4.10 *Major Valleys*; Units Associated With Drainage Lines

The results of this report show two low impact sites occurring on Major Valley land form units (V_2 and V_3) (Table 4.2 h). These two classes have similar vegetation characteristics, but the V_2 unit has yellow duplex soils where as the V_3 unit soils are deep and loamy (Churchward *et al.* 1982).

Table 4.2 h also shows Southern Jarrah Forest Site types S and K in association with the major valley units. Once again the sample is too small (two low impact sites) to supply any conclusions, except that the major valley unit did not occur on any of the 42 high impact sites and that the landform unit and SJFS types have characteristics associated with low potential *P.c.* impact.

The following landforms to be discussed, occurred through high and low impact sites.

5.4.11 *Mattaband Landform Unit (MT)*

The Mattaband unit occurred 4 times throughout the survey, twice on low impact sites and twice on high impact sites.

The two low impact sites were both found to have Southern Jarrah Forest Site type P.

The two high impact sites had Southern Jarrah Forest Site types P and S.

Vegetation and soil descriptions of the Mattaband unit, class yellow, are most similar to the Southern Jarrah Forest Site type P description and therefore an association is formed between the two types. However, this does not explain the occurrence of the P type on a low impact site. Results of this report have shown P type in strong association with high impact sites (Table 4.2 g).

P types may have clay or concreted laterite subsoils (Strelein 1986 p 16), but it is the types with laterite that are entirely associated with high impact *P. cinnamomi* sites. In summary, the P site type with concreted laterite will mostly be associated with potential high impact forest. However, the P type with clay subsoil is a variable combination with an unknown potential for *P. cinnamomi* impact. Therefore, the Mattaband yellow class (with lateritic duricrust), may be considered a potential high *P. cinnamomi* impact class, but the Mattaband shallow and duplex sand classes may be considered variable or unknown *P. cinnamomi* impact classes.

To support the above statement Southern Jarrah Forest Site types P and S were located on Mattaband yellow high impact sites. Type P was also located on a Mattaband shallow high impact site.

5.4.12 *Keystone Landform Unit*

The Keystone unit has four soil classes (d,b,y and p). Two high impact sites were located on the Keystone unit, one each on the brown and yellow classes. One low *P. cinnamomi* impact site was also located on the Keystone brown class.

The Keystone yellow class consists of yellow duplex soils over either mottled yellow and light grey clays or more commonly, lateritic duricrust.

The high impact site on the Keystone yellow class was recorded as a P SJFS type. There are common soil and vegetation characteristics between the Keystone yellow class and the P SJFS type. The occurence of a high impact plot suggests that a high potential for *P.c.* impact is possible on this class where shallow soils occur.

The Keystone brown class is dominated by brown duplex soils with brown gravelly surfaces over yellow brown clay subsoils. Lateritic duricrusts occur on the crests and upper slopes of the class. Both high and low *P.c.* impact sites were recorded on the Keystone brown class. The low impact plot occurred on the deep brown soils associated with this class and had a SJFS type K . The high impact plot occured on shallow lateric duricrust high in the profile, on P SJFS type. These results suggest that the majority of the Keystone brown class is subject to low potential *P.c.* impact, except were associated with lateritic duricrust, resulting in an impeded drainage site of low fertility.

5.4.13 *Stream Landform unit*

Stream categories are classified as minor valleys in the granitic plateau often upstream from $Valley_2$. $Stream_1$ units are usually less than 20m deep, often with swampy floors and sometimes without stream channels.

Soils are composed of gravelly yellow duplex soils on smooth flanking slopes with some red earths or brown gravelly duplex soils. Peatty and humus podzols occur on deep sands of the swamp floor.

The forest is usually a mixture of *E. marginata, E. calophylla* and *E. diversicolor* with a scattered understorey of *Banksia grandis, Agonis flexuosa* and *Persoonia longifolia*. The dense shrub layer varies with the different mixtures of forest growing on the site (Churchward *et al.* 1982). Three plots were recorded on the Stream, category, two were high impact plots and one low impact plot.

The two high impact plots were of the Southern Jarrah Forest Site type S and P, both of these plots had influences of R Southern Jarrah Forest Site type also. As the stream, vegetation and soil description is so variable, the S and P site types both can occur on this unit. The R influence is noted because of the deep sands present on both these sites. The low impact plot was of the Southern Jarrah Forest Site type P and was also recorded as having an R site type influence.

From this information the stream can be seen as having varied soil and forest structure. There will be therefore a variety of Southern Jarrah Forest Site types occurring on this unit and *P. cinnamomi* impact will also be varied.

