DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

Please address all enquiries to: Inventory Section.
Conservation & Land Management,
3042 Albany H'way,
KELMSCOTT, W.A., 6111.

Your Ref: 1 July, 1992
Our Ref: D.2.1.
Enquiries: D. Meehan

AS PER DISTRIBUTION

DIEBACK INTERPRETERS MANUAL

This is a provisional Dieback Interpreters Manual circulated for your comments. Comments should be forwarded to Dave Meehan or the Disease Standards Officer Bunbury by January 1993. The manual will be revised by June 1993.

D.P. Meehan
.....
For. Syd Shea,
EXECUTIVE DIRECTOR.

DPM:ekh

June 1992

CONTENTS

PAGE No.

June 1992

ACKNOWLEDGMENTS

This document was compiled by Paul Brennan (CALM, Kelmscott Inventory) and Tony Passchier (Alcoa, Environmental, Booragoon) in May 1992.

The assistance of the following groups in preparing the manual is acknowledged and greatly appreciated.

- Dieback Interpreters, Inventory Section, CALM
- Staff from Environmental Protection Branch, Bunbury, CALM
- Staff from the Environmental Department, Alcoa, Booragoon
  (In particular, Cheryl Sanders, for patiently typing it all.)

SECTION 1: INTRODUCTION

1.0 INTRODUCTION

This procedure manual has been prepared as a guide for all interpreters. As procedures change it will be necessary to issue revised or different procedures which should be inserted into this file. Old procedure information should be discarded at this time.

Though any procedure manual provides information that is appropriate to the most usual conditions that apply, it may be possible to practice methods or techniques not recorded in this manual. Where changes or improvements are required, interpreters should notify the Disease Standards Officer (currently Kevin Helyar, CFR, Bunbury) for approval to make such changes. A written report should follow.

Conventions and standards are sometimes viewed with distaste and frustration. They are necessary however, and should be followed. It can save a lot of problems down the line! If you follow these guidelines and adopt the conventions, it makes it a lot easier for someone else to

i) pick up the task where you left off (for whatever reason; leave, sickness, resignation ....), and

ii) enables everyone to understand and follow your work. Less questions need to be asked, everyone is speaking the same language. The benefits are many and obvious.

Finally, be sure to read the entire manual to properly understand the whole interpretation process.

1.1 DEFINITIONS

Perhaps the most important things to get right from the outset when talking *Phytophthora* caused dieback are the definitions of the various hygiene categories. It is most important that they are understood and correctly applied. They are as follows.

SECURE DIEBACK FREE (S.D.F.):
Vegetation apparently free of dieback, and upslope from dieback, suspect, uninterpretable and NEQ Roads.

LOW POTENTIAL RISK (L..P.R.):

Vegetation apparently free of dieback, but downslope from uninterpretable or NEQ and considered to have a low potential for natural infection by *Phytophthora cinnamomi* by natural spread.

UNINTERPRETABLE (U.I.):
Vegetation in which susceptible (indicator) plants are either absent or too few to enable the interpretation of *Phytophthora cinnamomi* presence or absence. (The key here is the LACK OF SUITABLE INDICATORS).

Also areas that have been disturbed by logging, burning or some other activity are considered to be uninterpretable for at least 3 years from the time of disturbance.

NOT EFFECTIVELY QUARANTINED (NEQ):
Vegetation adjacent to roads in which there is considered to be some potential for incipient disease.

HIGH POTENTIAL RISK (HPR):
Vegetation apparently free of dieback or uninterpretable, but downslope from or in the same swamp as dieback or suspect. Considered to have a high potential for infection by *Phytophthora cinnamomi* by natural spread.

SUSPECT (SUS):
Vegetation in which the evidence for *Phytophthora cinnamomi* presence or absence is NOT conclusive.

DIEBACK (D/B OR Pc):
Vegetated areas which show dieback symptoms, which are supportable by laboratory recovery of *Phytophthora cinnamomi* from soil and/or tissue samples.

ARMILLARIA (ARM):
Location where susceptible plants show symptoms of infection by *A. luteobubalina*.

Note the deliberate order in which the above categories are listed. This will be explained later in the manual.

Other definitions to come to grips with include

ISD: Indicator Species Death
P.c: *Phytophthora cinnamomi*, or dieback infected vegetation
NPc: Not P.c., otherwise referred to as dieback free.

INCIPIENT DISEASE:
Forest in which *Phytophthora cinnamomi* may be present, however the symptoms are yet to appear.

DRA:
Disease Risk Area - quarantined forest. Special permit required for entry. Contact local district for details. Access may be denied on certain roads in wet weather. Areas of DRA are shown on the CALM 1:50 000 sheet series; and were first declared in 1976 under the Forest Diseases Regulations.

DIEBACK FREE MAP:
Map showing dieback and dieback free areas only. No other hygiene categories have been determined or shown. Not to be confused with a hygiene map!

7-WAY TEST:
The department's formal process to evaluate a proposed operation in terms of the possible dieback threat to the health of the vegetation complex. Test develops the appropriate hygiene prescription to apply, should the proposed activity "pass".

DIEBACK HAZARD:
Dieback hazard relates to the inate site characteristics which directly influence the development and expression of disease and is an indication of what the final impact will be on that site when the disease has reached its climax and can do no more damage. Dieback hazard does not give an indication of ecological hazard. That is, the consequences on a biological community as a result of the loss of one or more plant species due to dieback. For example, the loss of one species of banksia from an area could

severely affect nectar dependant animals such as pygmy possums and bird species. Similarly hazard does not quantify productivity loss in terms of growth increment, flower or pollen production etc which are significant in the commercial use of natural resources.

1.2 HISTORICAL PERSPECTIVES: D/B Interpretation Film

The basis of any hygiene strategy is a good knowledge of where the disease is and is not. This knowledge is usually represented in map form.

The science of disease mapping has developed since it was first attempted in 1975. Small scale black and white photographs were used to locate the broad scale extent of disease. The resultant information was considered suitable for strategic planning but not good enough to determine accurate hygiene strategies for individual operations.

In 1978 a mapping technique to accurately map the location of disease using 70mm, 1:4500 scale colour photographs was developed. This was used until 1986.

Since 1986, 230mm, 1:4500 scale colour photographs have been used for dieback mapping. Cell 86/45 was the first done using 230mm film. The method allows accurate mapping of disease symptoms and the confident implementation of hygiene prescriptions.

The advantage of 230mm film is that much less film is needed to cover the same area, it is laminated and therefore more durable and weather resistant. 70mm required the use of a battery operated light source and more equipment needed to be carried in the field. The numerous film changes that were required slowed production.

Orthophotos are used in conjunction with 230mm film where interpretation is done over Alcoa minesites. A brief summary of the film types and their cost is given below.

Costs current to early 1992

	70mm	230mm	ORTHOPHOTO (Alcoa minesites)
Area covered	6 ha	100 ha	1150 ha
Actual size	70mm x 70mm	230mm x 230mm	approx 800mm x 700mm
Approx unit cost	Not available	1st frame in Run: diapositive $52.00 colour print $32.00 b&w print $8.00 Subsequent frames in run diapositive $20.00 colour print $8.00 b&w $4.00	Lib original $600.00 Reprint $65.00

1.3 WEATHER CONDITIONS FOR PHOTOGRAPHY

The photography must be taken in shadowless conditions, so that the understorey is not in shadow - if it were, ISD's would be obscured and interpretation would not be possible using this method.

To attain shadowless conditions, the weather for the day must consist of full 8/8 cloud cover at a minimum ceiling of 6000 feet.

There is probably only 2 to 5 days in each year when this combination of conditions prevails!

Usually this occurs in summer and autumn when high level cloud moves down from cyclonic lows in the north of the state.

Shadowless photography is organised by the Section Manager, Inventory Section.

SECTION 2 BIOLOGY AND SYMPTOMS

Phytophthora sp, Armillaria, Canker Fungi, and Drought

FUNGI CAUSING DIEBACK - Biology & Symptoms

There are many things to be understood about the biology and symptoms of the various diseases which cause vegetation to die-back.

Most of these are beyond the scope of this manual and are detailed in many publications, some of which are listed as references in Section 3.3 (preparation), on page 14.

The various fungi causing dieback that are of concern to interpreters include

i) *Phytophthora* species, of which 7 have so far been isolated in Western Australia.
P. cinnamomi is the most virulent and of greatest importance. Refer to the publication reprint "Dieback of Native Plant communities caused by *Phytophthora* species - A major factor affecting land-use in S-W W.A." by B. Shearer, included as appendix 9.

ii) *Armillaria luteobubalina* , and

iii) Canker fungi

The fundamental differences in biology of these fungi are summarised in the table which follows:

SUMMARY

	Dieback caused by: *Phytophthora*	*Armillaria*	Cankers
Pathogen	7 species	*A. luteobubalina*	*Botryosphaeria* *Endothia* *Diplodina* *Cytospora* *Zythiostroma*
Sporulation	zoospores chlamydo - spores oospores	basidiospores	conidia
Spread	soil/water/ roots	air/roots	air/rain splash
Host range	Wide, mainly *Proteaceae, Epacridaceae*	Wide, hosts resistant to *Ph.* susceptible to *Arm.*	Wide, hosts resistant to *Ph.* susceptible to canker

Summary Table Cont..

	Dieback caused by: *Phytophthora*	*Armillaria*	Cankers
Impact			
Forest			
jarrah	low-very high	low-high	low-int
karri	low	low-high	low-int
wandoo	low	high	high
Coast dune	low-high	high	low-int
Banksia woodland	high-very high	low-high	low-high

The lesions beneath the bark are also different.

Phytophthora lesions move from the roots upward to the collar region (junction of stem and roots, equates roughly with soil surface) and are usually brown to black in colour.

Armillaria lesions are white or yellow-white and leathery and also move upwards from the roots. Mycelia sheaths are clearly visible.

Cankers are characterised by lesions moving down the branch from a wound toward the main stem. Plants affected by cankers are often "part deaths". The lesion is usually brown or black in colour. In advanced stages of infection, the affected stem bark is dotted with dark spore-bearing conidia.

For the most part, interpreters are concerned with mapping infections of *Phytophthora cinnamomi* and *P. citricola*, and *A. luteobubalina*.

Interpreters must be able to distinguish between deaths caused by 4 agents, being

i) *Phytophthora spp.*
ii) *Armillaria*
iii) Cankers and
iv) Drought.

With practice, this is not so difficult and where tricky, sampling can be employed to be certain.

Whilst *Armillaria* is usually given away by the presence of white mycelium beneath the root bark, it is important to ascertain that it is not working in conjunction with *Phytophthora*, by sampling.

For 3-4 weeks of the winter (June), orange *Armillaria* fruiting bodies can develop which assist in decision making.

Drought affected trees will often recover - they may look dead at first glance, but closer examination will often reveal epicormic resprouting on the lower stem and sometimes on branches.

With practice and guidance from experienced interpreters, the distinctions between the various agents become quite clear. Refer also to the decision making guide included in Section 5.2.

SECTION 3A: OFFICE WORK PRIOR TO FIELD INTERPRETATION

3.1 PREPARATION

Before commencing interpretation, you need to answer the following questions:

1. Has the area been previously interpreted? When? By whom?
2. Was there a report or map produced? Other map products?
3. When was area last burnt?
4. When was area last logged?
5. When was area last drilled or otherwise disturbed?
6. Will a DRA or minesite entry permit be required? Do I need keys to gates?
7. Are there any special areas within the cell? e.g. Rare Flora, Research or Inventory plots etc.

As a rule of thumb if an operation (3, 4 & 5) has occurred within the last 36 months (3 years) the area is uninterpretable.

Office preparation should generally only take no more than half a day, and entails searching the files for any reports, checking hanging plans for previous mapping, checking CIMCIS (HOCS) for past forest operations and fuel age plans for year of last burn.

The district is probably the best source to answer questions 3, 4, 5, 6 & 7 accurately, whereas the Inventory office should hold copies of all previous interpretation information.

If required, DRA permits must be arranged with the district prior to field work. Make sure you observe any condition set down in the permit and be aware of its expiry date. You are legally bound to hold a current permit whilst working within DRA. Driving permits are required on Alcoa minesites. These are arranged through the minesite Security office.

Further, you should check the system 6, Atlas of Natural Resources maps to determine landforms and vegetation complexes that you will encounter in the area.

Finally, inform the district of your daily location with a 4 figure reference off the CALM 1:50 000 series map sheet. It is a good idea to visit the office and put your name and call sign on the District disposition board.

3.2 EQUIPMENT (see Appendix 3 for supplier details)

OFFICE

To interpret 230mm film

* Wild Aviopret ST4 Mirror Stereoscope mounted over a transmitted illumination light source.

FIELD

Ensure first aid kit is kept in your vehicle.

If using 230mm

* Sample kit bag, which includes plastic bags etc. See 4.3.
* 2 spray bottles (1 for alcohol/methylated spirits to sterilise mattock, 1 for distilled water to irrigate soil sample)
* Sample mattock
* Wild TSP-1 pocket mirror stereoscope
* Acrylic translucent light board with bulldog clips
* Waterproof over the shoulder photo satchel
* A map tube may be useful
* Dayglo orange, red, white and green tape rolls.

If Stripping

* Booking board and booking sheets
* Compass (orienteering type may be more suitable)
* Sample kit bag. See 4.3.
* Hip chain and spare cotton reels
* Maps of strip line alignment
* Tape rolls - colours as above.

3.3. REFERENCES LIST

1. Manual of Logging Specifications, CALM. Updated annually.

2. Bulletin 86, 1975
"Site Vegetation mapping in the Northern Jarrah Forest (Darling Range) 1. Definition of Site Vegetation Types" by J.J. Havel.

3. Technical Paper No. 3, 1983
"Introduction to the detection and interpretation of the symptoms of jarrah dieback disease in W.A." by A. J. Brandis. Included as Appendix 8.

4. Landscape Reprint, Vol 5(1) : 38-44, 1989.
"Tree Killer", by B. Shearer & R. Bailey.

5. Research Bulletin No. 3, 1989.
"Jarrah Dieback : The dynamics and management of *Phytophthora cinnamomi* in the jarrah (*Eucalyptus marginata*) Forest of South-Western Australia" by B. L. Shearer and J. T. Tippett.

6. Bulletin 85, 1977.
"Environmental Factors of the Northern Jarrah Forest in relation to pathogenicity and survival of *Phytophthora cinnamomi*" by S.R. Shea.

7. System 6, 1980.
"Atlas of Natural Resources Darling System, Western Australia" by (the then) Department of Conservation and Environment.

8. CALM Policy Statement No 3 (as revised)
Phytophthora dieback

9. Land and Water Research News, Issue No. 5, Feb 1990. "Dieback of Native Plant Communities caused by *Phytophthora* species - A major factor affecting land-use in S-W Australia". by Dr. B. Shearer. Included as appendix 9.

10. Guidelines for 7-Way Test Preparation, CALM (as revised). The section on hazard ratings has been included as appendix 10.

SECTION 3B: OFFICE WORK PRIOR TO FIELD INTERPRETATION

3.4 Film Interpretation
3.5 Transfer - Stereo Overlap

NOTE: The guidelines in 3.4 and 3.5 may vary in your area. Consult Senior Interpreters for advice.

3.4 FILM INTERPRETATION

Interpreters work in pairs. Each film frame covering the area of interp. is closely scanned by both - the first interpreter using three power magnification, the second 8 power, under the Wild Aviopret desk mounted mirror stereoscope. The second interpreter to view the frame (under 8x) must ensure he/she contributes to the interpretation by marking on the areas where he differs from his/her partner eg.

- extra I.S.D.(s)
- dieback and uninterpretable boundary differences
- extra check sites

On every frame viewed determine if there are sufficient indicator species visible to detect the presence of *P. cinnamomi*. If there are insufficient indicator species visible the area is to be labelled uninterpretable. Indicate possible uninterpretable areas with a purple chinograph pencil.

All indicator species deaths (I.S.D's) are to be circled on the even numbered film in permanent red marker.

Due to the large area covered by each frame (100 ha), great care is to be exercised when scanning for I.S.D.'s and Check Sites. A grid (25 x 25mm) is to be marked on the office light source and a systematic approach to scanning these squares must be adopted by each interpreter. Any suspicious areas that require field checking and are not associated with I.S.D's should be shown thus

CHECK, circled in permanent blue marker.

These areas could be old gravel pits, landings or poorly vegetated sites etc.

Demarcate what appears to be obvious Pc with red chinograph pencil on even numbered frames. This will reduce the number of ISD's requiring subsequent field check. The 1: 20,000 water catchment photos may be of assistance. The status of these areas will be confirmed during later field checks.

Circle ISD's on 3 power over the even number frames. Shade in or mark off even frames on flight line map as you go. Use the colour allocated to you specifically for use on the ISD/flight line plan.

Subsequently, ISD on 8 power over the even frames. Must be different interpreter from the one who did the 3x. Cross off even numbered frames on flight line map as you go, again using your allocated colour.

Keep ISD demarcation circle's small.

In summary, on the even frame, adopt the following conventions,

Permanent Red	-	ISD's
Permanent Blue	-	Check Sites
Purple Chinograph (or omnichrom)	-	Possible uninterpretable areas (lacking sufficient indicators)
Permanent Black	-	Boundary of interpretation
	-	Transfer lines (stereo overlap)
Red Chinograph (or omnichrom)	-	Obvious Pc.

3.5 TRANSFER - STEREO OVERLAP

Do stereo overlap (within run) using the following method. The diagram overleaf will help to clarify the steps.

A. Transfer either up or down. Try to be consistent
B. Mark transposed edge of film on to adjacent ISD frame
C. Transfer ISD's one way only
D. Transfer by scanning one square at a time, as with ISD'ing
E. Record on flight line map using your colour. Record on film.

Do run overlap (between runs) using the following method

A. Transfer from one run to the next for the entire run. Try not to change directions.

B. Try to maintain the same direction for the entire area (e.g. transfer from east to west, or north to south).

C. As per steps B → E above.

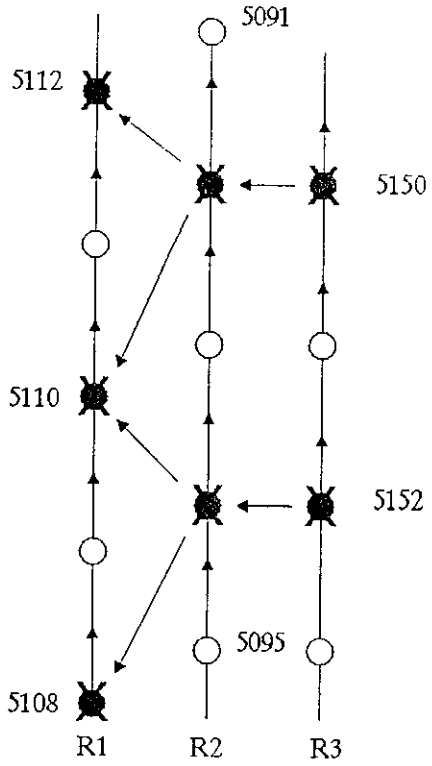
Exceptions to these methods.

i. If a priority area is demarcated within a larger area, make sure all ISD's are transferred into the area regardless of the direction that they have to be moved. (see diagram below for clarification).