6 CONCLUSIONS

The results of this report test the prediction of *P. cinnamomi* impact in the Southern Jarrah Forest in three ways;

a. Predicting impact using plant indicator species.
b. Predicting impact using Southern Jarrah Forest Site types.
c. Predicting impact using landform and soil types.

6.1 Localised Prediction of *P. cinnamomi* Impact

Small areas of forest may be tested for potential *P. cinnamomi* impact by analysing presence of plant indicator species. However, the accuracy of this method is not more than 50% at this stage. Further studies are being done to increase the accuracy level of this method. The area of forest that may be tested by this method is limited to the area of forest that may be covered by strip line survey, together with the practical limitations of time and manpower.

6.2 Broadscale Prediction of *P. cinnamomi* Impact

The results of this report have shown that certain landforms are exclusively associated with either low or high *P. cinnamomi* impact categories. These landforms, in association with Southern Jarrah

Forest Site types, may be regarded as the best available information for predicting *P. cinnamomi* impact on a broadscale basis. Other landforms associated with both high and low *P. cinnamomi* impact sites may also be used for predicting *P. cinnamomi* impact, but sites tested for impact on these landforms should not vary from descriptions of soil and vegetation given in the discussion section of this report. Also, not all of the landform mapping units described on the C.S.I.R.O. maps (Northcliffe to Mt Many Peaks) were found in the results and no conclusions can be made about the landforms that were not found in this survey.

Broadscale prediction of *P. cinnamomi* impact is also possible using Southern Jarrah Forest Site types and large scale colour aerial photography (70mm and 230mm formats). If Southern Jarrah Forest Site types can be recognised by characteristics visible from the air (e.g. P type recognised by Casuarina and ironstone floaters), then impact categories may be given to associated Southern Jarrah Forest Site types.

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APPENDICES

APPENDIX I

PLOT NUMBER .....