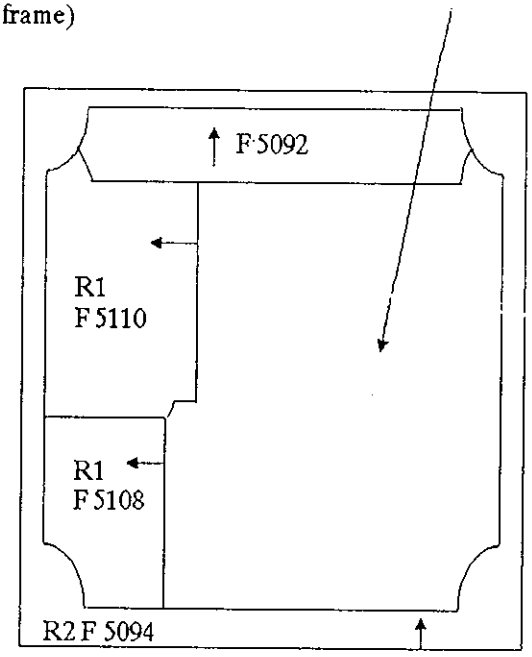
ii. If an ISD occurs on the transposed line, put a bump in the line around it to keep it where it is.

If you have any queries, ask your Senior Interpreter to clarify the steps for you.

Example of complete flight line map and completed film



All mapping & comments from field checks of ISD's should be in this section only (of even numbered frame)



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SECTION 4: SAMPLING

SAMPLING

4.1 Laboratory Process

The sampling process at the Como Research lab usually takes between a minimum of 2 and maximum of 4 weeks. In short, the process entails

i) Tissue plated onto agar. Result within 2 weeks by study of mycelium under microscope to determine if P.c. is present.

ii) Soil is placed in distilled water into styrofoam cups or trays. *Eucalyptus seiberi* (east coast species) seedlings at cotyledon stage are floated on the water surface. If the cotyledons turn purple there is a possibility that P.c. is present.

iii) If so, the cotyledons are plated out on agar. Result within 4 weeks of arrival of sample at Como.

4.2 Why Sample?

Sampling is used initially to ensure *P. cinnamomi* can be recovered by the laboratory from certain species and to establish the reliability of indicator plants in a particular cell. Once this is achieved samples should be taken to maintain interpretation standards within the cell. In most cases sampling isolated dead plants is the only way of determining if *P. cinnamomi* present. Samples should be used to verify that the interpretation was correct.

In possible *Armillaria* sites, it is important to sample to prove the absence of *Phytophthora*.

Interpreters should use soil and root tissue samples to set and then to verify interpretation standards.

Therefore samples should cover all I.S.D. categories and cover a range of plant species on various landforms.

4.3 Sampling Equipment

This should include:

a) Suitable back pack or over the shoulder bag
b) Sterilant - alcohol or methylated spirits in spray bottle
c) Aluminium tags
d) Plastic bags (see supplier list, appendix 3)
e) Nylon tie strips
f) Artline 70 or similar permanent marker
g) Sample record sheets
h) Distilled water in spray bottle
i) Flagging tape
j) Mattock
k) Ball point pen (blue preferably)

4.4. Sites Visited and NOT Sampled

The situation often occurs where plant deaths marked on the (even) film as an ISD are investigated and no sample is taken. This occurs when the death detected is too old to sample and there are no recent deaths or, false symptoms were detected. False symptoms could be other features resembling I.S.D's (ant nest resembling a Blackboy or boulders of orange rock), or plants that have recovered eg. fire affected Banksias with a large number of epicormics. A brief description of the area can be written on the photograph ie. "NOT P.c. epicormics present" or "all other IS (i.e. indicators) healthy".

If your decision is NPc, tie some day-glo orange tape near ground level in the centre of the site checked. This enables the senior interpreter to cross-check at a later date.

4.5 Field Sampling Procedure

a) The sample sent to Como actually contains 2 bags.
   i) a 380mm x 250mm bag, with a label attached (see g below). This is for soil from the sample, and

ii) a smaller 300mm x 200mm bag for tissue material and 1 of the 2 aluminium tags.

Upon reaching the site and having thoroughly investigated the area, select a recently killed plant for sampling.

b) Ensure the mattock has been sterilised with metho or alcohol. Allow to dry before taking sample.

c) Clean leaves, twigs and soil from around the base of the plant

d) Chop sections of root, bark and cambium from all sides of the plant

Special Note: it is most important to sample roots from ALL sides of the plant as the fungus can gain entry via just one root.

Banksia species:

Collect sections of the collar region, include lateral roots. Try to locate a lesion and include a piece of affected tissue in the sample.

Xanthorrhoea spp: (Blackboys)

Collect small radiating brittle roots and pithy plant core.

Patersonia species:

Collect all the below ground sections of the plant, include the small brittle roots.

Persoonia longifolia: (Snottygobble)

Collect sections of root, bark and cambium similar to Banksia.

Podocarpus drouyniana: (Emu Bush)

Collect sections of large underground stem, lower stem sections and roots.

Macrozamia riedlei: (Zamia palm)

Collect sections of fibrous tissue from the bole and roots.

Others:

Ensure some root and collar region tissue is collected. Try to locate a lesion and include in sample.

e) Collect several handfuls of soil from around the base of the plant. The mattock can be used to lift soil into the larger sample bag. This reduces the risk of cross contamination due to infected material on the hands. Irrigate soil with distilled or deionised water if necessary.

f) All plant tissue is placed in the smaller plastic bag along with an aluminium tag on which is written the cell, run and frame numbers, sample number, interpreters initials, region and date. The smaller tissue big is placed inside the large bag.

g) Label the outside of the larger bag with a permanent marker, again completing the details below. Tie off the neck of both bags with the nylon tie strip.

eg.

CELL : .....
RUN : .....
FRAME : .....
SAMPLE : .....
INTERP : .....
REGION : .....
DATE : .....

h) Attach the second aluminium tag to the sampled plant or to a nearby plant showing the details as above. Flag site with day-glo orange or blue tape to enable easy re-location at a later date.

Sampling of plants suspected to be susceptible to *P. cinnamomi*
(i.e. not well-known indicators)

1. If plant identity is unknown, collect a part of the branch/leaf section and if possible a specimen of the flower. These may be identified by the Como Herbarium if need be.

2. Collect root and collar tissue plus a soil sample from around the plant.

3. Sample is processed in the normal fashion except for:

i) Como Research is to be informed of the nature of the sample ie. a plant being tested for susceptibility as an indicator of *P. cinnamomi*.

ii) Ask for the roots to be surface sterilised and then plated.

iii) If root material is found to have *P. cinnamomi* then the number of cuttings plated and the number of cuttings showing fungal growth will be recorded.

iv) If a sample returns a positive result only in the cup on the first process, it must be processed again as a positive result on the plant is essential.

v) It is important to know the *P. cinnamomi* condition of the area that the sample is taken from as this affects later calculation of the plants susceptibility rating.

vi) It is essential that the sampler keep clear, accurate records of all sampling done to test reliability or susceptibility of plants as *P. cinnamomi* indicators.

4.6 Completing Sample Information Sheets

The information recorded must provide the reader with a brief, but detailed insight to the forest within close proximity, ie. the site characteristics - the factors that determined why the sample was taken; the factors that were reviewed in making the interpretation; perhaps a comment about what the disease might do in the future ie. R.O.S., impacts; and what type of activity has taken place in the past - where this can be determined. Interpreters must be able to fill out these sheets to a satisfactory standard. The Senior Interpreter must be able to quickly and easily gain an insight to the salient features occurring at any site.

1. Field

There is an individual sample sheet for each sample taken.
See the example attached.

Note that when using 230mm film, samples are numbered in the order taken within a frame. When stripping, samples are recorded numerically along each line.

The original is retained and filed with your records for the area.

2. Office

A summary sheet is maintained for all samples taken.
All the samples taken within a film run are recorded on the same sheet.
This is kept with the original field sample sheets in the file for the area.
When stripping, group samples according to line number on the same sheet.

A summary sheet is sent to the lab with each batch of samples.

FIELD SAMPLE INFORMATION SHEET

CELL NUMBER _____

DATE ____/____/____

SAMPLE No. _____

RUN _____

FRAME _____

INTERPRETER _____

PLANT S SAMPLED _____

I.S.D. CLASS Isolated Scattered Cluster Multiple

PROBABLE DISEASE VECTOR _____

PATTERN DEVELOPMENT _____

SLOPE POSITION Ridge Upper Slope Mid Slope Lower Slope Gully

SITE DESCRIPTION AND INTERPRETATION FACTORS

VEGETATION TYPE _____

LANDFORM TYPE _____

ASPECT N S E W

OVERSTOREY (%) ≤10 20 30 40 50 60

UNDERSTOREY IMPACT(%) <10 10-50 >50

OVERSTOREY IMPACT(%) <10 10-50 >50

PREDICTED IMPACT Low Mod High V.High

SOIL TYPE _____

SLOPE ≤5° 6-10° 11-15° 15-20° >20°

PROFILE DRAINAGE V.Good Average Poor Impeded

DROUGHT EVIDENCE Yes No

FIRE EVIDENCE Yes No

ARMILLARIA PRESENT Yes(mycelium) No Possibly

SITE DISTURBANCE(LOGGING/ANIMAL/ROADING) _____

OTHER DEAD INDICATOR SPECIES (not sampled at site) _____

OTHER COMMENTS:

MUD MAP

FIELD DECISION	LABORATORY RESULT	
	RESULT	
	COMMENTS	

EXAMPLE

FIELD SAMPLE INFORMATION SHEET

CELL NUMBER 91/999

DATE 25 / 12 / 91

SAMPLE No. 7

RUN 18

FRAME 5043

INTERPRETER PB, AP

PLANTS SAMPLED B. grandis, P. longifolia

I.S.D. CLASS Isolated Scattered Cluster (Multiple)

PROBABLE DISEASE VECTOR Track

PATTERN DEVELOPMENT Not obvious

SLOPE POSITION Ridge Upper Slope (Mid Slope) Lower Slope Gully

SITE DESCRIPTION AND INTERPRETATION FACTORS

VEGETATION TYPE ts

LANDFORM TYPE DWELLINGUP

ASPECT (N) S E W

OVERSTOREY (%) ≤10 (20 – 30) 40 50 60

UNDERSTOREY IMPACT(%) (<10) 10-50 >50

OVERSTOREY IMPACT(%) (<10) 10-50 >50

PREDICTED IMPACT Low (Mod) High V.High

SOIL TYPE GRAVEL LOAM

SLOPE ≤5° (6-10°) 11-15° 15-20° >20°

PROFILE DRAINAGE V.Good (Average) Poor Impeded

DROUGHT EVIDENCE Yes (No)

FIRE EVIDENCE (Yes) No

ARMILLARIA PRESENT Yes(mycelium) (No) Possibly

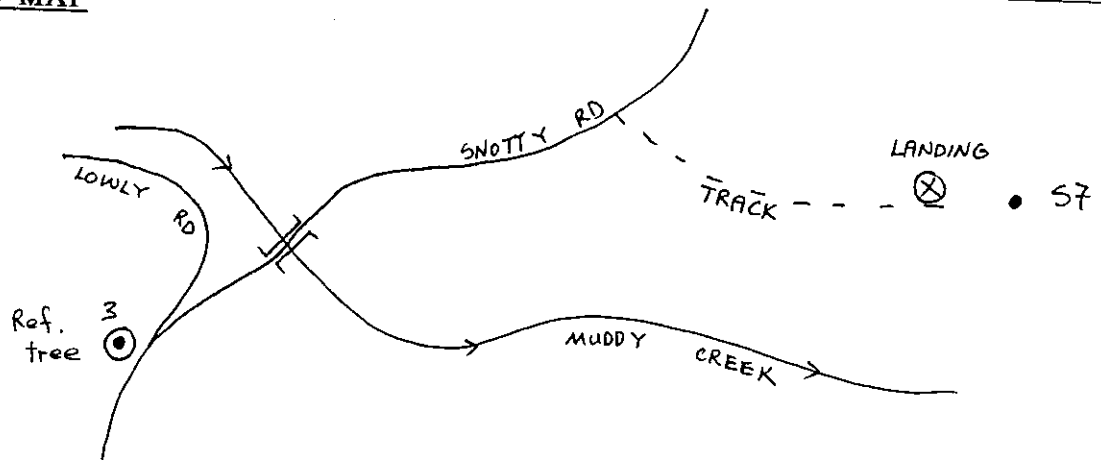
SITE DISTURBANCE (LOGGING/ANIMAL/ROADING) LOGGING – FIREWOOD ?

OTHER DEAD INDICATOR SPECIES (not sampled at site) X. gracillis

OTHER COMMENTS:

Grouping of deaths 60m uphill from landing. Most banksias on disturbed areas healthy. Evidence of firewood cutting nearby. Spot infection ?

MUD MAP



	LABORATORY RESULT	
FIELD DECISION Pc x 2	RESULT	
	COMMENTS	

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OFFICE SAMPLING RECORDS SHEET

CELL NUMBER: _____

RUN NUMBER: _____ PAGE NUMBER: ____ of ____

FRAME & SAMPLE No.	DATE	LN	SY	FIELD INT.	DATE REC.	DATE OF PROCESSING 1ST	2ND	SUBS	RESULT PLATE	CUP	DATE MAPPED

1. LN - LOCATION CLASS
2. SY - SYMPTOM CLASS
3. FIELD INT - FIELD INTERPRETATION BY INTERPRETER
4. DATE REC - THE DATE THE SAMPLE IS RECEIVED AT COMO RESEARCH.

NB: If stripping, frame & sample No. becomes lines and sample No.

SECTION 5: FIELD WORK

5.1 Reconnaissance

Before commencing internal interpretation work, it pays to spend a short while familiarising yourself with

i) layout of the area, topography etc...
ii) internal access, impassable sections of tracks (bogs, deep creeks...)
iii) breaches of quarantine restrictions (vehicle trespass)
iv) recent burning or cutting not shown on office records (in particular wildfires, illegal logging/firewood cutting)
v) the general level of disease expression, location of uninterpretable areas
vi) vegetation types and landforms
vii) old blaze lines

Make notes on a 1:25,000 scale plan as you drive around the external boundary to the area.

Again, remember to advise the district daily of your whereabouts, giving the 4 figure reference of your location.

5.2 Decision - Making Guide

It is imperative that all interpreters read Technical Bulletin No. 3, of 1983, by A.J. Brandis: "Introduction to the detection and interpretation of the symptoms of Jarrah Dieback Disease in W.A." It has been included as appendix 8 to this manual.

A range of factors need to be considered at once, not in isolation, to decide whether or not

i) an area is in fact infected by *P. cinnamomi*, and
ii) whether or not a sample is needed.

The very useful decision making guide from Tech Bulletin 3 follows.

RELATIVE IMPORTANCE OF OBSERVABLE FACTORS

Associated with the Interpretation for Presence or Absence of *P. cinnamomi*

	Observable factor indicating high likelihood of *P. cinnamomi* presence			Observable factor indicating low likelihood of *P. cinnamomi*
Observation Factors				
ISD TYPE	Multiple ISD'S	Cluster	Scattered	Isolated
SPECIES	More than one indicator species	Any one indicator species	Any one indicator species	Any one indicator species
PATTERN DEVELOPMENT	Obvious			Not obvious
TOPOGRAPHIC	Gully/Flat	Lower to Mid Slope	Midslope to Upper Slope	Ridge
CAUSAL AGENT	Obvious			Not obvious
INTERPRETATION RESULTING FROM OBSERVATION:	High likelihood of *P. cinnamomi* Presence			Low likelihood of *P. cinnamomi* presence
REQUIREMENT FOR SOIL AND TISSUE SAMPLE	Low Requirement For Soil and Tissue Sample	High requirement for Soil and Tissue Sample	High Requirement for Soil and Tissue Sample	Low requirement for Soil and Tissue Sample

5.3 Procedures for Ground Stripping

Stripping is used in the absence of 230mm photography. The same requirements for office preparation exist - see 3.1 on page 12. In addition follow these steps;

i) Obtain a suitable map of areas to be stripped. If the area has been pegged by ALCOA, a 1:10,000 ALCOA map is useful for navigation in the field.

ii) Refer to the 1:20,000 water catchment photos and delineate what appears to be obvious P.c., for example creek and swamp systems.

The first couple of days can be spent determining and taping large areas of P.c. which can be excluded from stripping. This reduces overall interpretation time and effort. However, the areas so excluded must be field checked to verify P.c. status.

iii) Select a road or track that is close to or forms part of the boundary of the area to be stripped. This is called the base line. When considering a appropriate baseline, look for readily identifiable features that can be located on either Alcoa or CALM maps e.g. pegs, ref trees, track intersections, tracks crossing creeks.

iv) Draw and number on the base plan parallel lines at a scale interval of not more than 50m. The 50m interval is the maximum spacing between lines. The more subtle the expression (lower impact) and the more infrequent the indicators, the closer the spacing required.

Discuss with the Senior Interpreter what spacing to use. A field reconnaissance will help to determine what is best.

(v) If the base line is not straight or at right angles to the strip lines, the actual ground distance between lines must be calculated using a scale rule. (See example overleaf, where PIGDOG ROAD is the baseline).

(vi) Working from a known start point easily located in the field, such as a Ref. tree or track intersection, demarcate where the strip lines cross the base line. This is done using a hipchain or odometer (tripmaster) to determine the position, and a numbered piece of tape to mark it. TIE the 'tape' in position.

(vii) Using a compass and hipchain, walk along the strip lines and record against the linear distance the disease status of the bush. Any spot infections away from the line should be recorded. Refer to the field booking sheet attached (p35).

Remember, you may be plotting a map to scale from the booking sheet some time after the field work. Ensure sufficient comments are recorded to aid mapping. Particular mention of features such as creeks, tracks etc. should be made, along with the relevant distance they occur along each line. Impact and vegetation type should be noted in the comments column as you go.

Sample locations should be recorded on booking sheets by distance along the strip line and by distance at right angles away from the line. eg. line 5, 212m and 7m east.

(viii) Continue in this manner until the area has been covered. (Remembering to reset the hipchain at the start of each line).