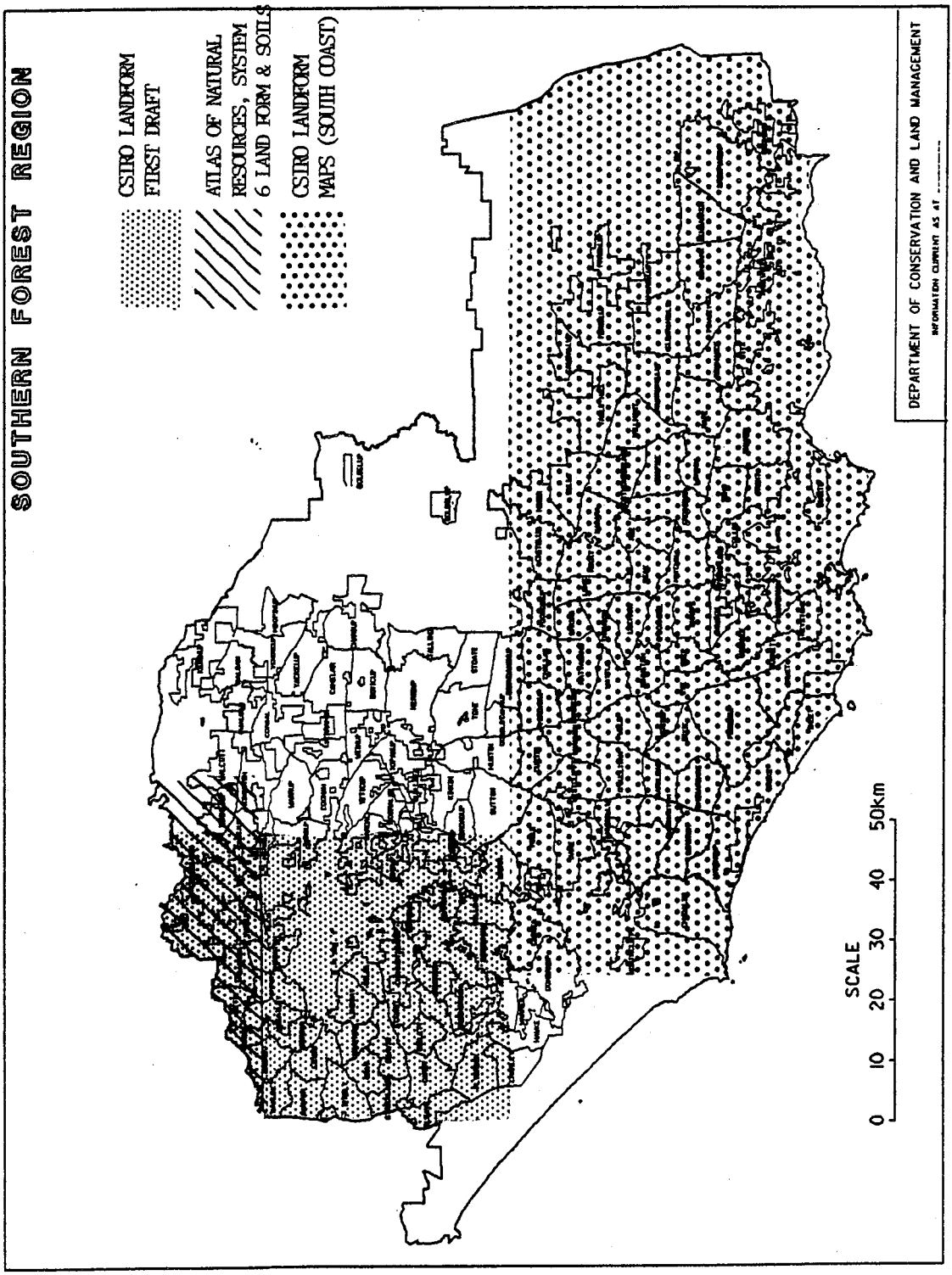
Acacia alata
Acacia browniana
Acacia divergems
Acacia drummondii
Acacia extensa
Acacia myrtifolia
Acacia nervosa
Acacia pentadenia
Acacia pulchella
Acacia saligna
Acacia urophylla
Acacia stenoptera
Adenanthos barbigera
Adenanthos cuneatus
Adenanthos meissneri
Adenanthos obovata
Agonis flexuosa
Agonis linearifolia
Agonis parviceps
Agonis hypericifolia
Anarthria prolifera
Anarthria scabra
Anigosanthos flavida
Astartea fascicularis
Astroloma ciliatum
Astroloma epacridis
Astroloma pallidum
Baeckia camphorossmae
Banksia attenuata
Banksia grandis
Banksia ilicifolia
Banksia littoralis
Banksia quericifolia
Banksia sphaerocarpa
Beaufortia sparsa
Beaufortia decussata
Billardiera floribunda
Boronia crenulata
Boronia denticulata
Boronia gracilipes
Boronia spathulata
Bossiaea eriocarpa
Bossiaea laidlawlana
Bossiaea linophylla
Bossiaea ornata
Bossiaea webbii
Brachysema latifolia
Brachysema praemorsum
Burtonia scabra
Callistemon speciosus
Calothamus lateralis
Casuarina decussata
Casuarina fraserana
Casuarina humilis
Choralaena quercifolia
Chorizema ilicifolium
Clematis pubescens
Conospermum caeruleum
Conospermum flexuosa
Crowea dentata
Cyathachaete aveneca
Dampiera alata
Dasypogon bromeliaefolius
Dasypogon hookeri
Daviesia eordata
Daviesia alternifolia
Darwinia citriodora
Darwinia oederpides
Darwinia vestita
Dianella revolutus

Dodonea attenuata
Dodonea ceratocarpa
Drosera gigantea
Dryandra armata
Dryandra hipinnatifida
Dryandra carduaceae
Dryandra formosa
Dryandra nivea
Dryandra sessilis
Eristemon spicatus
Euandra aristata
Eucalyptus calophylla
Eucalyptus cornuta
Eucalyptus decipiens
Eucalyptus diversicolor
Eucalyptus guilfoylei
Eucalyptus jacksoni
Eucalyptus marginata
Eucalyptus megacarpa
Eucalyptus occidentalis
Eucalyptus patens
Eucalyptus rudis
Eucalyptus staeri
Eucalyptus wandoo
Gahnia trifida
Gastrolobium bilobum
Gastrolobium forrestii
Gastrolobium spinosum
Gompholobium ovatum
Gompholobium polymorphum
Grevillea brownii
Grevillea brevicuspis
Grevillea occidentalis
Grevillea pilulifera
Grevillea pulchella
Grevillea quercifolia
Hakea ambigua
Hakea amplexicaulis
Hakea ceratophylla
Hakea cyclocarpa
Hakea elliptica
Hakea florida
Hakea lasianthoides
Hakea lissocarpa
Hakea
Hakea prostrata
Hakea ruscifolia
Hakea trifurcata
Hakea undulata
Hakea varia
Hardenbergia comptoniana
Hemiandra pungens
Hibbertia amplexicaulis
Hibbertia cunieformis
Hibbertia glaberrima
Hibbertia pulchra
Hovea chorizemifolia
Hovea elliptica
Hypocalymma angustifolium
Hypocalymma robustum
Hypocalymma strictum
Isopogon attenuatus
Isopogon formosus
Isopogon sphaerocephalus
Jacksonia furcellata
Johnsonia lupulina
Kennedia prostrata
Kennedia coccinea
Kingia australis
Kunzea recurva

PLOT NUMBER .....