(ix) Upon completing each strip line that returns to the base line, check your finish position with the numbered demarcation flags. The accuracy desired, considering human error and magnetic variation, is 1m in 100m allowable deviation. If at any time the distance to the flag is greater than this allowable distance the line must be re-aligned and walked to maintain 50m intervals, and subsequently, mapping accuracy.

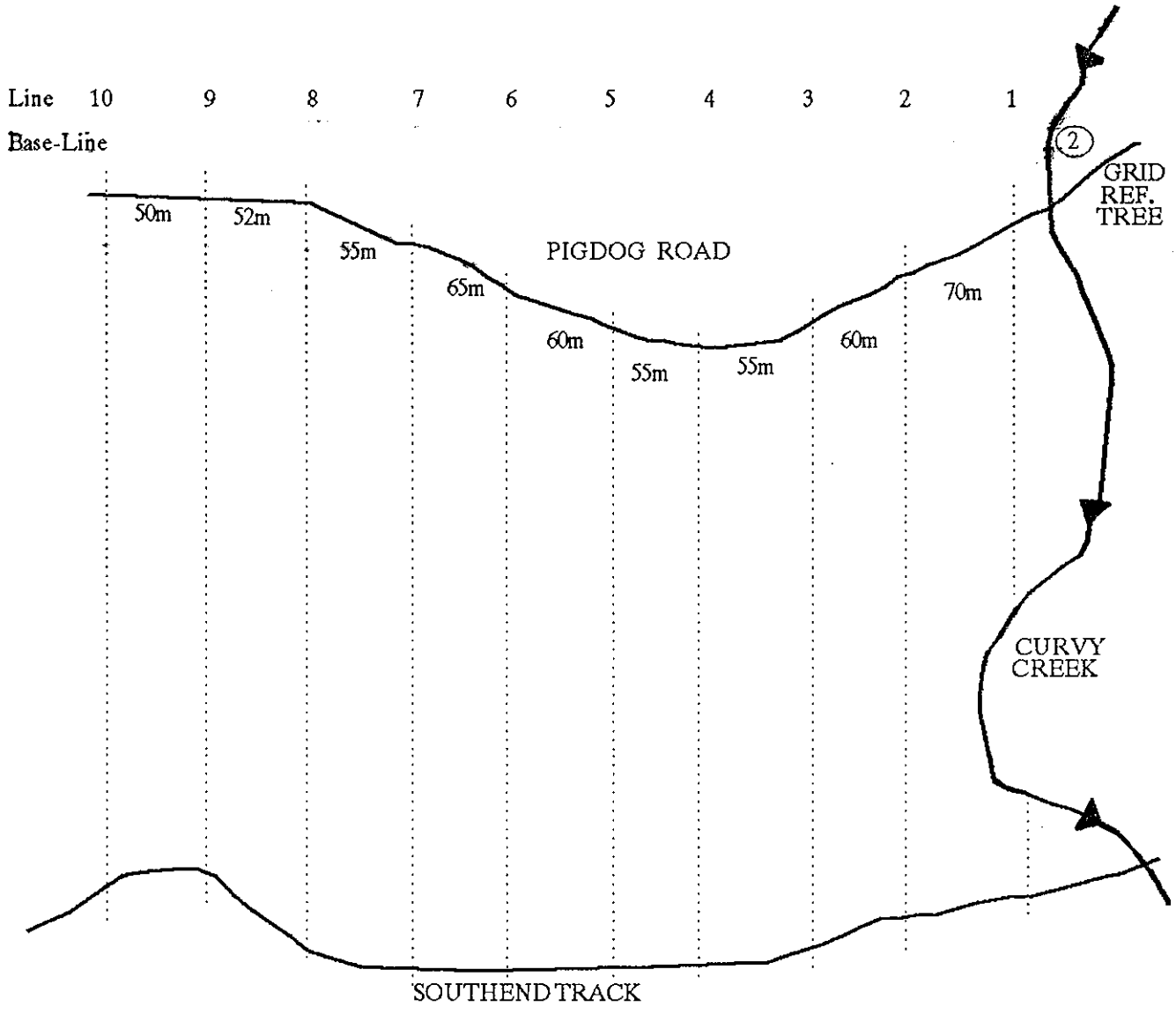
Working examples of allowable deviation:-

100m strip line is up to 1m out.
2000m strip line is up to 20m out.

(x) Plot a dieback/diebackfree map from the strip sheets using a scale rule.

(xi) At this stage an area may be demarcated after sample results have been received. Depending on your judgement and knowledge of the area, taping may be completed before sample results return.

(xii) Add hygiene categories if a hygiene map is required. Demarcation maps may also be requested, see section 6.3.



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STRIPPING BOOKING FORM

DISTRICT: _____ **FOREST BLOCK:** _____ **DATE:** _____
AREA NAME: _____
NAME: _____
GRID REF START POINT LINE 1: _____ **on 1:50 000 SHEET** _____

LINE No.	°BEARING M/T	START FROM	DISTANCE (m)	P.C. STATUS	COMMENTS e.g. Veg Type, Impact
			0m		

5.4 Procedures Using 230mm Film

Again, these guidelines may vary in your area.

5.4.1 Field Use of the Even Numbered Frames

It is important to remember that the stereo PAIR consists of 2 frames:

i) An even No., onto which I.S.D.'s are marked and check sites etc. It is often referred to as the ISD frame.

and,

ii) A odd No., into which things such as P.c. boundary, taping and slope are marked. It is also known as the "mapping" frame.

Decisions made in the field regarding the disease status of check sites and ISD's are recorded on the even No. frame. Each I.S.D. and check site visited and marked as NOT P.c, is to have a short length of day-glo orange tape anchored at or near ground level in centre of the site checked. This enables the supervisor to crosscheck at a later date and verify the decision.

Further, both photo's should be initialled and dated by the interpreters upon completion field checking, mapping and taping. This will help the senior interpreter follow up queries.

Convention for annotation of ISD's on even No 230mm frame (refer back to diagram on p19) with permanent red marker.

⊙ Awaiting sample result

⊠ NPC

Ø PC - otherwise, annotate next to circle with "P.c." if required.

Note that these ISD's will subsequently be enclosed by a P.c. boundary, so annotation may not be necessary.

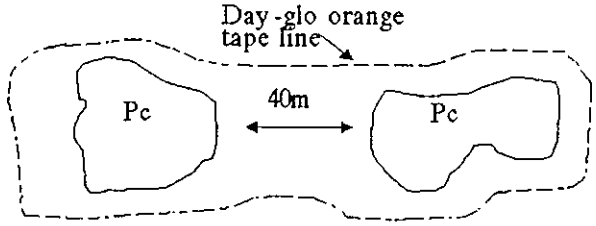
5.4.2. Mapping and Taping - Guidelines to assist in decision making.

Taping will generally be carried out over a section as the interpreters navigate and map the P.c. boundary (disease front) in the field, using the 230mm diapositives. Map the boundary and/or demarcation line on the odd-numbered film as you go, aiming for an accuracy of ± 5m.

District staff are responsible for blazing (permanent demarcation).

When taping, the following guidelines will apply:

i) Neighbouring Infections: The boundary of all spot infections are MAPPED individually on the odd No. photo. Whether or not neighbouring infections will be taped individually is a matter of judgement, experience and practicality for operational purposes. Depending upon the distance between neighbouring infections, and inherent site factors, the taping may or may not group the infections. Where the boundaries of infections are 40m or closer, they should normally be grouped for taping as the buffers will obviously overlap, as 20m is the minimum buffer applied.



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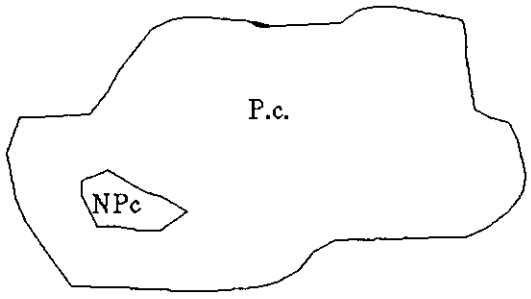
For distances greater than 40m, slope and current impact need to be assessed to determine if the buffers, will overlap (see buffer width table, which follows on p42).

ii) Small island of "Not P.c." surrounded P.c. < 1ha in size:
These should be given the same classification as the surrounding area.

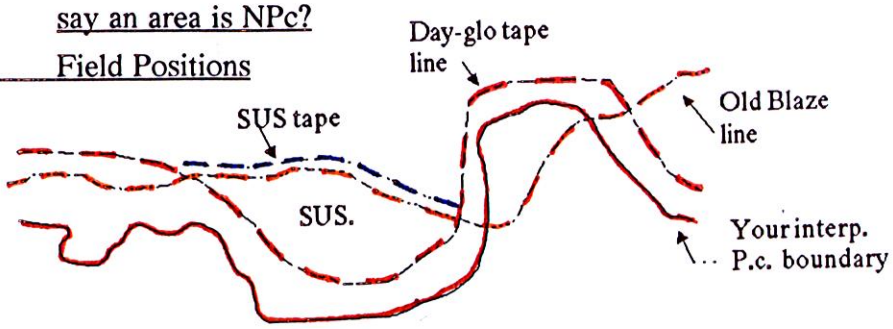


1ha: Approx 50m radius or 100m diameter.

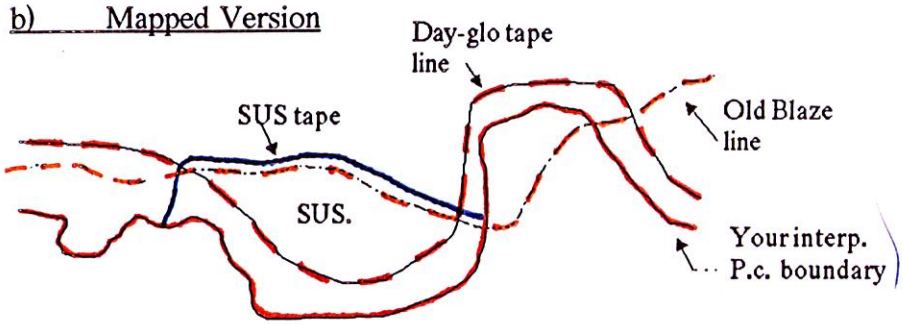
Consider the diagram shown in ii) on p38. By the time tapes are put in on buffers, the NPc area would be too small to manage. Furthermore, there is a greater than normal chance of incipient disease. Quite probably, symptoms will be manifest soon after interp. is completed, particularly if the NPc island is downslope of the P.c. (which does happen!).

iii) Time limit/lapse since operation has occurred - is it safe to say an area is NPc?

a) Field Positions



b) Mapped Version



Note: Compare the field positions in a) with the mapped version in b). Note how the SUS line extends to meet the P.c. edge in b).

Examine the area below the old blaze but upslope of the recently interpreted P.c. edge.

If you refer to the definition of suspect, you will see that there is absolutely no harm and definitely no risk in calling this area SUS. Suspect forest cannot be treated as part of either dieback or dieback free. It is a separate category.

Be wary of calling such areas dieback-free. A minimum of 3 years should lapse between the operation and the time of re-interp. before you would even consider calling it d/b free. Remember to consider:

i) the level of impact or subtlety of expression, and

ii) the level of disturbance.

Consider it is only safe to confidently say such areas are NPc, where disturbance is light or moderate, and the expression is obvious in adjacent P.c. (ie. high impact).

Remember, labelling an area suspect DOES NOT CONDEMN IT! Quite the reverse!

Where areas are significantly disturbed there is usually a requirement for intensive sampling. Senior Interpreter advice must be sought. Exclusion can be recommended by way of the cell report if it is indeed too difficult to determine the appropriate category. However, exclusion should be viewed as a last resort - every effort must be made to determine the hygiene status of a piece of bush. Again suspect is a legitimate category and should be considered if appropriate.

5.4.3. Category Demarcation - Tape Colours and Guidelines

(i) Demarcation - Time limits, general

Interpreters should complete dieback demarcation within areas of forest for which Hygiene Maps have been prepared during field interpretation.

All forest classified as Dieback, Suspect or Uninterpretable should be demarcated as close to the time of logging or mining operations as possible. If it is imperative that forest be burnt prior to logging, taping and blazing must be completed before burning.

When an operation has not taken place within six months of demarcation, it will be necessary to recheck (and demarcate again) all areas of forest downslope from dieback or suspect, particularly on moderate to steep slopes (greater than 5°). Areas of forest that have been mapped as secure dieback-free (ie, upslope from dieback, suspect, NEQ, uninterpretable)

should be rechecked within a period of twelve months. Checking should be from late spring to autumn if possible as disease expression is most obvious at these times.

Field demarcation of dieback, suspect and uninterpretable is best achieved by blazing and painting non merchantable trees. All demarcation must be easily seen, even where dense scrub occurs. Trees should be blazed on three sides; two of the blazes should face along the boundary while the third blaze must face the appropriate category. Place tape where possible on non-merchantable trees, with the knot facing the category.

ii) Dieback

The system of mapping disease occurrence is based on visible symptoms that take varying periods of time, after infection, to manifest. As the most recent indicator plant deaths occur at or near the edge of disease infections, it is logical to conclude the *P. cinnamomi* may be in the soil, or root systems of both susceptible and resistant plants outside the visibly affected area, but that the susceptible plants may not have died. That is to say there may be some risk of transporting infected soil and root material from within a zone outside of, but in close proximity to the infection. It is necessary therefore to have a zone which buffers forest operations from disease infections.

The buffer zones should be varied to account for the potential for disease to be present, but not manifest, under different vegetation, topographic, and edaphic situations. Two variables must be considered in varying buffer width - slope and disease impact. Where disease impact is low, it is often difficult to detect and interpret symptoms of the disease and the risk of incipient disease is greatest in this situation. The following table sets out the downslope buffer width under different slopes and impact situations.

		DOWNSLOPE BUFFER WIDTH (m)		
SLOPE (degrees)	16-20	50	50	40
	11-15	50	40	30
	6-10	40	30	20
	0-5	30	20	20
		LOW	MOD	HIGH +
		IMPACT (Current)		

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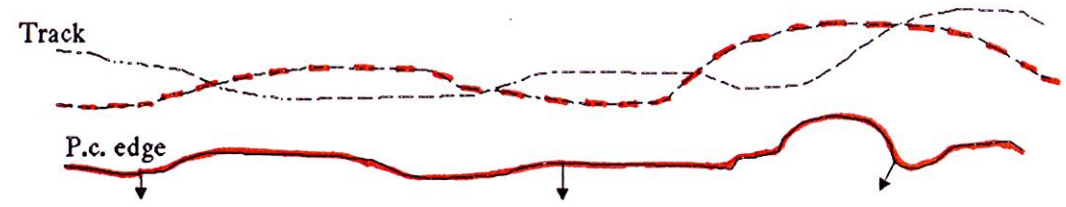
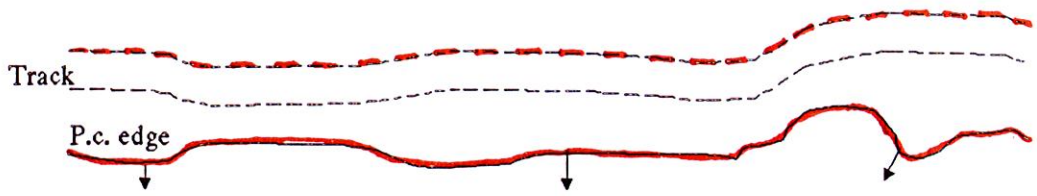
Buffer zones on the Uphill side of the infections should not be less than 20m and increased to 30m in situations where the uphill gradient is small and disease impact is low.

Taping may sometimes need to be done by interpreters working in liaison with Operations staff. This is particularly important where tapes fall near tracks. Consider the diagram below.

a) Position of dayglo orange tape as determined by buffer width table.



b) Agreed location for dayglo orange tape after discussion with district.



Should the tape be moved above the track?
GUIDELINE: Interpreters tape, where they see fit, according to the disease front and applying the correct buffer width. If the track is close by, say within 30m of the tape, it is important that the local Forest officer be consulted. If he/she would move the tape for reasons of operational practicality, and would like it moved then the tape should be moved where mutual agreement is reached. If agreement is not forthcoming, seek advice from the Senior Interpreter.

iii) **Suspect and Uninterpretable**

a) **Abutting NPc.**

Note that there <u>are no</u> specified buffer widths for either Suspect or UI. These categories are to be taped with red (SUS) or white (UI) flagging respectively, into and on NPc' side of the "boundary" as determined in the field. Record the position of the taping on film, with a dashed line in the relevant colour (blue for SUS, purple for UI).
There is often some conjecture as to the true cut-off between NPc Suspect or Uninterp.

Use your judgement but ensure you place your taping 5 or so metres <u>into</u> what you can confidently determine as being interpretable.

b) **Uninterp abutting Suspect**

Similar guidelines apply as above - however suspect takes priority. Therefore, map and tape suspect into and onto the uninterpretable side of the "boundary". Remember that suspect vegetation is by definition, interpretable i.e. it does have sufficient indicators present. The boundary can be decided by keeping the fundamental difference between the two categories clear.

Uninterpretable means a lack of sufficient reliable indicators, or a site disturbed within the last 3 years.

iv) ***Armillaria*** (currently Swan Region only)

The location of infections of *Armillaria* is denoted by the use of dayglo-orange and white tape hung together. Again, there is no specific buffer required for *Armillaria*. Use your judgement. Dead patches or "ulcers" less than 30m in diameter are not normally taped.

However, Alcoa may require *Armillaria* infections of any size to be taped and subsequently blazed prior to mining operations. Check with the Minesite Environmental Scientist what the local requirements are.

Blazing of *Armillaria* is not usually required for logging operations.

If blazing is required by Alcoa:-

i) Where occurring on its own, demarcation will be by 3 orange blazes, with the third facing *Armillaria*.

ii) Where abutting another category, *Armillaria* assumes the lowest priority eg. *Armillaria* within UI, 3 white blazes facing UI, the fourth orange blaze facing *Armillaria*.

v) NEQ Tracks

Are not normally taped, but can be at the special request of the District.

The district will specify the "buffer" width to apply, but generally it will be 20m down hill and 10m uphill from the track in question.

The taped position of NEQ may not necessarily agree with its nominal mapped location. Refer to p54 regarding the mapping of NEQ.

vi) Concluding Remarks re Taping

Generally speaking, the demarcation will mirror the P.c., SUS or UI boundary shown on the hygiene plan. However, in some circumstances, for reasons of operational practicality, small areas of dieback free forest (islands, strips..) may not be protected - a decision which is a matter of liaison between the interpreting team, Alcoa and CALM district staff.

Following this discussion, if it is necessary to adjust some demarcation taping:-

i) Take the 230mm film to the field. Shift taping, then re-map its alignment on the odd No. diapositive,

ii) Accordingly, amend the red dashed line on the orthophoto, recording date of amendment and names of those interpreters involved. Note the hygiene categories do no change on the hygiene map ie. the P.c., Sus and UI boundaries as interpreted don't alter. (The taping overlay or demarcation map will show whether or not they have been demarcated.)

iii) At last a final (amended) demarcation map can be produced, which truly reflects the demarcation taping in the field.