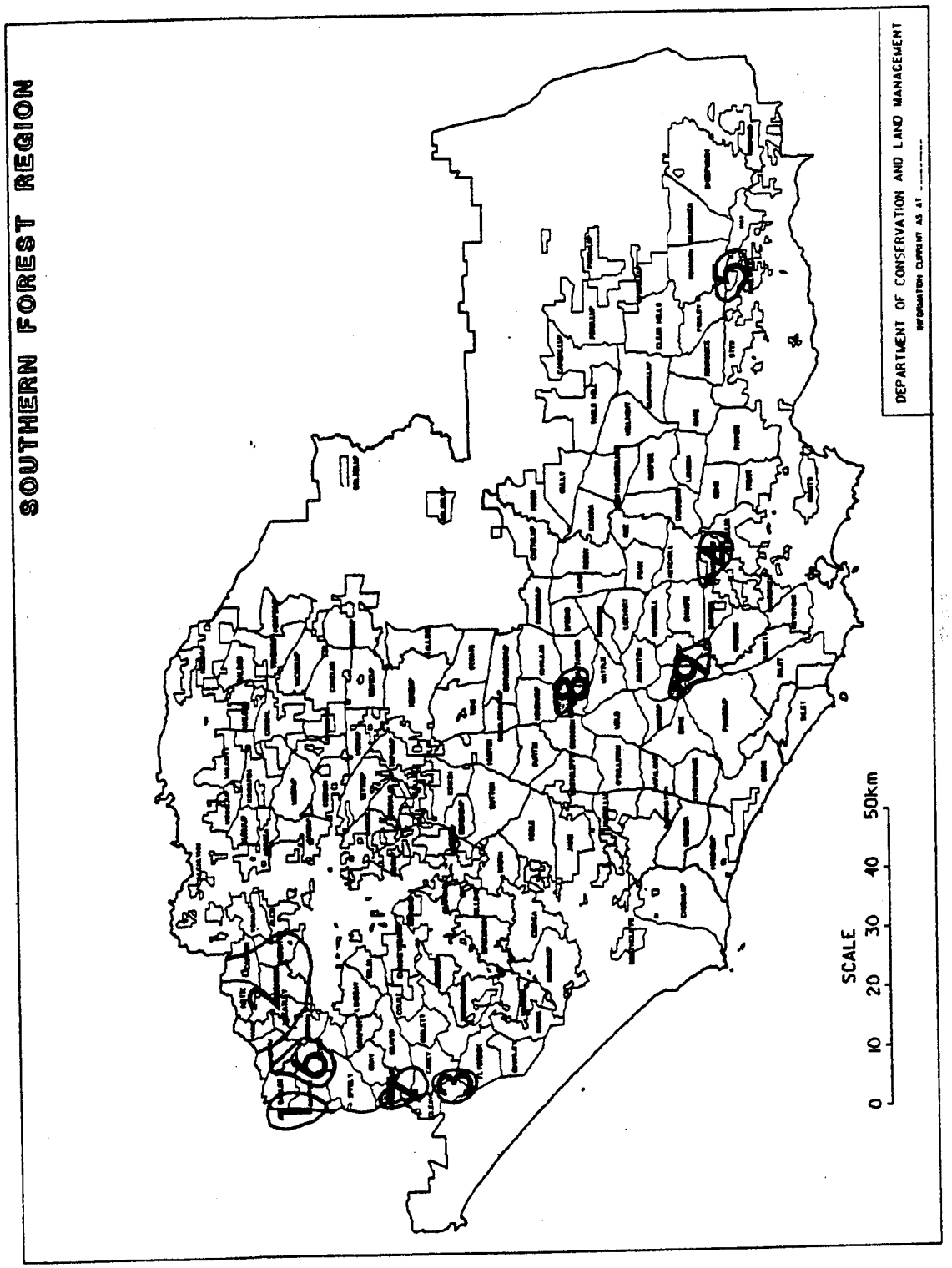
Kunzea west.ta
Labichea punctata
Lasiopetalum floribundum
Lechenaultia biloba
Lepidosperma angastatum
Lepidosperma tetraquetrum
Leptocarpus scariosis
Leptomeria cunninghamii
Leptospermum crassipes
Leptospermum ellipticum
Leptospermum erubescens
Leptospermum firmum
Leucopogon australis
Leucopogon capitellatus
Leucopogon concinnus
Leucopogon oxycedrus
Leucopogon pendulus
Leucopogon propinquus
Leucopogon pulchellus
Leucopogon revolutus
Leucopogon verticillatus
Logania vaginalis
Loxacarya fascicularis
Loxacarya flexuosa
Loudonia aurea
Macrocamia reidlei
Melaleuca incana
Melaleuca preissiana
Melaleuca scabra
Melaleuca thymoides
Melaleuca viminea
Mesomelaena tetragona
Mirbelia dilatata
Olax benthami
Opercularia hispidula
Orthrosanthos
Oxylobium lanceolatum
Patersonia xanthina
Persoonia longifolia
Persoonia microcarpa
Petrophile diversifolia
Petrophile linearis
Petrophile longifolia
Petrophile serruriae
Phylanthus calycinus
Platytheca verticillata
Podocarpus drouyniana
Pteridium esculentum
Pultenea ericifolia
Pultenea reticulata
Scaevola microphylla
Scaevola striata
Sollya leterophylla
Sphaerolobium medium
Stypandra imbricata
Stirlingia latifolia
Strangea stenacarpoides
Sywaphae polymorpha
Styplelia tenuifolia
Tetratheca setigera
Thomosia grandiflora
Thomosia quercifolia
Tremandra stelligera
Trymalium ledifolium
Trymalium spathulatum
Verticordia plumosa
Viminaria juncea
Xanthorrhoea gracillis
Xanthorrhoea preissii
Xanthosia atkinosonia
Xanthosia rotundifolia