Always assume the person doing the blazing (which will most often be when you are not there) knows nothing about dieback. MAKE SURE THE TAPE KNOT FACES the category. Never tape alone - the interpreter should walk the disease edge, with another person taping. Remember to use the buffer width applicable to the immediate situation.

Finally, try to tape non-commercial trees or species that are of large enough diameter to allow 3 distinct blazes. In some cases, you may need to increase the nominal buffer width to

do so e.g. to avoid old sparsely vegetated landings, thick waterbrush..

A summary of pen colours and markings is given as Appendix 1.

5.4.4 Old Blaze Lines in the Bush

Needless to say, these confuse the issue beyond a joke. Where likely to cause confusion they must be removed by browning out and this shall be the responsibility of districts. Interpreters must make districts aware of this complication as old information cannot and must not be used to guide new operations.

This will be facilitated by:-

i) Marking on film the location of any old blazes that still have visible yellow paint, that are discovered in the course of interpretation.

A permanent dotted red marker is to be used on the film, annotated with OBL. The information should be transferred to the DISTRICT-USE demarcation map where it is shown as a dashed yellow line. Crews can then brown out the unwanted blazing.

ii) Making note of the occurrences and the requirement for browning out where confusion is likely to arise, in the subsequent cell report and handover.

5.4.5 Info to Record on the Odd Numbered Frames

The majority of the sub-cell will now be taped. The field or odd No. 230mm diapositives will show.

- The alignment of the P.c. boundary as determined, in permanent solid red marker.

- Its associated management line demarcation, or in other words, where the day-glo orange taping is in the field, in permanent dashed red marker. (currently Swan Region only).

- Slope direction, indicated by arrows from the P.c. boundary, also in permanent solid red marker.

Note that individual spot infections will be mapped on the odd No. 230mm diapositive. This is a HISTORICAL RECORD of the dieback location at the time of interpretation.

In addition, the following information is recorded on the odd No. 230mm diapositive.

- Other hygiene categories; SUS permanent dashed blue
  UI permanent dashed purple
- Significant tracks, with permanent dashed black marker, annotated NEQ.
- Position of sample sites, with a red dot annotated with the sample number and date
- Havel Type eg. [tS] (sub-dominant followed by dominant category,) also in permanent black marker
- Position of old blaze line, in permanent dotted red marker, annotated OBL.
  and
- *Armillaria,* in permanent orange marker, annotated ARM. Spot infections marked with orange cross and annotated ARM.
- Finally, the position of 'navigation trail', if present, should be recorded using a permanent dotted black marker.

These standard markings are summarised in appendix 1.

Current Impact for different sites and vegetation types should also be recorded. This is explained further on page 62. Doing so enables products such as predicted impact and Moist/Dry soil logging plants to be prepared without the need for subsequent field visits.

SECTION 6: OFFICE WORK - AFTER FIELD INTERPRETATION.

Once the results of any samples taken have been received and incorporated into boundary decisions, the information from the odd No. (field) 230mm diapositive can be transferred to the orthophoto, if provided, or 1:4,500 prints of the area. Prints can be either colour or B&W. Orthophotos are B&W.

6.1 **Orthophotos** - Swan Region only at present

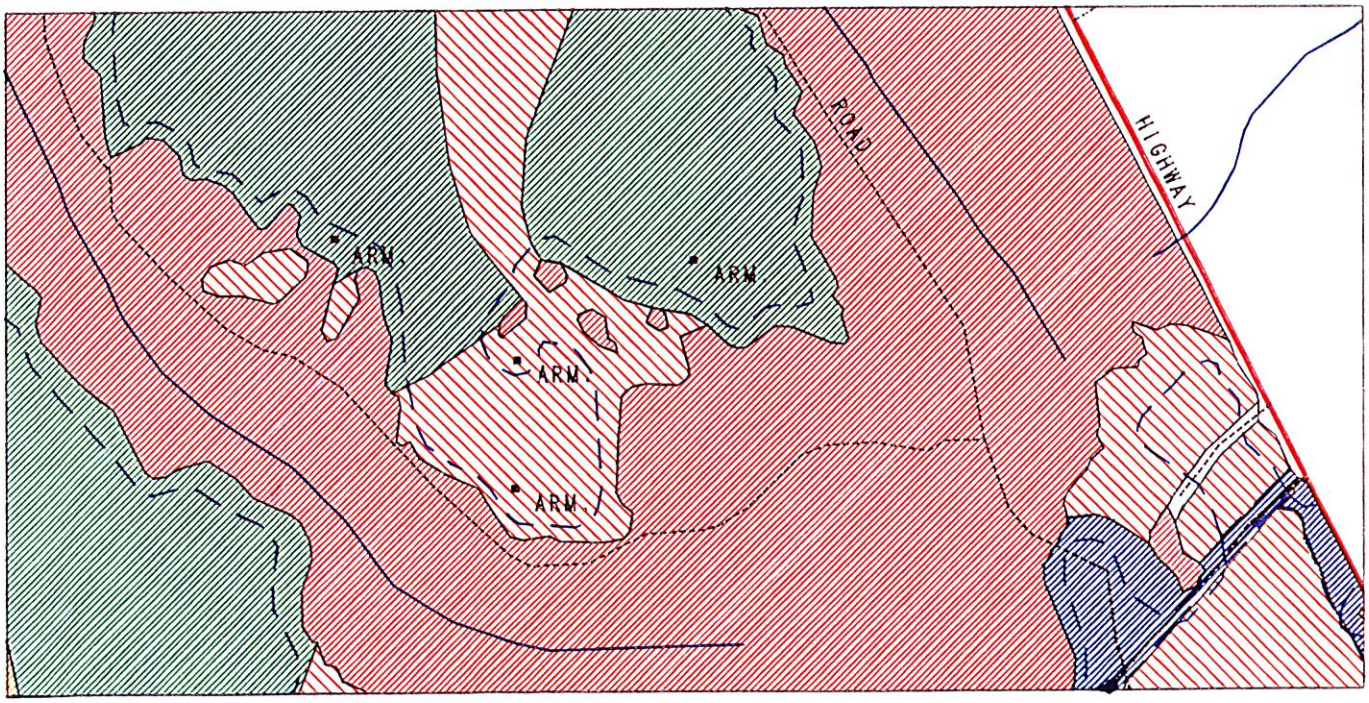
The orthophoto provides the base for subsequently producing 2 maps.

i) The hygiene plan and
ii) The demarcation map

The orthophoto shows the accurate mapped location of the P.c. infections. Hygiene categories are determined and added. It is a record showing interpreter decisions regarding the dieback and hygiene status of the area at time of interpretation.

Refer to appendix 1 for the standard pen colour assignments for use on orthophoto's.

Note the diagram which follows. Categories must be continuous - they do not emanate from or end on the day-glo orange P.c buffer tape line. Rather, they should start from or end on the position of the disease boundary (solid red line).



The orthophoto, with P.c. boundaries and appropriate hygiene categories is then given to Alcoa for digitizing, to produce a PRELIMINARY hygiene map or "Check Piot". This must be rechecked and verified by interpreter staff. Once verified, the FINAL hygiene map is available to accompany the cell report.

6.1.1 Scale Differences - 230mm/Orthophoto Mismatch

Orthophoto's are a constant 1:4500 scale. They are ground truthed and very accurate in themself. The 230mm diapositives vary in scale within a frame. The variation is greater where there is more relief, ie steep hills and deep gully's (eg. compare Dwellingup's Murray River Valley as opposed to the swan Coastal Plain).

This relief is "flattened" out in preparing the orthophoto.

Consequently, there are often scale differences which make it difficult to match features and correctly align the 230mm with the ortho for transfer of mapped details. A degree of "fudging" is usually required to achieve a reasonable fit. Sometimes however, where the mismatch is severe, no amount of "fudging" will produce a satisfactory fit. In those cases approval may be obtained from the Section Manager to submit the relevant photos to LIB (Land Information Branch, Como) for "manipulation" with the B8 stereo plotter (or similar). Trained staff at LIB will carefully plot the diapositive information onto a "flat" format to enable easier transfer to the orthophoto.

However, the work is slow and costly and must be justified. Arrangements with LIB should be made via the Inventory Section Manager.

Note also the nominal 1:4500 film scale is not always correct. Not only does it vary within frames, but also from frame to frame within an area. To check film scale, follow the procedure in appendix 4.

The hygiene map categories are listed in a particular order. This was done with the intention of assigning a priority to each category that is relative to disease presence. The category considered to have the least likelihood of Dieback presence and is not considered at risk from natural spread is at one end of the scale of priorities, while at the other end is the Dieback category. Relating this to operations then, it is considered there is little or no risk of spreading Dieback from secure Dieback-free forest, but there is certain risk of spreading disease from dieback areas. The categories between are considered to have different levels or risk equated to the position within the hierarchy of categories.

In working with the low and high potential risk categories the interpreter is stretching his knowledge of disease behaviours to the limit. What he is predicting may in fact not occur, relative to degree or place.

Though the definitions of the categories set down guidelines for the determination of particular risk, they must be considered guidelines only, and not as institutionalised laws.

6.2.2 Mapping the Categories

P.c. location needs to be accurately mapped - ie it must reflect the mapped position of the disease front as determined at the time of interpretation. Once this is complete, hygiene categories can be added to complete the picture.

Note that the other categories cannot be mapped with the same degree of precision as the P.c. boundary.

i) Dieback (D/B or Pc):  RED

Forest areas which show dieback symptoms and are supported by laboratory recoveries of *P. cinnamomi* from the soil and tissue samples.

- *P. citricola* infections are shown on the Hygiene plan as the same colour as *P. cinnamomi* infections with a notation identifying the infection as *P. citricola*

ii) Suspect (SUS):  Dark Blue

Where indicators are present, but the evidence for *P. cinnamomi* presence or absence is inconclusive. The suspect category is a legitimate category, not a haven for indecision. Some sites will exhibit some but not all the diagnostic elements of an infection - these sites are most accurately described as suspect. Intensive sampling can often be used to determine if *P. cinnamomi* is present in these areas.

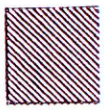
iii) High Potential Risk (H.P.R.):  Orange
(Dark Brown on other than digitized plans)

The high potential risk category is determined from local knowledge, contours and aerial photographs. It is that forest downslope from or in the same swamp as Dieback or Suspect. Considered to have a high potential for infection by *P. cinnamomi* by natural spread.

iv) Not Effectively Quarantined (N.E.Q.)  Yellow

Roads and tracks within the cell that have had considerable use during all seasons with an unknown degree of Hygiene are shown as not effectively quarantined. The forest adjacent to these roads is shown as N.E.Q. on the map. All open access roads fall into this category plus roads and tracks where breaches of quarantine have occurred. The N.E.Q. Zone is approximately 10 metres wide on both sides of

N.E.Q. roads and tracks, when mapping on orthophotos. For hand drawn hygiene plans at smaller scales (1:25 000 etc), a 50m strip is usually required for the NEQ to be easily visible.

v) Uninterpretable (UI):  Purple

This category is used to account for a number of situations.

1. Forest recently burnt or logged will be delineated and identified by the words burnt or logged and the date this occurred. Such areas are considered to be temporarily uninterpretable and may require further interpretation some time after burning or logging.

2. Areas of non forest such as gravel pits, transmission lines, roads, areas of rock, areas of forest cleared.

3. Forest in which susceptible indicator plants are absent or too few to enable interpretation for the presence or absence of *P. cinnamomi*.

When not using orthophotos, all categories less than 1 hectare are not considered, but are mapped in conjunction with the forest around the area. To map such small areas would require a change in the map scale.

The uninterpretable category requires considerable investigation. It maybe necessary to use the "strip line" approach with the parallel lines about 15-20m apart to determine if sufficient indicators exist.

The boundaries of uninterpretable forest are often difficult to determine. In such situations boundaries should be shown at a point where interpreters are absolutely sure that it is possible to detect, interpret and map disease occurrence ie. the boundary is mapped and taped into the interpretable side of the "line", 5 or so metres. (Similar guidelines applies for suspect - refer back to p43 section iii).

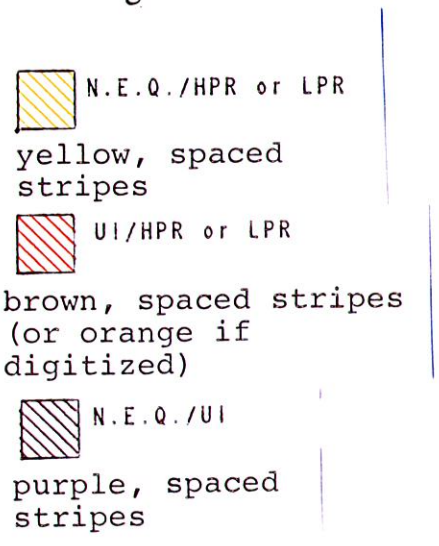
This mapping category must be used with the same degree of reliability as any other. This will mean considerable time must be expended in accurately determining the degree of interpretability and the boundaries of such areas.

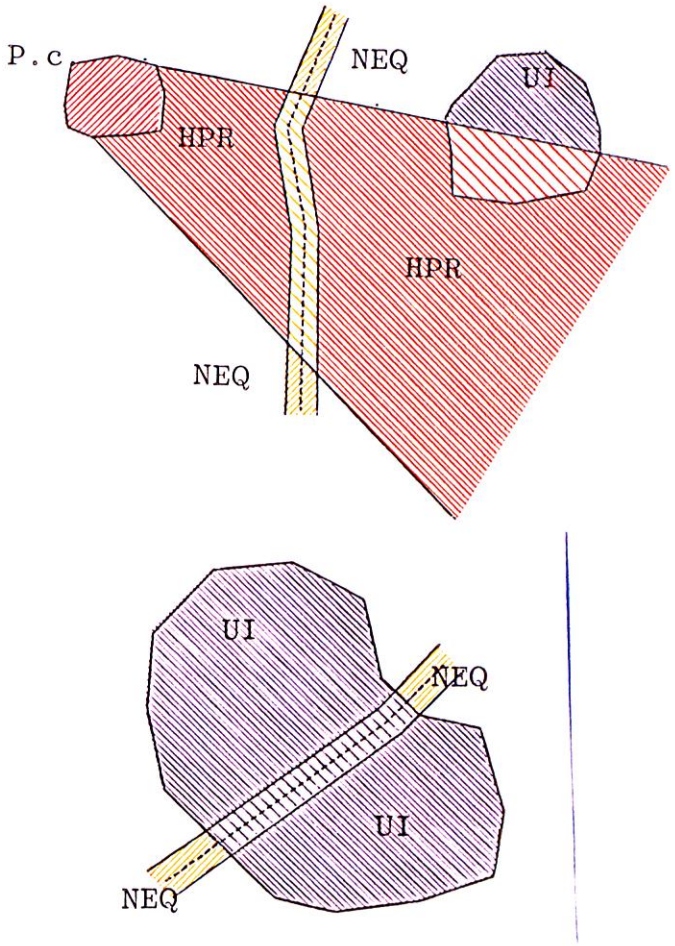
Uninterpretable will have a hatch over it, where it overlaps another category. See point 7 for more detail on category overlap.

6. Low Potential Risk (LPR):  Light Blue

Areas of forest downslope from NEQ and UI considered to have a low potential for infection by *P. cinnamomi* by natural spread.

7. Category Overlap: 3 category overlaps are possible. Refer to diagram for clarification





Remembering - only possible to have 1 colour from digitizing process
- 3 distinct overlaps, hence 3 distinct colours
- Simple black line hatcharing is too simplistic given 3 possibilities

8. Secure Dieback-Free:  Green

The area of forest apparently free of Dieback, and upslope from Dieback, Suspect, Uninterpretable and N.E.Q.

9. Other

In addition, the following procedures should be rigorously applied by all interpreters.

1. Areas of forest that are known to be infected with P.c. and adjoining the area mapped, but are outside the existing mapping boundary,

should be included and plotted to approximately 50 metres outside mapping boundary.

2. Areas of forest known to be infected with P.c. that are outside the mapping boundary and do not adjoin any part of the mapping areas, but will influence that area are not to be shown on the map. The influence zone from this infection will appear on the Hygiene map within the boundary of the mapping cell.

3. N.E.Q. roads will continue to be plotted on both sides of the road, even when this means that one half of the road will be shown as yellow colour outside the mapping boundary.

If an orthophoto is not provided, a 1:12500 or 1:2500 scale hygiene map will need to be plotted by hand, The 1:4500 prints will assist in preparing this map.

In summary, the hygiene legend is as follows.

HYGIENE MAP LEGEND

SECURE DIEBACK-FREE: Forest apparently free of dieback and upslope from dieback, suspect, uninterpretable and N.E.Q. roads.

LOW POTENTIAL RISK: Forest apparently free of dieback but downslope from uninterpretable or N.E.Q. Considered to have a low potential for infection by PHYTOPHTHORA CINNAMOMI by natural spread.

UNINTERPRETABLE: Forest in which susceptible plants are absent or too few to enable the interpretation of P.CINNAMOMI presence or absence.

CATEGORY OVERLAP:

N.E.Q./HPR or LPR

N.E.Q./UI

UI/HPR or LPR

N.E.Q.: Forest adjacent to roads in which there is a potential for incipient disease.

HIGH POTENTIAL RISK: Forest apparently free of dieback or uninterpretable but downslope from or in the same swamp as dieback or suspect considered to have a high potential for infection by P.CINNAMOMI by natural spread.

SUSPECT: Forest in which the evidence for P.CINNAMOMI presence or absence is inconclusive.

DIEBACK: Forest areas which show current dieback symptoms and are supported by laboratory recoveries of P.CINNAMOMI from soil or tissue samples.

- P. citricola
- Spot Infections

ARMILLARIA:

- Spot Infections

6.2.3 Dieback-Free and Hygiene Map Reliability Labels
(Currently Swan Region Only)

Hygiene maps are also labelled with reliability information which includes

i) a reliability index eg B2

The reliability index is composed of a number and letter, with meaning as follows:

INTERPRETATION INFO DERIVED FROM		MAPPING OF CATEGORY BOUNDARY	
1.	Interpreters using 230mm film	A	Survey of blaze lines
2.	Interpreters ground stripping	B	Survey of taped lines
3.	District staff assessment	C	Off orthophotos
4.	Aerial Photo Interpretation	D	Ground stripping with drill pegs in place
5.	Historical Data, > 3 years	E	Ground stripping
0.	Nothing	F	Historical, > 3 years (regardless of method)

RELIABILITY INDEX MATRIX

	A	B	C	D	E	F
1	A1	B1	C1	D1	E1	F1
2	A2	B2	C2	D2	E2	F2
3	A3	B3	C3	D3	E3	F3
4	A4	B4	C4	D4	E4	F4
5	A5	B5	C5	D5	E5	F5

\PE2\0422b.Gem

Different levels of reliability will mean different end-uses for the plan, as follows:

A1-C2 "This plan may be used for detailed operational planning. Hygiene category boundaries as shown will need rechecking after "DATE 2". If map is out of date, refer to Inventory before proceeding with any operation in the area covered by this plan. Boundaries within areas that have had operations become unreliable and should be checked prior to further/new activities."