SITE TYPE MAP COVERAGE FOR SOUTHERN FOREST REGION



GEOGRAPHIC DISTRIBUTION OF
SURVEY PLOT CLUSTERS

1 to 5 - High Impact
6 to 9 - Low Impact



APPENDIX IV

SOUTHERN JARRAH FOREST TYPES

G.J. STRELEIN

SOUTHERN JARRAH SITE CLASSIFICATION

TYPE X

1. General Description

Low to moderate quality forest (JMB) on deep sands of ridges and slopes of lower fertility with dense understorey.

2. Occurrrence

These sites are from the high rainfall coastal areas of low to moderate dissection. They generally occupy smaller but scattered areas in moist sites. Type X may occur on landform types COy, COp, COd, Q, A and HA.

3. Soils

The deep sandy soils have some organic matter accumulation in the surface which is generally a grey sand and overlays a leached white sand. There may be some quartz grit and rounded pebbles through the profile (800mm +).

SOUTHERN JARRAH SITE CLASSIFICATION

4. Indicator Species

Acacia myrtifolia, Anigozanthos flavidus, Dasypogon bromeliefolius, Leucopogon propinquus, Macrozamia riedlei, Persoonia longifolia and *Pteridium esculentum* should all be present. *Agonis flexuosa, Bossiaea linophylla, Hovea elliptica* and *Xanthorrhoea preissii* are generally present also. *Acacia browniana, A. pulchella, Anarthria scabra, Banksia grandis, Clematis pubescens* and *Tremandra stelligera* are common.

5. Management

These infertile sites would only have low growth potential. The moist, infertile soils may be susceptible to dieback but the impact should be low. Regeneration numbers may be low and can be difficult to establish in these heavy scrub types.

TYPE N

1. General Description

Low to moderate quality forest (JMB) on infertile sandy podzols, generally on wet poorly draining uplands and slopes with tall dense undergrowth, particularly tea-tree. This type includes sites where karri may be present in low numbers.

SOUTHERN JARRAH SITE CLASSIFICATION

2. Occurrence

These sites occur mainly in the high rainfall moderately dissected country, are common in these areas and can occur in large units. Type N may occur on landform types CRd, Ky, Kp, MTd, COb, COp, COd, A and HA.

3. Soils

The soils are variable but all have a grey sandy surface, either fine or coarse grey sand or sandy loam. There is often small amounts of quartz grit increasing with depth. There is a change to clayey sand or gradually to a sandy clay at about 300mm with some lateritic gravel, and then to a yellowish clay at about 400mm. On the poorer sites drainage is more impeded by development of a heavier clay layer or hardpan.

4. Indicator Species

Acacia bronwiana is common and some sandier types will have *A. myrtifolia, A. pentadenia* and *Agonis flexuosa* and karri. *Agonis parviceps* usually dominates and *Banksia grandis. Boronia gracilipies, Leucopogon australis, Macrozamia riedlei* and *Persoonia longifolia* are generally present.

SOUTHERN JARRAH SITE CLASSIFICATION

Allocasuarina decussata, Chorizema ilicifolium, Hovea elliptica, Leucopogon concinuus, L. propinquus, Podocarpus drouynianus, Petrophile diversifolia, Pteridium esculentum and *Tremandra stelligera* may be present.

On lower slopes and depressions with poorer drainage and sandier soil *E. megacarpa, E. patens* and *Anarthria scabra* occur and *Acacia myrtifolia, Kingia australis* and *Xanthorrhoea preissii* become more common.

5. Management

The growth potential of these sites would be low to moderate. Dieback does occur but generally with a low impact. However with disturbance and opening up of the stand the impact may become more serious. Regeneration in these scub types is often sparse and can be difficult to establish.

TYPE P

1. General Description

Low to medium quality forest (JMB), with shallow sandy surface soils over clay with impeded drainage, on the uplands and slopes generally with denser, often tea-tree scrub.

SOUTHERN JARRAH SITE CLASSIFICATION

2. Occurrence

This is a common type in the main jarrah forests of moderate to high rainfall areas and moderate dissection, but occurs less frequently north-east of Manjimup. Type P may occur on landform types CRd, Kp, Lp, MTp, MTd, COy, COp, COd, A, HA and TRc.

3. Soils

Generally soils consist of brown or grey sands or sandy loams with varying quantities of fine to medium lateritic gravel over yellowish medium clay or concreted laterite at about 500mm.

4. Indicator Species

Acacia browniana is most common on these sites but *Acacia extensa* may occur. *Agonis parviceps* is usually prominent. ***Banksia grandis, Bossiaea ornata, Hakea amplexicaulis, Hovea chorizemafolia, Leucopogon propinquus, L. verticellatus,*** *Macrozamia riedlei, Persoonia longifolia* and *Podocarpus drouynianus* should all be present. *Loxocarya fascicularis, Patersonia umbrosa, Sphaerolobium medium, Xanthorrhoea gracilis* and *Xanthorrhoea preissii* often occur. *Allocasuarina fraseriana* may occur on some sandy gravel sites.

SOUTHERN JARRAH SITE CLASSIFICATION

5. Management

Generally these are poorer sites with moderate growth potential but there can be quite good forest on sites where the sandy loam surface is deeper. Regeneration numbers can be inadequate on some sites, and difficult to establish if advanced growth is not already present. Dieback can be serious with overstorey impact likely. The feature which distinguishes these sites is the poor drainage.

TYPE R

1. General Description

Generally open low quality forest (JMC), on grey sands and quartz sands in upland depressions, saddles, broad valley heads and drainage lines in moderately dissected gravelly uplands. This type covers a wide range of sites but all with similar characteristics. Generally they have thick scrub and are seasonally wet but dry out very quickly in summer.

2. Occurrence

These sites are mostly restricted in area but widespread throughout the jarrah forest on many landform types and all rainfall zones.

SOUTHERN JARRAH SITE CLASSIFICATION

Type R may occur on landform types Kp, Ks, Lp, Ls, MTp, MTd, COp, COd, CA, PI, BU, MO, Q, A, HA, QN, TRs and F.

3. Soils

The soils are generally a dark grey or grey sand, sometimes loamy sand, overlying sand, often brownish yellow, becoming paler with depth, often with quartz grit and rubble. Frequently it becomes a sandy clay at about 1000mm which may be overlain by a gravel layer or an organic stained hardpan.

4. Indicator Species

Agonis parviceps is generally prominant on these sites. *Acacia extensa, Leucopogon australis, Macrozamia riedlei,* and *Persoonia longifolia* should be present. *Bossiaea linophylla, Banksia grandis, Hakea ruscifolia, Loxocarya fasciculata, L. flexuosa* and *Podocarpus drouynianus* commonly occur.

This type covers a range of similar sites and species such as *Acacia myrtifolia, Adenanthos obovatus, Anarthria prolifera, A. scabra, Agonis flexuosa, Allocasuarina fraseriana, Anigozanthos flavidus, Banksia ilicifolia, Boronia spathulata, Dasypogon bromeliefolius, Kingia australis, Lepidosperma angustatum, Leucopogon concinuus, Melaleuca thymoides, Pultenea reticulata, Scaevola striata, Thomasia grandiflora, Xanthorrhoea preissii,* and *Xylomelum occidentale*, may occur in different situations.

SOUTHERN JARRAH SITE CLASSIFICATION

5. Management

These infertile sites would only have low growth potential. Because of the infertile soils they may be affected by dieback and the impact can be moderate to high. Regeneration numbers on this type are often low and would be difficult to establish.