OTHERS

"This plan should ONLY be used for strategic planning purposes. IT IS NOT AN OPERATIONAL GUIDE."

ii) Use by Date

The date of interpretation (DATE 1) is also shown, along with the name of the interpreter(s) responsible for the area. This date will be the first month/year of the commencement of field interp.

The use-by-date (DATE 2) will be 12 months on from Date 1.

e.g. Date 1: Oct 1991 - Date of Interp.
Date 2: Oct 1992 - Use-by-Date

6.3 Demarcation Map

Where requested, interpreters produce a demarcation map.

i) For Use by C.A.L.M. Districts: Using a black and white CALM map, a 1:12500 or 1:25000 scale version of the final demarcation taping locations is drawn by the interpretation team for use by CALM blazing crews.

To assist them in locating infections separated or isolated from main boundaries, a trail of green tape linking the two can be used.

Where interpreters do this, the 'navigation trail' should be transferred onto the plan, using a dashed green line.

A sample demarcation map is shown in appendix 7. It has a standard legend and colour assignments. The colours are summarised in appendix 1. A blank legend is included in Appendix 7 also.

Record the date, scale, location, area, interpreter's names and total length of demarcation for all categories on the legend. The length estimate will assist the district in costing the blazing work.

ii) For Use by Alcoa: The amended orthophoto can be returned to Alcoa for digitizing for their purposes.

Subsequently, the blaze line can be "picked-up" by Alcoa surveying teams, if required. A copy of the demarcation map is normally supplied to Alcoa. Another is produced for hanging in the Inventory plans cupboard.

Normally then

a) logging ops - 2 copies; 1 to district, 1 to inventory
b) mining areas - 3 copies; as above plus 1 to Alcoa.

6.4 Other Map Products

Interpreters may be asked to produce a range of other map products to cover the area under study, depending upon the type of operations that are planned.

For most mining operations, computer assisted design or digital plotting is made available.

In the case of harvesting operations not overlapping with mining, it is most likely that additional map products if required, will have to be hand drawn.

The table which follows is a guide that indicates what map types are usually required in different areas for particular operations (of May 1992).

REGION→	SWAN		CENTRAL FOREST		SOUTHERN FOREST		SOUTH COAST
MAP TYPE	HVSTING	MINING	HVSTING	MINING	HVSTING	MINING	
HYGIENE	√	√	√	√	√	-	
HAZARD	-	Maybe	√	√	-	-	
VEGETATION	-	Maybe	*	*	-	-	
LANDFORM	-	-	*	*	-	-	
MOIST/DRY	-	-	√	√	-	-	
J.S.I.	-	-	under review		-	-	

* 1 or the other. Usually vegetation.

6.4.1 Current Impact

Note that current impact information is recorded on photos. Maps are not usually required. The current situation in terms of the impact related to *P. cinnamomi* infections, provides information on the effect the disease is having on the forest. (That is the number of plants being killed.) It provides information relating to the area of forest being affected severely, less severely or hardly at all. This enables planning

and operations staff to direct logging and roading operations to particular areas under given weather conditions. The information is an important step to identifying potential impact in areas of forest not yet affected.

Legend

No Impact: This includes areas of dieback free, uninterpretable and suspect.

Low Impact (L): Some susceptible plants in the understorey killed by *Phytophthora cinnamomi*.

Moderate Impact (M): Many susceptible plants in the understorey killed by *P. cinnamomi* with less than 10 % of the overstorey dead or dying.

High Impact (H): Many susceptible plants in the understorey killed by *P. cinnamomi* with greater than 10 % but less than 50 % of the overstorey dead or dying.

Very High Impact (VH): Most susceptible plants in the understorey killed by *P. cinnamomi* with greater than 50 % of the overstorey dead or dying.

N.B. Within the forest there are always a number of dead and dying trees. These do not necessarily die as a result of *P. cinnamomi* infection and are referred to as 'background deaths'. In determining the percentage of dead or dying trees within an area of diseased forest, the level of background deaths are considered.

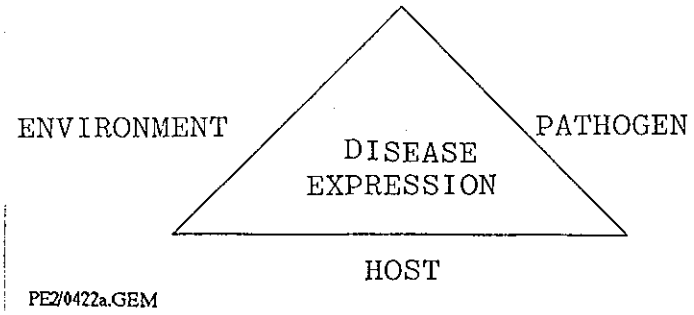
Compiling Impact Data

The information is compiled from local knowledge acquired during interpretation of the cell and plant deaths visible on the film. The boundaries will be a zone rather than a distinct

line. Indicate zones by recording the letter code on the film adjacent to the vegetation type boxes e.g. [ps] L.

6.4.2 Vegetation Types and Hazard Map

The impact of the disease will vary from site to site, depending on factors such as soil structure and moisture levels, vegetation type, the presence of agents antagonistic to the development of the pathogen and so on.



If the current impact in a particular vegetation type within an area is known, it is possible to predict the impact for as yet uninfected vegetation of the same type in a similar topographic position and soil type. This is known as hazard (i.e. potential impact)

In the northern forest the vegetation typing system used in the process of predicting hazard was developed by Joe Havel, and is therefore known as Havel-Type. Refer to Bulletin 86. "Site Vegetation Mapping in the Northern Jarrah Forest (Darling Range) 1. Definition of site vegetation Types" by J.J. Havel. (Reference #2).

Familiarity with the site types comes quickly with practice and by referring to the book in the field. Key species in certain topographic positions equate with particular site types. The T type for example, is characterised by the presence of bracken fern *Pteridium esculentum*, the creeper *Clematis pubescens* and the wattle *Acacia urophylla* in the understorey of tall jarrah/marri forest on mid to upper slopes of convex ridges in the high rainfall zone.

Vegetation type "boundaries" are indicated on the film as discussed in Section 5.4.5 on page 47 e.g. pS.

Hazard is defined as the combination of site, vegetation and climatic factors that influence the potential damage done by disease. For example, impeded drainage is quite often correlated with areas of disease exhibiting high impact. Any vegetation type that is commonly associated with impeded drainage can, therefore, be used as an indicator of high hazard. eg. *Hypocallyma sp.* on concreted laterite.

Although knowledge on hazard prediction is relatively imprecise, there are several methods currently being used to map hazard. The method used depends on the information available for the area being mapped. Refer to appendix 10 taken from the guidelines for preparation of a 7-way test.

Five common methods are outlined below:

a) The Shearer hazard prediction system is best used in the northern jarrah forest of the high and intermediate rainfall zone. It is however quite time consuming.

b) System 6 landform types and Havel vegetation types are most commonly used in the Central Forest and Swan Regions.

c) McCutcheon soil types are used in the sunklands

d) Beard's vegetation association and Churchwoods landform types are used on the south coast.

e) Strelein vegetation types in the Southern Forest Region and the more southerly parts of the CFR, along with Grant and Blankendeal landform types where applicable.

Where there is any doubt about the reliability of decision relative to disease presence or absence, the areas should be classified as suspect.

Hazard maps are used in conjunction with the hygiene map and the 7-way test to make managerial decisions about what, how and when operations are to be carried out and what hygiene constraints are most appropriate.

6.4.3 Moist/Dry Soil Map Preparation

Information to be collated

1. Hygiene Map
2. Current Impact information
3. Vegetation/Landform plan
4. Vegetation Type & Hazard Plan

You will need the Manual of Logging Specifications and the tables for predicting impact, taken from the guidelines for preparation of a 7-way test.

P.c. infected areas are generally moist-soil as long as they are low in the topography profile ie. other areas of forest will not be put at risk downslope.

Suspect and uninterpretable - DRY SOIL only

In other areas that are NOT Pc, SUS or UI, if predicted impact or hazard is-

Low	-	Moist soil
Moderate	-	Borderline. Discuss with district and make decision
High	-	Dry Soil
V. High	-	Dry Soil

Having knowledge of the vegetation site types and the current impact being expressed in those, it is possible using that local knowledge and the hazard rating tables to determine the likely development or impact of the disease should it infect a particular vegetation site type. From there, decide which section can be logged under moist or dry soil.

After considering the hygiene categories,

You should finish with a plan showing logging categories with area statement as follows

1. Moist soil, P.c. infected. Soil movement permissible.
2. Moist soil, not infected. No soil movement allowed.
3. Dry soil, P.c. infected. (Areas above high or very high predicted impact)
4. Dry soil, not infected.

Consult the Senior Interpreter for advice.

6.5 Cell or Area Report

In all cases, a report or letter should accompany map products resulting from the field interpretation. The standard format to adopt follows.

Report Headings:

i) Title Page

Forest block, compartment, cell number, author and date should be detailed on the title page.

ii) Index

1) INTRODUCTION

This section should include -

i. Details of previous interpretation (eg. 70mm Feb 1982 etc)
ii. Description of the cell position
iii. Who was involved?
iv. When the cell was started and finished? Specify dates.
v. The total area of the cell
vi. Background information; land use, logging and burning history and rainfall.

2) METHOD

2.1 Interpretation

Unless the method deviates from that described in the interpretation procedure manual, a brief sentence stating the method as per the procedure manual will suffice.

2.2 Demarcation

Where the method of demarcation varies between regions, this should be described in full.

2.3 Sampling

Describe any sampling techniques unique to the cell and mention that procedure was followed according to the procedure manual. Sample results should not occur in this section.

2.4 Hygiene Category Allocation

Describe the method of allocating hygiene categories by observing field conditions and topographical displacement noticed on small scale stereo photographs. Also briefly mention the method of transferring hygiene category

boundaries to small scale photography (i.e. 1:20,000 or 1:25,000).

2.5 Mapping

A brief description of transferring P.c. boundaries onto orthophotos, or otherwise onto smaller scale photography and then to a base plan, is all that is required.

3) RESULTS

3.1 Disease Distribution

Report results of previous mapping. Where did disease occur? (e.g. creeks, gullies, ridge tops). What was the proportion of diseased to uninfected area? Report results of current mapping. Address the above questions. Do not compare the results in this section.

3.2 Disease Expression

Describe various forms of current impact P.c. is having on sites within the cell. List known P.c. indicator species occurring within the cell and comment on particular species that have and have not succumbed to the disease.

Also comment on vegetation types found within the cell and how they affect disease expression (e.g. S type commonly has P.c. indicator species *Xanthorrhoea gracilis* and *Banksia grandis*). Only comment on disease expression. Do not mention hazard or predicted impact in relation to vegetation types. However, this result will be used to support hazard predictions in the discussion section.

3.2.1 Uninterpretable

Comment on uninterpretable forest with regard to P.c. expression. Address the question "Why does Pc have nil expression within uninterpretable in the Cell?"

3.2.2 Drought

Report drought symptoms found within the cell. A nil result should be reported.

3.2.3 Expression Anomalies

Report any unusual P.c. expression (e.g. P.c. suspect sites, drought and P.c. symptoms combined).

3.2.4 *Armillaria*

Report locations of *Armillaria* infections (six figure reference) and a brief description of symptom expression within the cell.

3.3 Landform and Vegetation Types (if required)

Detail separate landform types found within the cell and their associated vegetation types (under separate headings).

Hazard should not be discussed in this section.

3.4 Disease Impact (current) (if required)

Describe the current impact occurring within the cell.

Tabulate impact category areas.

3.5 Hygiene Data

Under separate headings (3.3.1, 3.3.2 etc) detail the area of each hygiene category used on the map and briefly describe why the category was applied. The legend will help.

3.6 Moist and Dry Soil Operations Map (if required)

Detail areas and reasons for placement of moist and dry soil categories.

3.7 Sample Results

A brief summary of tabulated sample results from the appendix should be presented in this section.

3.8 Area Statement

Areas should be calculated for all categories on the hygiene map and tabulated in this section.

3.9 Jarrah Stand Improvement map (if required)

Report technique used and final area suitable for JSI

4) DISCUSSION

4.1 Disease Distribution and its effect on hygiene Categories

Address the following questions in this section

1) Has Pc distribution changed since previous mapping, and if so, how has it affected hygiene categories (e.g. more HPR, less SDF).

Where do you expect most P.c. spread? This would generally be in HPR areas, depending on recent activity within the cell.

Use the section to emphasise the differences in definition of HPR as opposed to Hazard or predicted impact.

4.2 Disease Impact (if required)

By referring to and summarising the results, draw conclusions on the predicted impact (hazard) status of various landforms found within the cell. Tabulate the information.

4.3, 4.4, 4.5 etc

Comment on topical subjects/recommendations giving support from the results.

5. CONCLUSION

Summarise the report, detailing all maps produced and highlighting the map age limitations. Mention if any further mapping is taking place adjacent to the cell in the near future.

6. RECOMMENDATION (optional)

Detail recommendations supported by the report (careful wording is required).

7. APPENDICES

1. Map of the cell - Hygiene, others as required
2. Sample results table
3. Costing analysis (cost per hectare (includes salaries & vehicles), and hectares covered per man day)

All appendices must have a reference within the report otherwise do not include them!

Role of Section Manager

All reports should be read by the Section Manager, prior to handover to the District. The report should be discussed with the Section Manager, particularly if you have recommended unusual action to the Districts. The Section Manager may decide to discuss this with the Regional Operations officer and then set guidelines for the interpreter in his/her discussion with District staff during the handover.

APPENDICES

1. Summary of Colour Assignments
2. Standardisation of Blazing - Uninterpretable, Dieback, Suspect
3. Equipment Suppliers
4. Calculating Film Scale
5. Storage, Care and Handling of Film
6. Care and maintenance of Stereoscope Equipment
7. Demarcation Map & Standard Legend.
8. Technical Bulletin #3
9. Shearer's Article - reference #9, *Phytophthora spp.* in W.A.
10. Hazard Ratings
11. P.c. indicator species by zones.
12. Motorbike Use and Safety.

APPENDIX 1

SUMMARY OF COLOUR ASSIGNMENTS

Use permanent pen for field work. Note omnichrom & chinograph are interchangeable.

i) Odd No. 230mm Diapositive

RED	chinograph pencil*	- Possible P.c. areas (to be verified)
PURPLE	chinograph pencil*	- Possible UI areas (to be verified)
RED,	dot,	- Sample point, annotated with number and date.
RED,	solid,	- P.c. boundary.
RED,	dashed	- Day-glo orange taping line.
RED,	arrows,	- Slope Direction.
BLACK,	dashed,	- Tracks.
BLACK,	dotted,	- Green navigation taping.
RED,	dotted,	- Old blaze lines, annotated OBL.
PURPLE,	dashed,	- White UI taping line.
BLUE,	dashed,	- Red suspect taping line.
ORANGE,	solid,	- *Armillaria* location, annotated ARM.
ORANGE,	dashed,	- *Armillaria* taping line.
BLACK,	boxed letters eg pS	- Vegetation type
BLACK,	letters (L,M,H, or VH)	- Current impact
BLACK, solid		- Interp Boundary.

ii) Orthophoto:

RED,	solid,	- P.c. boundary as rationalized.
RED,	dashed,	- Day-glo orange taping line.
PURPLE,	solid,	- U.I. category.
BLUE,	solid,	- Suspect category.
BLACK,	solid,	- L.P.R. category
YELLOW,	solid,	- N.E.Q. category.
BROWN,	solid,	- H.P.R. category.
BLACK HATCHING,	solid,	- Category overlap.
ORANGE,	solid or cross	- *Armillaria*

iii) Demarcation Map - for use by CALM districts: (and copy to Alcoa)

PINK,	dashed,	- Day-glo orange taping line.
GREEN,	dashed,	- Green "navigation trail" taping.
YELLOW,	dashed,	- Old blaze lines.
PURPLE,	dashed,	- White UI taping line.
BLUE,	dashed	- Red Suspect taping line.

iv) Hygiene Map

RED,	- Dieback
DARK BLUE,	- Suspect
BROWN,	- High Potential Risk
YELLOW,	- Not Effectively Quarantined
PURPLE,	- Uninterpretable
LIGHT BLUE,	- Low Potential Risk
YELLOW HATCHURE,	- NEQ over HPR or LPR
PURPLE HATCHURE,	- NEQ over UI
BROWN HATCHURE,	- UI over HPR or LPR
GREEN,	- Secure Dieback Free

Note that orange is used instead of brown for HPR on digitized hygiene plans, and similarly orange hatchure for the UI/HPR or LPR overlap.

APPENDIX 2

STANDARDISATION OF BLAZING - UNINTERPRETABLE, DIEBACK, SUSPECT. (FEB 91, ENV PROT'N BRANCH)

1. DIEBACK

(a) Initial demarcation of all P.c. boundaries will be with Day-glo orange tape with the knot facing P.c.

(b) Permanent demarcation will be 3 yellow painted blazes with the third blaze facing P.c.

2. UNINTERPRETABLE

(a) Initial demarcation of all uninterpretable boundaries will be with white tape with the knot facing uninterpretable.

(b) Permanent demarcation where required by District will be with 3 white painted blazes, the third blaze to face uninterpretable.

3. SUSPECT

(a) Initial demarcation of suspect will be with red tape. The knot to face suspect.

(b) Permanent demarcation where it is required by the District, will be with three red painted blazes, the third blaze to face suspect.

4. WHERE HYGIENE CATEGORIES ABUT

(a) Initial demarcation will often require the demarcation of P.C. from UI, or P.C. from SUS, or SUS from UI etc.

When this occurs both categories may need to be demarcated using the appropriate coloured tapes on the same tree. The knots will be

facing opposite directions. (Discuss the with your local district - the second tape may not be required).

(b) When this situation arises, permanent demarcation as follows:

(i) Pc will always be blazed with 3 yellow blazes. If required, the abutting category will be indicated by a fourth, appropriately coloured blaze facing the adjoining category.

(ii) Suspect will take priority over UI. That is, the suspect/UI boundary will be demarcated by 3 red blazes with an additional white blaze facing UI.