TYPE I

1. General Description

Low to medium quality forest (JMB) on moist poorly drained sites with gravelly duplex soils in high rainfall areas.

2. Occurrence

This type is more common in the southern high rainfall areas in moderately dissected landscape. It generally occurs on lower slopes but also on uplands where drainage is impeded. Type I may occur on landform types CRy, CRd, Kp, Lp, MTp, COy, COp, COd and TRc.

SOUTHERN JARRAH SITE CLASSIFICATION

3. Soils

There is generally a shallow sandy surface over a clayey sand (sometimes sandy loam) with some quartz grit and small amounts of gravel increasing with depth to about 50%. This changes to a sandy clay or clay at about 300mm or less with about 30% lateritic gravel.

4. Indicator Species

Acacia browniana and *Agonis parviceps* dominate, *Banksia grandis, Kingia australis, Leucopogon australis, L. concinnus, Macrozamia riedlei, Petrophile diversifolia* and *Podocarpus drouynianus* should be present. *Agonis hypericifolia, Bossiaea linophylla, Gompholobium ovatum, Hakea amplexicaulis, H. lasianthoides, Hovea chorizerifolia, H. elliptica, Leptomaria cunninghamii, Leucopogon verticellatus, Loxocarya fasciculata, Persoonia longifolia* and *Xanthorrhoea gracilis* are common.

5. Management

These sites may carry good timber volumes but probably have only low to moderate growth potential. The sites are similar to Type P but moister. Dieback is likely to occur and the impact may be low to moderate or possibly worse with opening up of the stands and disturbance. Some sites may lack adequate regeneration.

SOUTHERN JARRAH SITE CLASSIFICATION

TYPE B

1. General Description

Poor quality blackbutt and jarrah forest (JBbtC). On seasonally wet infertile sands on flats and along drainage lines. Marri is not common on these sites and there is usually a heavy scrub layer. Drainage is very poor.

2. Occurrence

This type does not occupy large areas but is common in the moderate to high rainfall areas of low to moderate dissection. Type B may occur on landform types COd, CM, CA, A, HA, S3 and S4.

3. Soils

These soils consist of coarse grey sands, often with quartz material, sometimes over a light clay or more often deeper sands with an organic hardpan.

SOUTHERN JARRAH SITE CLASSIFICATION

4. Indicator Species

Agonis parviceps dominates, *Pultenea reticulata* and *Kingia australis* should be present. *Adenanthos obovatus*, *Leptomaria cunninghamii* and *Xanthorrhoea preissii* are common. *Acacia browniana*, *A. pentadenia*, *Leucopogon australis*, *L. concinnus*, *Persoonia longifolia* and *Podocarpus drouynianus* may also occur.

5. Management

These poor sites have low growth potential, regeneration numbers are often low and would be difficult to establish in this scrub type. There is some dieback occurrence and the impact may be low to moderate.

TYPE F

1. General Description

Southern treeless flats and swamps with dense low vegetation and sometimes with scattered stunted jarrah. These sites are poorly drained and waterlogged in winter.

SOUTHERN JARRAH SITE CLASSIFICATION

2. Occurrence

There may be only small areas involved but these may become larger and more common in the south. These sites are in the high rainfall areas of low to moderate dissection. Type F may occur on landform types LS, SC, CA, PI and F.

3. Soils

The soils are humic podzols with a thick surface root mat in fine grey sand with some surface quartz material, over a deep fine sand becoming darker with depth (to 800mm +) over clay.

4. Indicator Species

Beaufortia sparsa, Dasypogon bromeliefolius, Evandra aristata and ***Homalospermum firmum*** should occur and species such as ***Adenanthos obovatus, Agonis parviceps, Anarthria prolifera*** and ***Leucopogon australis*** are common.

5. Management

Dieback is likely to be a problem in these flats because although the impact may only be classified as low (understorey only) it is very noticeable on these open flats. The impact may be high in the jarrah fringes asscociated with these flats.

SOUTHERN JARRAH SITE CLASSIFICATION

TYPE S

1. General Description

Good to medium quality (JMB+), predominantly jarrah forest of lower fertility on gravelly podzols often with much surface laterite rock. These sites are variable in the understorey, structure and drainage.

2. Occurrence

These sites are generally found in moderately dissected landscape on the uplands and slopes of higher rainfall areas. This type is widespread where lateritic remnants remain. Type S may occur on landform types BEy, CRy, Ky, Ly, MTy, MTb, COy and TRc.

3. Soils

The soils are mostly brownish-yellow loamy sands with about 50% lateritic gravel and some stone in the profile, changing to a brownish-yellow light clay at about 500mm. Soils can tend to greyish sandier textures in depressions and concave slopes, with less gravel.