APPENDIX 3

EQUIPMENT SUPPLIERS

ITEM	SUPPLIER DETAILS		COST APRIL 91
Esky - 26l Coleman	J.S. Sadique P.O. Box 922 West Perth 6005	321 2522	$37.75
Methylated Spirits "Hovex" 4l	William. J. Pascoe 14 Tighe Street Jolimont 6014	381 5762	$8.25 per 4l + $4.00 delivery
Light Board, translucent acrylic 545 x 300mm	Armadale Glass & Mirrors 253 Railway Pde Kelmscott 6112	399 7000	$10.00 ea
Sample Carry Bag	Armadale Army Surplus 56 Fourth Road Armadale 6112	399 1167	$5.75 ea
Pocket Stereoscope Wild TSP-1	Leica (Wild Leitz) Aust 164-166 Railway Pde Leederville 6111	382 3922	$270.00 ea
Plastic 20l Drum with tap	W.A. Salvage Albany H'way Cannington	458 3321	$6.95 ea
Plastic Sample Bags Soil 380mm x 250mm size 150 micron Tissue 300mm x 200mm size 100 micron	Gromark Packaging 15 Valentine Kewdale	353 3488	$165.00 per 1000
Trigger-Top Plastic Spray Bottles 500ml	K-Mart (nursery section)		$1.88 ea
Tape Rolls (all colours)	Sussex Industries Box 13 Maylands 6051	272 1344	200 roll/box $1.60 to $1.90 per roll
Mattocks Cyclone Homemaster 80mm hatchet	Mazzega Timber and H'Ware Cnr Gillam Dve & 3rd Ave Kelmscott 6111	390 4110	$27.50 ea for box of 10
Scale Rulers	Jacksons Drawing Supplies Box 156 (103 Rokeby) Subiaco 6008	381 2488	
Distilled Water	Supermarket or Como Research		

ITEM	SUPPLIER DETAILS		COST APRIL 91
Portable Handheld Radio KYODO Sawtron #KG10908B05KW	Through Communications Branch Como		$1300.00 ea
Hip Chains (Aussie-Chain)	Trugrade 65 Edwards St Osborne Park	242 3313	$
Hanging Plan Suspension Strips RODIA #722	National Drafting Industries P.O. Box 147 (7 Loftus St) Leederville 6111	382 4444	$53.90 pkt
Map Tubes (adjustable black)	"A-Just Case:SAS 100" Sakurai Co		N/A
Map Tubes (screw together grey, cylindrical)	Cylopak "LC" Type, 10cm ext. dia avail through Mapping Branch, Como		$23.50 ea
W/Proof Photo Satchels P.V.C. Stitched 27x33x7cm	Delray Ritcher Road Bunbury	097 254433	$35.00 ea
W/Proof Brief Case 6185 ABS	W.A. Travelgoods Cnr Drake & Howe St (98 Howe St) Osborne Park 6017	444 9027	$55.95 ea
Seat Belt Webbing	Green's Canvas Works John St Welshpool	458 2290	$2.00 per metre
Tags Aluminium	Sussex Industries	272 1344	$19.50 per 1000
Miracle-Mat (holds TSP-1 in place on lightboard)	Fleetwood Maddington	459 2511	$12.95 per metre
Nylon Tie-Strips	Engineering Supplies Aitken Way Kewdale	353 3844	$36.00 per 1000

APPENDIX 4

CALCULATING FILM SCALE

Locate two easily identified features in the field.

Measure the distance between the features in the field (actual length) and on the film.

$$\text{SCALE} = \frac{\text{LENGTH IN FIELD}}{\text{LENGTH ON FILM}}$$

e.g. Length on film - 5.8 cm
Actual length - 246 m

$$\text{SCALE} = \frac{246\ \text{m}}{0.058\text{m}} = 1{:}4241$$

APPENDIX 5

STORAGE, CARE AND HANDLING OF FILM

SYNOPSIS:

The introduction of the 230mm format for Dieback interpretation and mapping should be seen as a further refinement of the overall photography programme. The generated forms in which photography is now presented to interpreters, inherits considerable advantages over the earlier 70mm format; physical care and handling being foremost.

As a major characteristic of the new system, and perhaps the main difference between the two formats - the film, upon which the initial image is acquired, is now safely stored as the "Master Copy" without the dangers inherent in using the Master for office and field use. Interpretation and mapping now uses first generation reproduction in the form of colour transparencies and prints; the transparencies in particular being high quality and robust products ideally suited to the exacting procedures, of office and field, necessary for accurate interpretation.

TRANSPARENCIES

These are currently produced on an Agfa film, but Kodak manufacture a similar product. Both mediums are suitable and either may be used in future contracts.

The manufactures describe the film base as dimensionally stable and colour fast ie. considerable (for photographic film) variation in temperature can be experienced without change in lateral dimension or colour drift. As a product specifically designed for backlit display purposes the film will endure temperatures up to 50°c before irrevocable damage, in the form of buckling or curling, is sustained.

The actual emulsion surface is vulnerable to physical damage and abrasion, so for extra protection the transparencies are presented in a laminated form, which renders the film virtually waterproof. However, they should be kept dry and wiped dry before storage at the end of each day. Otherwise, water will seep between the laminated layers and affect the film quality.

GUIDELINES TO BE OBSERVED

* STORAGE

- It is the interpreters responsibility to ensure that all frames within the cell coverage are returned in correct order to storage. Missing film must be located.

- Transparencies should be kept in the flat envelope sachel provided - whenever not in use.

- In the field, the same envelope should be used for carriage and storage. This envelope should further be enclosed in a large plastic bag as protection from excessive dust and moisture.

- Ensure (at all times) that the transparencies are stored in a cool dry and dark place whenever possible.

- Protect form extreme heat (e.g. vehicle dashboard) and prolong exposure to extreme sunlight.

* HANDLING

- Avoid excessive dust and dirt (especially in the field) - this will scratch the laminated surface with resultant loss in image quality and stereo clarity.

- If excessive moisture is encountered (rain, waterholes, dams, flood) - wipe excess off with a soft cloth and separate to dry individually as soon as possible. If the product dries while stuck together there is a risk of the lamination lifting when separated).

- Remove transparencies from light tables (portable) if the job is left for any length of time. Do not leave transparencies on illuminated light table for extended periods - (switch off).

* N.B. The larger format of the 230mm photography is more vulnerable to uneven variations in temperature. This will be observed first by curling at the corners. Extremes in temperature may cause prominence of the curling and other faults such as lifting of the laminate. To ensure proper imaging and stereo vision, it is essential that this distortion is avoided and that the diapositives are maintained in a flat condition.

CLEANING

- Dust and dirt should be removed using water, a mild detergent and a soft cloth - sparingly. Stack individually to dry.

- For removal of pen markings - use either methylated spirits or turps, sparingly - dependant upon the pen type used. If possible use cotton wool with these liquids as it is the least abrasive.

* - Do not use solvents of any type.

Remember, although the product is described as being "robust", reproduction of damaged frames will cost approx $20.00 with associated admin. charges.

PRINTS

Used for boundary transfer at the mapping stage, in the absence of orthophotos, the prints are produced on a "Resin coated" paper, made by either Agfa or kodak. "R.C." paper is virtually a type of plastic, but the emulsion surface will become soft and sticky in contact with water.

- If moisture is encountered separate, carefully and dry naturally as individual sheets.

- To erase pen marking use turps or methylated spirits sparingly. (Most rubber erasers will remove the pigment layers of the emulsion).

APPENDIX 6

CARE AND MAINTENANCE OF STEREOSCOPE EQUIPMENT

1. WILD AVIOPRET - with Mirror Stereoscope

The most vulnerable part of this equipment are the mirrored surfaces. The mirrors are surface coated to ensure a distortion free image, therefore, scratches and abrasion of the mirror will adversely effect the image reproduced.

HANDLING

When not in use:

- Swing shadow wings up to protect mirrors.
- Fit dust cover provided.
- Place mobile light table under stereoscope assembly.
- Disconnect power supply.

In use:

- When swinging 3 x lens pods avoid dropping to the viewing position.

- Avoid touching any of the mirrored surfaces - the grease of fingerprints is extremely difficult to completely remove and continued cleaning may result in deterioration of the reflective surface.

CLEANING

- Dust should be removed from lenses and mirrors with the lens brush provided; excess can then be expelled using air from the pressurised "Dust off" cylinder. **NOTE:** When using these pressurised cylinders, observe the operating instruction carefully - **Keep upright, Do not shake.**

- Lenses should be cleaned carefully using lens cleaning tissue. This tissue is designed specifically to be non-abrasive and lint free. Most other materials available do not meet these constraints. Used in conjunction with lens cleaning fluid, grease and fingerprints are easily removed.

2. POCKET MIRROR STEREOSCOPE

The same principles of handling and cleaning apply to this unit: the same type of mirrored surfaces are used and are just as vulnerable. The outer mirrors, particularly, are susceptible to finger prints during handling. A Teflon strip is added to the magnetic feet of the stereoscope to protect the transparencies. Ensure this teflon is maintained in good condition - replace if necessary.

The unit should be stored in its carrying case when not in use.

*** SPECIAL NOTE:**

If mirrors from either piece of equipment require any cleaning other than the "dusting" already described, the matter should be referred to the O.I.C. Interpretations Standards who will make arrangements for cleaning.

AVAILABILITY OF CLEANING STORES

*FALCON "Dust Off II" Dust Propellant Cylinders.
from Perth Professional Photographics
268 Lord St., East Perth
Approx. cost $5.50/can

*KODAK Lens Cleaner (Fluid) (Kodak Cat # 4151494)
from Kodak A/Asia
Chivas St., Kewdale
Approx. cost $1.50/100 ml bottle

*KODAK Lens Cleaning Paper (40 packet carton)
(Kodak Cat # 1546027)
from Kodak A/Asia
Chivas St., Kewdale
Approx. cost $23.00/carton

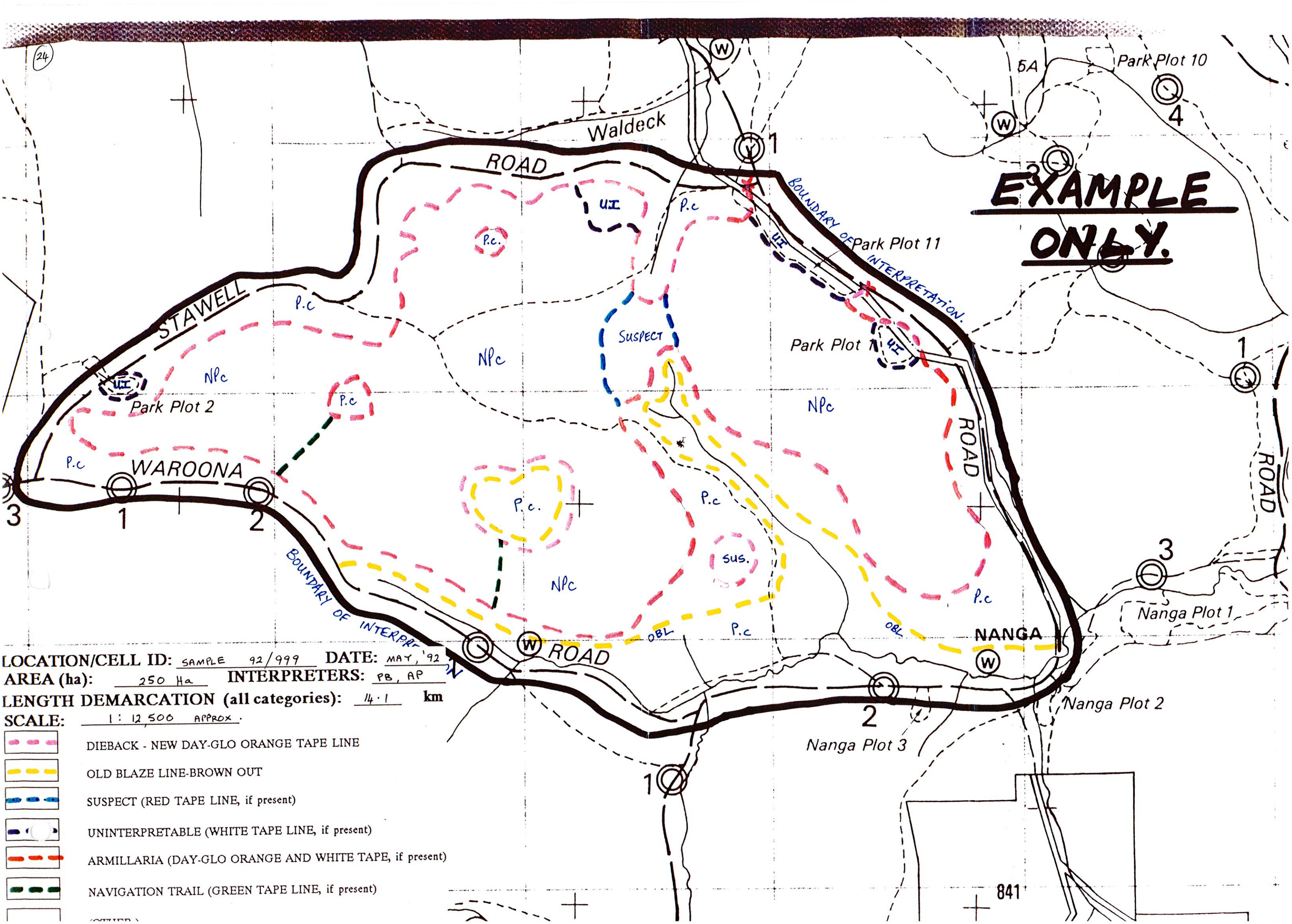
APPENDIX 7

STANDARD LEGEND - DEMARCATION MAP

LOCATION/CELL ID: _____ **DATE:** _____
AREA (ha): _____ **INTERPRETERS:** _____
LENGTH DEMARCATION (all categories): _____ **km**
SCALE: _____

☐	DIEBACK - NEW DAY-GLO ORANGE TAPE LINE
☐	OLD BLAZE LINE-BROWN OUT
☐	SUSPECT (RED TAPE LINE, if present)
☐	UNINTERPRETABLE (WHITE TAPE LINE, if present)
☐	ARMILLARIA (DAY-GLO ORANGE AND WHITE TAPE, if present)
☐	NAVIGATION TRAIL (GREEN TAPE LINE, if present)
☐	(OTHER:)

\pe2\0422.92



LOCATION/CELL ID: SAMPLE 92/999 **DATE:** MAY, '92

AREA (ha): 250 Ha **INTERPRETERS:** PB, AP

LENGTH DEMARCATION (all categories): 14·1 **km**

SCALE: 1 : 12,500 APPROX.

- DIEBACK - NEW DAY-GLO ORANGE TAPE LINE
- OLD BLAZE LINE-BROWN OUT
- SUSPECT (RED TAPE LINE, if present)
- UNINTERPRETABLE (WHITE TAPE LINE, if present)
- ARMILLARIA (DAY-GLO ORANGE AND WHITE TAPE, if present)
- NAVIGATION TRAIL (GREEN TAPE LINE, if present)
- (OTHER)

APPENDIX 8

TECHNICAL BULLETIN #3

Note that some sections of this document may not be relevant, or indeed, may now be outdated.

Therefore, Interpreters should refer mainly to the following pages;

a) METHOD, pages 8-11 inclusive,

b) DISCUSSION, pages 14-15 inclusive
and

c) CONCLUSION, page 16, along with its appendix 4, shown on page 21.

The selected material contains useful descriptions of ISD class, pattern development, topographical situations and causal agencies.

APPENDIX 9

FEATURE ARTICLE

Dieback of Native Plant Communities Caused by Phytophthora Species —A Major Factor Affecting Land Use in South-Western Australia

Dr Bryan Shearer
Department of Conservation and Land Management
Dwellingup Research Centre
DWELLINGUP WA 6213

Introduction

Dieback disease caused by *Phytophthora* species is a major threat to the ecology and conservation of susceptible plant communities of south-western Australia. During the relative short time since introduction, infection by *Phytophthora* species has irreversibly destroyed the structure and diversity of many plant communities widely distributed throughout the area bordered by Kalbarri in the north, Cape Arid in the south and Boyagin Rock to the east.

Phytophthora cinnamomi is the most destructive and widespread of the seven *Phytophthora* species that infect native plant communities in this state. Historically, the threat that *P. cinnamomi* infection posed to timber production and protection of water catchments has received greatest attention. Thus more is known of the interaction between *P. cinnamomi* and the jarrah forest than for other *Phytophthora* species and plant communities. Our current understanding of the various interactions between *P. cinnamomi* and the jarrah forest ecosystem has been reviewed recently (Shearer and Tippett, 1989).

This article is about the impact and consequences of disease caused by *Phytophthora* species in native plant communities of south-western Australia. It is not the intention to simply dwell on negative aspects of dieback disease. Improved understanding of impact helps identify factors affecting disease dynamics and guides land use planning and the commitment of resources needed for effective control.

History

In the early 1920s unexplained deaths of jarrah (*Eucalyptus marginata*) and understorey species were observed near Karragullen 35 km south-east of Perth (Podger, 1968). These deaths were the earliest report of what is now commonly called 'jarrah dieback'. It was not until the mid-1960s that Dr F.D. Podger firmly established the association between death of jarrah and infection by the introduced soil-borne fungus *P. cinnamomi*.

During 40 years following the first observation of jarrah dieback, failure to identify a cause hampered effective control. Unfortunately, the unsuspected fungus was spread unintentionally throughout south-

western Australia in infected soil moved by human activity. For example, gravel from dieback areas was unwittingly used in road construction. From the initial small dead patches of forest, impact of the disease has increased in range and severity throughout the south-west. Diverse plant communities ranging from coastal shrub-heath to forest are now affected. An estimated 280,000 ha of Crown land was infected by 1977 (Shea, 1978).

The discovery of the association between *P. cinnamomi* infection and jarrah dieback (Podger *et al.*, 1965) had far-reaching influences on the public and research priorities. By the late 1960s Podger's breakthrough had stimulated research on the distribution of *P. cinnamomi* throughout Australia and the effects of environment on disease.

Knowledge gained aided the development of hygiene prescriptions in the 1970s aimed at preventing the spread of the fungus and infection of healthy areas. In the mid 1970s, northern jarrah forest with little disease in high salt hazard areas was quarantined. Significant progress was made by the mid-1980s in the development of hygienic procedures and application to all operations in the forest as well as national parks and nature reserves. Accurate methods of detecting and mapping disease from shadowless colour aerial photographs were developed in association with the hygienic procedures. Critical to the success of hygiene methods is an understanding by the public of the biology of the fungus and the reasons for the methods used. In this respect dieback protection plans have aided implementation of control procedures (Department of Conservation and Land Management, 1986).