SOUTHERN JARRAH SITE CLASSIFICATION

4. Indicator Species

Banksia grandis, Bossiaea linophylla, Boronia gracilipes, Gompholobium ovatum, Grevillea brevicuspis, Hakea amplexicaulis, Hovea chorizemifolia, H. elliptica, Leptomaria cunninghamii, Leucopogon verticillatus, Macrozamia riedlei, Persoonia longifolia, Petrophile diversifolia, Podocarpus drouynianus, Sphaerolobium medium and *Xanthorrhoea gracilis* are all generally present. Others which are common on some sites are *Acacia browniana, A. myrtifolia, A. pulchella, Agonis hypericifolia, Bossiaea laidlawiana, B. ornata, Crowea angustifolia, Hakea lasianthoides, Isopogon sphaerocephalus, Lechenaultia biloba, Loxocarya fasciculata, Patersonia umbrosa, Pteridium esculentum* and *Xanthorrhoea preissii.*

In water gaining or wetter sites with impeded drainage soils will be moister and species such as *Adenanthos obovatus, Agonis parviceps, Kingia australis* and *Leucopogon concinnus* can occur.

5. Management

These sites have moderate growth potential. Regeneration numbers are normally adequate, but may be low on sites with dense scrub. Dieback does occur on these sites and the impacts may be more serious in moist situations such as depressions or concave slopes.

SOUTHERN JARRAH SITE CLASSIFICATION

TYPE T

1. General Description

Good quality forest (JM B+/A) on well drained and moderately fertile, gravelly duplex soils with tall undergrowth of medium density.

2. Occurrence

These sites are common and can cover large areas of the uplands and slopes in medium to high rainfall areas of moderate dissection. Type T may occur on landform types BEy, BEb, PP, CRy, Ky, Ly, MTy, MTb, COy, V2, V3, S1 and S2.

3. Soils

The soils have a dark grey brown sandy loam surface with some gravel changing to a generally yellow or brownish clay at about 650mm. There can be considerable laterite rock on some sites.

SOUTHERN JARRAH SITE CLASSIFICATION

4. Indicator Species

Species to be found on these sites are *Clematis pubescens, Hakea amplexicaulis, Hovea elliptica, Leucopogon verticillatus, Macrozamia riedlei, Persoonia longifolia, Podocarpus drouynianus* and *Pteridium esculentum.* Others which commonly occur are *Acacia alata, A. browniana, A. pulchella, Banksia grandis, Hovea chorizemifolia, Leucopogon propinquus, Patersonia umbrosa* and *Xanthorrhoea gracilis. Agonis parviceps, Bossiaea laidlawiana, B. linophylla, B. ornata, Leptomaria cunninghamii* and *Sphaerolobium medium* may occur on some sites.

5. Management

These fertile well drained sites have good growth potential. Regeneration numbers are usually adequate. Dieback may occur but the impact should be low.

TYPE K

1. General Description

Good quality forest (JMB+) on well drained moderately fertile slopes and uplands. Karri will often extend on to these sites in low numbers. There is usually a tall thick understorey.

SOUTHERN JARRAH SITE CLASSIFICATION

2. Occurrence

This type becomes more common south of Manjimup in the high rainfall areas in moderate to steeply dissected landscape. Type K may be found on landform types BEb, CRb, Kb, MTb, COb, V1, V2, V3 and S1.

3. Soils

The soils are generally grey sandy to a brown sandy loam surface with up to 50% lateritic gravel and/or quartz grit changing to clay, or sometimes sandy clay, with some grit and gravel at about 600mm.

4. Indicator Species

Agonis parviceps is often prominant on these sites and *Boronia gracilipes, Macrozamia riedlei* and *Pteridium esculentum* should occur. *Acacia browniana, Allocasuarina decussata, Banksia grandis, Chorizema ilicifolium, Crowea angustifolia, Lasiopetulum floribundum, Leucopogon verticillatus, Persoonia longifolia, Podocarpus drouynianus* and *Tremandra stelligera* are common. *Acacia pentadenia, Leucopogon australis, L. concinnus, L. propinquus* and *Petrophile diversifolia* may also occur.

5. Management

These sites have good to very good growth potential. There may be some dieback occurrence on these sites, but the impact should be low. Regeneration can be difficult to establish in the heavier scrub sites, if adequate advanced growth is not already present. These sites are distinguished from Type N by the deeper loamier soils, better drainage and presence of more karri type elements.

MACK BLOCK

Hazard Classes