Dieback research was stimulated in the early 1980s by funding from a Foundation for Jarrah Dieback Research financed by the alumina and timber industries. The formation of the foundation was partly in response to concerns that bauxite mining was intensifying dieback and that the quality of Perth's water supply would deteriorate should disease extend into catchments with high salt hazard (Shea, 1988). Research areas funded by the foundation included jarrah forest ecology, understorey manipulation, host response to infection, tissue culture of jarrah and activity of *P. cinnamomi* in the soil. Unfortunately the end of the foundation in 1987 resulted in many groups discontinuing active dieback research. In the few remaining centres, research is continuing to improve knowledge on the impact of disease on conservation and resource management values, the major stimuli affecting disease development and methods of control.

In his pioneering research, Podger (1968) monitored and described the impact of *P. cinnamomi* not only in the jarrah forest, but also in shrublands and woodlands throughout south-western Austra-

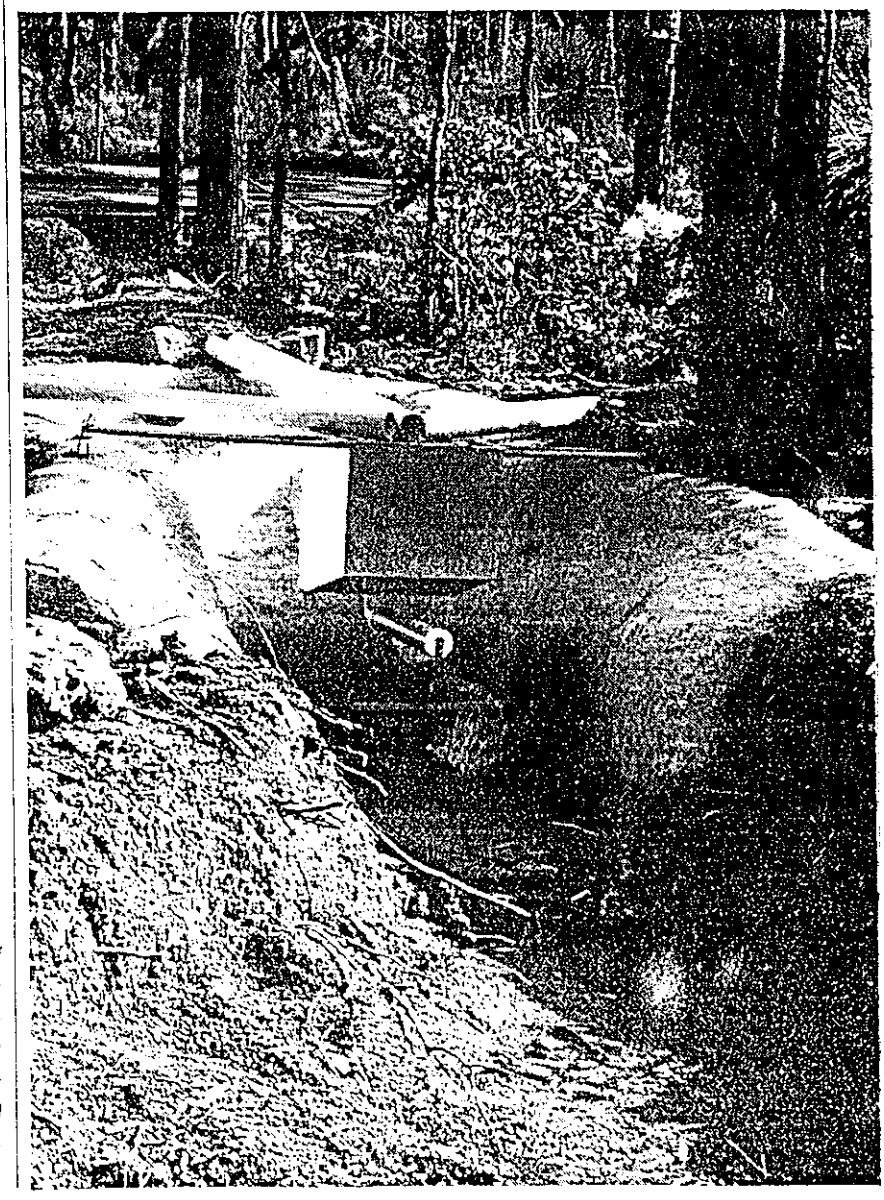


FIGURE 1: A main mechanism of passive dispersal of Phytophthora inoculum at depth is lateral near-surface seepage of water over a perching layer. (a) Monitoring near-surface lateral seepage of water in the jarrah forest.

lia. However in the two decades following Podger's initial monitoring, relatively little research has been done on the occurrence of *P. cinnamomi* in plant communities other than the jarrah forest. This situation changed in 1985 when the Departments of Forests, National Parks and Wildlife were amalgamated to form the Department of Conservation and Land Management. Emphasis is now being given to studies on host susceptibility, pathogen dynamics and control of *P. cinnamomi* in shrublands and woodlands. There is also a growing appreciation that *Phytophthora* species, other than *P. cinnamomi*, are a threat to native plant communities.

Life cycle of Phytophthora

Phytophthora cinnamomi and other *Phytophthora* species have complex life cycles. *Phytophthora* cinnamomi is an introduced soil-borne fungus belonging to the Oomycetes or 'water moulds'. The fungus is pathogenic requiring plant tissue as a food source. As the name 'water mould' suggests, the life cycle of *P. cinnamomi* depends on moist conditions that favour survival, sporulation and dispersal of the fungus, and host infection.

There are three types of spores produced. Warm, moist conditions and interactions with soil microflora favour vegetative production, from mycelial strands in the soil or host tissue, of thick walled *chlamydospores* and zoospores from sporangia. The *chlamydospore* is larger than the zoospore and survives in the soil or host tissue, provided conditions do not become too dry. They cannot move on their own and are transferred in infected soil or host tissue. When conditions are favourable, chlamydospores germinate to produce mycelium and zoospores. The interaction between mycelium of different mating types may induce production of thick walled resistant sexual oospores. However only one mating type of *P. cinnamomi* (the A2) is common in south-western Australia.

Reproduction in soil is mainly by the asexual sporangium-zoospore cycle which produces large numbers of infectious spores when conditions are favourable. *Phytophthora cinnamomi* has very specific requirements for sporangium production; no spores will be produced unless some inherent soil property stimulates the formation of sporangia. The precise nature of the stimulatory factor(s) in soil is unknown but it can be influenced by soil type and the composition of the soil microflora. In stimulatory soils, sporangium production is favoured by warm, moist and aerobic conditions. Release of motile zoospores from sporangia is favoured by wet soil conditions and fluctuating temperatures, modified by soil type and season. Once released, motile zoospores swim over short distances in water or are passively dispersed over larger distances in flowing water or infected moist soil moved by human activity.

Following introduction of the fungus into a site, lateral near-surface seepage of water is one of the main mechanisms of passive dispersal of inoculum at depth in soils where coarse textures or aggregate structure occur over a perching layer (Fig. 1). In the jarrah forest dispersal of inoculum in near-surface seepage of water linked disease development in upland areas with specific site factors that affected behaviour of the fungus at depth in the soil and the infection of jarrah. As south-western Australia is a mosaic of site-vegetation types, it is also a mosaic of sites with different drainage characteristics that can influence dispersal of *P. cinnamomi*. Relatively free draining sites favouring vertical percolation of water are interspersed between sites with near-surface seepage of water, with gradations between the two extremes.

The fungus can also be dispersed in infected roots either actively by growth through root systems or passively in infected roots transported in soil. Root to root contact facilitates mycelial growth between root systems and initiation of new infections.

Once dispersed fungal propagules must survive to produce new inoculum and infect host tissue. Temperature, moisture, floristic composition of the understorey, antagonistic microflora and soil type affect survival of *P. cinnamomi*.

The various components and interactions previously described are the building blocks from which *P. cinnamomi* develops in space and time. In free draining surface soil greatest number of sporangia form in autumn and spring when warm moist conditions favour sporulation. Generally sporulation is inhibited by dry summers and cool winters. Propagules surviving dry summers in plant tissue and soil act as sources of inoculum in autumn. Wet conditions in winter favour survival of this inoculum which may increase with the return of favourable conditions for sporulation in spring. Inoculum levels decrease rapidly as the surface soil dries out in late spring (Fig. 2). Viable inoculum occurs in infected, water-gaining lowland areas (Fig. 2) and in the soil at depth throughout the year, reflecting extended periods of moist conditions favourable for survival and maximum coincidence of warm, moist conditions favourable for sporulation. The seasonal pattern of inoculum increase varies from year to year depending on the timing of opening and closing rains, soil type and changes in canopy cover.

Once dispersed the spores of the fungus may infect a wide range of resistant and susceptible hosts. In 1980 at least 1000 species from taxonomically diverse families had been reported as known hosts of which nearly half have been recorded from research in Australia (Zentmyer, 1980). The pathogen only flourishes in susceptible tissue, so that a great variety of susceptible

hosts provides a food base for repetition of the life cycle.

The interaction between pathogen and host starts with infection. Zoospores probably initiate most infections. They encyst and germinate to produce germ tubes which penetrate roots. Hyphae proliferate within roots macerating all unlignified and unsuberized tissues; causing the roots to rot. *Phytophthora cinnamomi* readily infects most Banksia species because of their thin bark and the proliferation of rootlets associated with the specialized proteoid roots of the *Proteaceae*. How *P. cinnamomi* infects the root system of jarrah is poorly understood. However the vertical tap roots, on which jarrah depends to maintain internal water balance during dry periods, is prone to infection.

The patterns of fungal invasion and damage in infected root systems vary. The root systems of many susceptible species, of the families *Dilleniaceae, Epacridaceae, Myrtaceae, Papilionaceae* and *Proteaceae*, become extensively colonised and die once infected. In contrast invasion and damage in jarrah root systems are more variable. Although jarrah can resist extension of the fungus, site, temperature, moisture, mineral nutrition and the physiological status of host tissues influences the host-pathogen interaction. The fungus can invade and sporulate in the root systems of resistant species such as marri (Cahill *et al.*, 1989), but extension of the fungus is resisted and the host survives. The fungus cannot establish in some resistant species, such as wandoo (Tippett *et al.*, 1985).

Although *P. cinnamomi* is the *Phytophthora* species most frequently isolated from areas of dying vegetation, *P. citricola, P. cryptogea, P. drechsleri, P. megasperma* var. *megasperma, P. megasperma* var. *sojae, P. nicotianae* and unnamed *Phytophthora* species have been recovered from native plant communities (Shearer *et al.*, 1987, Hill, in press, Stukely and Hill, unpublished). Circumstantial evidence suggests that *Phytophthora* species other than *P. cinnamomi* have also been introduced into Western Australia. Compared to *P. cinnamomi*, relatively little is known about the factors affecting reproduction and survival of the other *Phytophthora* species in south-western Australia.

All the *Phytophthora* species recovered from native plant communities have a wide host range (Table 1) and a dependency on moisture to complete their life cycles. However the life cycle of *Phytophthora* species may differ from *P. cinnamomi*, in the main types of reproduction and responses to environmental variables (Table 1). For example, *P. citricola* and *P. megasperma* do not need the interaction between different mating types for sexual reproduction and readily produce resistant oospores. Thick-walled oospores are more resistant to desiccation than zoospores and assist survival under harsh conditions. The optimum temperature for growth of *P. drechsleri* and *P. nicotianae* is higher than that for the other *Phytophthora* species

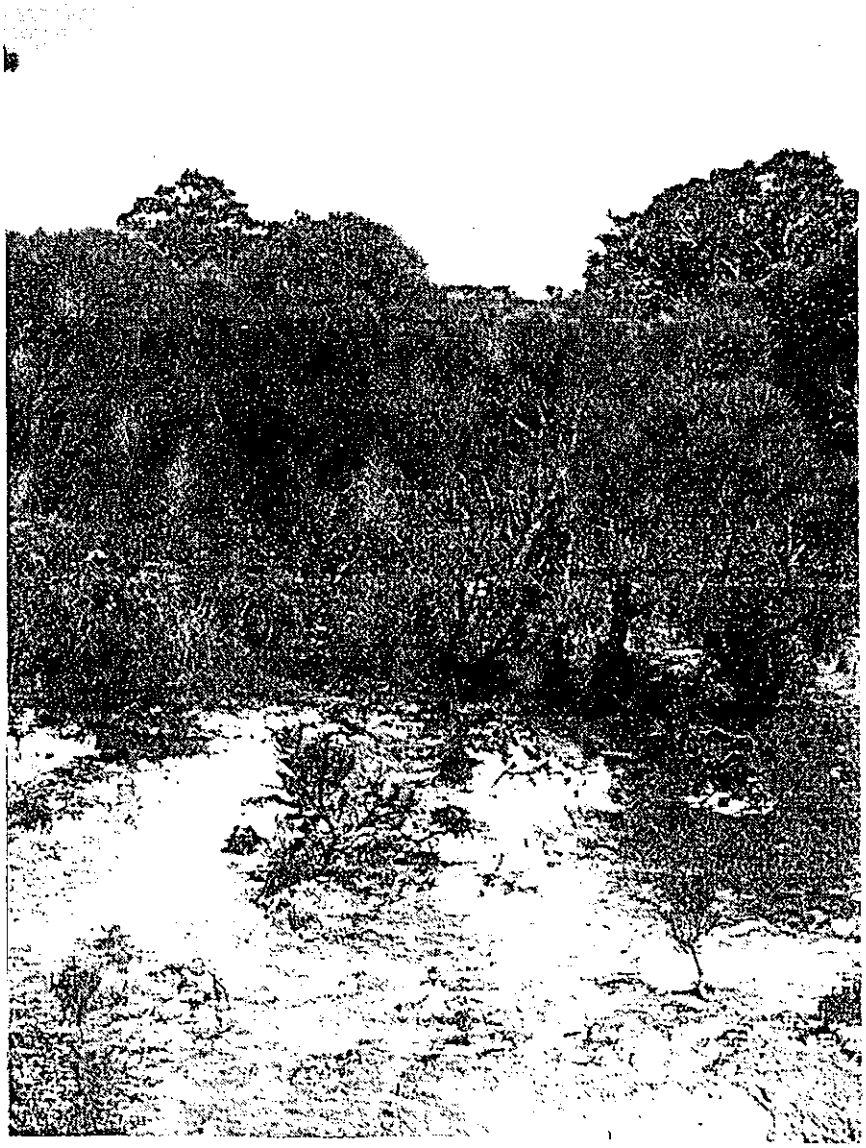


FIGURE 1(b) Sand over a clay perching layer near Albany.

(Table 1). Higher temperature optima may partly explain why *P. drechsleri* has only been recovered north of Perth. Prediction of the risk of infection by the different *Phytophthora* species will require a better understanding, than is available at present, of the relationships between environmental factors, sporulation, survival and infection.

Impact on conservation and resource management

There are obvious broad relationships between level of disease impact and composition of the vegetation. As the vegetation of south-western Australia has adapted and specialized over a long geological period in response to isolation by barriers to migration, nutrient-poor soils, recurrent climatic stress and a mosaic of landforms it integrates and hence serves as an indicator of environmental conditions. In addition members of the families *Proteaceae, Epacridaceae, Dilleniaceae* and *Myrtaceae* have adapted to poor soils and drought by specialization of root systems that are vulnerable to infection by *P. cinnamomi*. For these reasons, vegetation systems form a useful basis from which to describe the variation in impact of *Phytophthora* species in south-western Australia.

The impact of *Phytophthora* species can vary from none to low through to high. On low impact sites the fungus, although present, causes localised death in the shrub stratum. Most of the susceptible understorey and overstorey die in high impact sites.

Impact must be interpreted with care. For sites with other than high impact, one can never be sure how long the sites have been infected and if disease has been fully expressed in terms of damage. Although Phytophthora species have probably been present in parts of south-western Australia for at least 50 years, their introduction to some areas has been relatively recent.

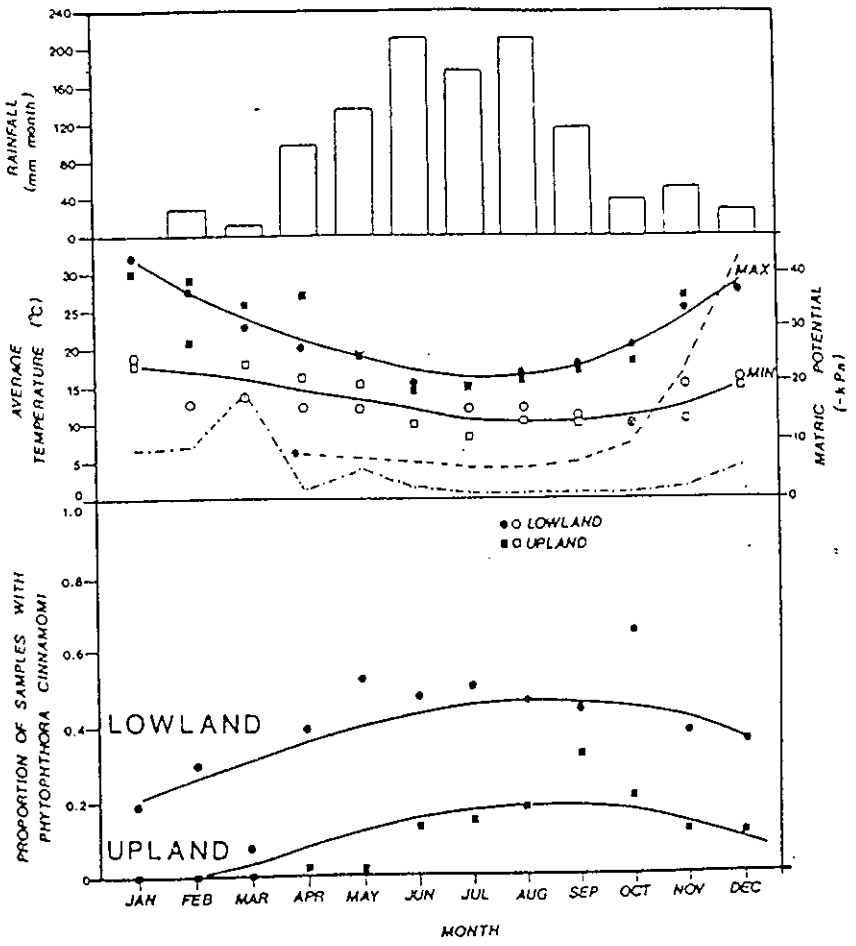


FIGURE 2: Phytophthora cinnamomi *was recovered throughout the year from a lowland but not in summer from an upland site in the jarrah forest. Soil matric potential for the lowland site is indicated by, and for, the upland site. Continuous lines represent predicted values from regression equations fitted to the data (Shearer and Shea 1987).*

Impact may worsen depending on climate, site and disturbance. Such difficulties in the interpretation of impact can be overcome by the development of risk and hazard systems to estimate potential impact, as briefly described in the following section on disease management. However further hazard systems development and testing is required before practical application in many plant communities.

Figure 3 shows grouping of the vegetation systems of Beard (1981) into relevant units for the description of *Phytophthora* impact. Because impact is expressed through the interaction of the pathogen with a complexity of factors, such as climate, vegetation, soil, topography, drainage, time since infection and intensity of human activity, only a description of general trends follows. Impact of *P. cinnamomi* is emphasized as it is the most widespread and destructive of the *Phytophthora* species in south-western Australia.

Vegetation associated with low impact

The incidence and impact of *Phytophthora* species tends to be low in shrublands and woodlands and forest on limestone on the coastal fringe (2, 3 and 12, Fig. 3). The reasons for this have not been determined and are worthy of further investigation. Inland

Phytophthora species	Introduced?	Soil-borne?	Temperature optimum for growth (°C)	Abundant formation of *chlamyd o-spores*	Readily forms *oospores*	Host range
P. cinnamomi	Y[1]	Y	24—28			v.wide
P. citricola	Y	Y	25—28		Y	wide[3]
P. cryptogea	Y	Y	22—25		Y/-[2]	wide[3]
P. drechsleri	Y	Y	28—31		Y/-[2]	wide[3]
P. megasperma var. *megasperma*	Y	Y	15—28		Y	wide[3]
P. megasperma var. *sojae*	Y	Y	25		Y	wide[3]
P. nic otianae var. *parasitica*	Y	Y	30—32	Y	Y/-[2]	wide[3]

Table 1: Variation between *Phytophthora* species for selected attributes affecting the life cycle (after Newhook *et al.*, 1978, Waterhouse, 1963).

1 Y = Yes.

2 Y/- = some isolates.

3 Host range in native flora poorly understood.

woodlands and shrublands (13, 16 and 17, Fig. 3) also have low incidence and impact of *Phytophthora* species. However low disease expression in inland areas is probably due to low rainfall unfavourable for pathogen survival and increase, rather than a lack of susceptible vegetation or soil profile characteristics favourable for pathogen development.

Vulnerable shrublands and woodlands

Phytophthora cinnamomi infection is destroying the structure and diversity of Banksia communities on leached sand (4, 5, 6 and 8, Fig. 3). Impact and incidence of *P. cinnamomi* is greatest in Banksia communities south of Perth and along the south coast. For Banksia woodlands on the Bassendean Dune System (4, Fig. 3), the dominant overstorey of *B. attenuata*, *B. ilicifolia* and *B. menziesii* is killed and often no overstorey remains in affected areas. Many understorey shrub species are similarly affected. Species richness in 64 m^2 quadrats decreased from 56 species in healthy woodland to 41 species in an affected area (Shearer and Hill, 1989). Biomass can be reduced by up to 90% following infection (Front cover). Despite the impact of *P. cinnamomi* on Banksia communities, information is lacking on the long term structural and floristic changes in affected areas and the specific requirements for pathogen survival, sporulation and spread as well as host infection in sandy soils. This information is needed particularly for the management of priority areas, such as the Banksia communities on the large Gnangara and Jandakot Mound groundwater resources.

Phytophthora megasperma var. *megasperma* and *P. drechsleri* have been associated with death of Banksia overstorey in seasonally flooded low lying areas of the Bassendean Dune System north of Perth (Hill, in press). However seasonally flooded areas are at greatest risk of infection by the *Phytophthora* species, and further monitoring is required to determine whether disease fronts will expand into freely drained woodland (Hill, in press).

Fortunately large areas of species rich shrublands on lateritic sandplain (1 and 10, Fig. 3) are disease free. However they are vulnerable to infection by *Phytophthora* species through the prevalence of susceptible vegetation combined with climate and soils favourable for pathogen development (Hill, in press; Moore *et al.*, 1989). This is illustrated by the high impact of *P. cinnamomi* in the Stirling Range National Park (9, Fig 3) and the high impact of *P. cinnamomi* and *P. megasperma* var. *megasperma* in localized infected areas in the Fitzgerald National Park.

The rich flora of the Stirling Range National Park is under immediate threat, as about 65% of the park is infected by *P. cinnamomi*. The pathogen was probably spread throughout the park by off-road vehicle activity and the construction of roads and firebreaks in the 1940s and 1960s. Walk trails are also infected. Sedgeland of low diversity replaces species rich shrubland and woodland in the infected areas of the park (Wills, in preparation).

The Fitzgerald National Park is one of the richest areas of flora diversity in Western Australia, containing 20% of the State's described plant species (Moore *et al.*, 1989).

Phytophthora megasperma var. *megasperma* is killing *Banksia speciosa* in a localized area near East Mt Barren. *Phytophthora cinnamomi* infects a narrow 6 km strip along Bell track, illegally constructed in 1971 in the northern-central part of the park. Within the infected area the pathogen is destroying *Banksia baxteri - Lambertia* thicket (Fig. 4) Infected *Hakea victoreae* survives for a time, but eventually dies. Of necessity a high priority is the protection of the healthy vegetation that covers most of the park, from infection by *Phytophthora* species (Moore *et al.*, 1989).

Jarrah forest

About 14% of the jarrah forest is infected with *P. cinnamomi*. The area infected varies greatly within the forest, however, with more than 50% of some forest blocks infected (e.g. Fig. 5 in Shearer and Tippett (1989)). Incidence and impact of *P. cinnamomi* infection is greatest on the western high rainfall forest (11a, Fig 3) and less in eastern forest low rainfall forest (11b, Fig 3). Dieback impact is low in plant communities occurring on the free draining fertile soils on steep slopes of the Darling Scarp and major valleys on the western edge of the forest. The decreasing incidence of *P. cinnamomi* with distance east is associated with decreasing gradients of rainfall, occurrence of the susceptible host *B. grandis*, impeding lateritic soils, and disturbance from human activity. There is also a north/south gradient with southern forest (11c, Fig. 3) less affected than northern forest. Infections in southern jarrah forest are mainly associated with drainage lines or roading before 1970 (Dieback Mapping Group Cell Reports). Historically, southern jarrah forest has been exposed to less disturbance that favours spread and intensification of *P. cinnamomi* than northern forest.

There is no doubt that *P. cinnamomi* infection dramatically alters the composition of the jarrah forest understorey. Many species of the families *Proteaceae, Epacridaceae, Dilleniaceae, Myrtaceae, Xanthorrhoeaceae* and *Papillionaceae* that make up a large component of the forest understorey and shrub layer are commonly killed, resulting in irreversible decline in the diversity of vegetation in infected areas. Some understorey species, mainly grasses and sedges, are resistant. These and a few other species such as marri (*E. calophylla*) colonize old dieback sites. Impact of *P. cinnamomi* in the jarrah forest may not be as evident as in shrubland and woodland, for although most of the susceptible shrub species die in infected areas, the overstorey often survives.

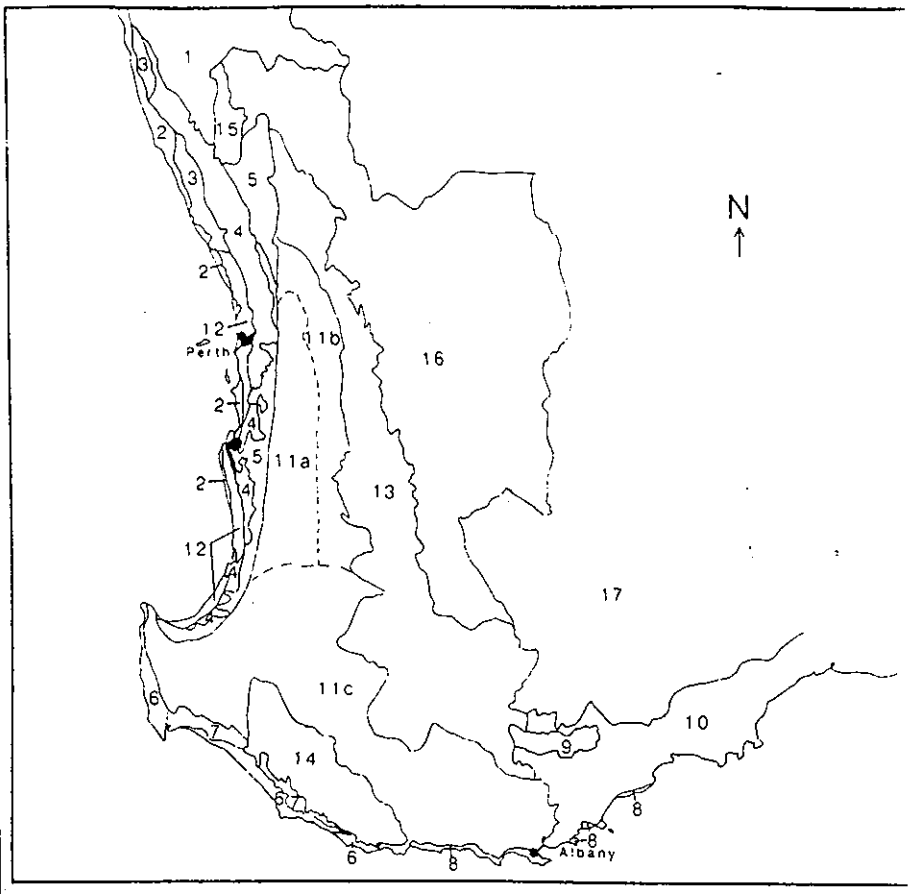


FIGURE 3: Grouping of the vegetation systems of Beard (1981) into units relevant for the description of impact of Phytophthora species in south-western Australia. 1.Shrubland on northern lateritic sandplain; 2. Acacia, Melaleuca shrubland on coastal limestone; 3. Banksia low woodland on limestone; 4. Banksia woodland on leached sand; 5. Banksia low woodland on sand derived from laterite; 6. Shrub to Banksia low woodland on calcareous sand; 7. Jarrah-Banksia woodland on seasonal swamp flats; 8. Banksia communities on young sands; 9. Stirling system; 10. Shrubland on gravelly sandplain; 11. Jarrah-marri forest—(a) Western, (b) Eastern, (c) Southern; 12. Tuart-jarrah forest; 13. Wandoo-jarrah-marri forest; 14. Karri forest; 15. Marri-Banksia woodland; 16. York-Salmon gum woodland; 17. Various shrubland and woodland.

Jarrah is the only eucalypt species of the jarrah forest killed by *P. cinnamomi*. Unlike the susceptible understorey, jarrah does not die in infected areas each year. Jarrah can resist invasion by the fungus on free draining sites and when cool, dry conditions disfavour rapid fungal growth. Spectacular rapid death of trees is probably brought about by climatic conditions which synchronize symptom expression following high levels of fungal activity in the soil.

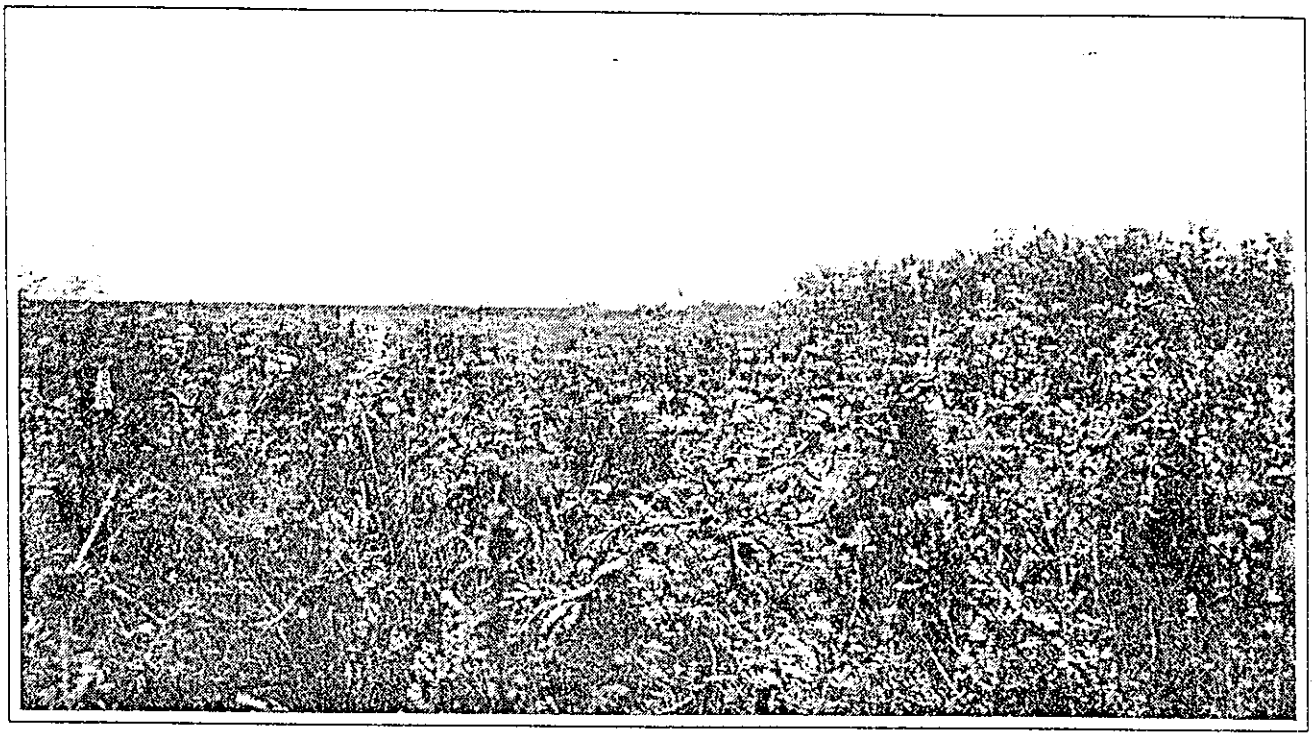


FIGURE 4: Destruction of Banksia baxteri—Lambertia shrubland by Phytophthora cinnamomi *on Bell Track, Fitzgerald National Park.*

Monitoring deaths of jarrah over the last two decades has shown that the relatively few deaths observed in some years did not mean that the fungus was not infecting and invading roots of trees in infected areas.

The excavation of infected root systems of jarrah has provided valuable information on the amounts of damage to fine and large root systems at a number of sites. Jarrah can suffer root infection and loss for a number of years before final symptoms expression and death occurs. Long term responses of trees to root loss include reduction in leaf area. Improved understanding is needed of the relationships between the severity of damage sustained by jarrah following infection and genotype, abundance of inoculum in the soil, chance of infection, site type and climate.

Phytophthora cinnamomi affects the water budget of catchments by permanently decreasing the density and composition of the vegetation. Streamflow in a group of catchments in the high rainfall zone of the forest increased with area affected by dieback (Fig 5). The contribution to the hydrological balance in infected areas of impeding horizons and the long term regeneration of tolerant species has yet to be determined.

Relative to *P. cinnamomi*, *P. citricola* is the second most frequently recovered *Phytophthora* species from the jarrah forest. *Phytophthora citricola* infections occur mainly along roads, and impact is confined to isolated deaths in the shrub layer. The area of forest infected by *P. citricola* has not been determined. As *P. citricola* established and caused extensive lesions in jarrah (Shearer *et al.* 1988), the pathogen could exacerbate the problem of dieback caused by *P. cinnamomi* in the jarrah forest.

Dieback management

Dieback management is based on hazard rating (recognition of vulnerable sites), assessment of risk of infection, hygienic procedures and manipulation of conditions to disfavour the pathogen and enhance host resistance. Hazard is determined by the influence of climatic, site and management factors on disease expression. Risk is the probability of spread and infection determined by disease proximity and the type of activity occurring in an area. Hazard systems have been developed to rate uninfected areas in the jarrah forest. There is now a much better appreciation that the jarrah forest is a mosaic of hazard types ranging from low hazard fertile red earths to high hazard infertile sandy gravels. Although some plant communities other than forest have been rated for hazard (Moore *et al.*, 1989; Hill, in press) further development and testing is required before application to shrublands and woodlands.

Following disease hazard mapping, disease distribution and the types of activities occurring in an area can be used to assess the risk of introduction and spread of *P. cinnamomi*. Risk and hazard can then be combined to determine the likely consequences of disease.

Significant progress has been made in using quarantine and hygiene procedures to minimize new infections by preventing or delaying

entry of the pathogen in disease free areas. These methods need integration with management practices aimed at reducing the rate of disease development, such as stimulation of antagonistic microflora, manipulation of drainage, chemical control, use of resistant species and enhancement of host resistance, all of which are still in the experimental phase.

Costs to the community

Estimates are needed of the direct and indirect costs of dieback caused by Phytophthora species to ensure sufficient allocation of resources for the appropriate management of plant communities threatened by disease. Table 2 gives estimates of the costs relating to control for 1989. These costs need to be balanced against present and potential losses in conservation, resource management and aesthetic values. Present losses must not be confused with potential losses in the following analysis. Identification of a potential loss does not necessarily mean that the loss will occur, but indicates areas of worth where the cost of disease protection is justified.

Dieback obviously causes serious losses in conservation values. These losses can be grouped into those relating to the loss of key species in plant communities and associated declines, and the moral obligation to pass on a healthy and diverse environment to future generations.

Often ignored are the deleterious losses to plant communities caused by the death of relatively common key plant species following infection by Phytophthora species. For example, many susceptible Banksia species are important food sources and habitats for honeyeaters and other animal taxa (Taylor and Hopper, 1988). Many animals can migrate to healthy areas at present, but the potential losses of food resource and habitat following infection by Phytophthora species is high.

Many key susceptible plant species have obligate vertebrate and invertebrate associations as illustrated for *Banksia menziesii* and *Adenanthos cygnorum* by Lamont (1989). Furthermore death of susceptible species may reduce pollinators essential to the survival of more resistant plant taxa (e.g. rare and endangered Eucalyptus rhodantha, Sampson *et al.*, 1989). Present losses through the death of key plant species would be high for obligate associations and could contribute not only to the long term decline of infected areas but neighbouring communities as well.

Infection by *Phytophthora* species directly threatens the survival of susceptible geographically restricted or rare plant species. Keighery (1988) estimates that 29 of the 171 species of the *Epacridaceae* known to occur in south-western Australia are at risk from *P. cinnamomi* infection. *Phytophthora cinnamomi* infects all of the few known locations of the rare and susceptible *Banksia brownii*.

In addition to loss of conservation values, *P. cinnamomi* infection may affect tourism and wildflower industries, water quality and timber production. Many plant genera that are important to the tourism and wildflower industries, such as *Banksia, Darwinia, Verticordia* are susceptible to infection by *Phytophthora* species. Because of the susceptibility of the vegetation to infection, 'wildflower dieback' is probably the most appropriate name for disease caused by *Phytophthora* species in native communities of south-western Australia (S. Hopper, personal communication). Areas of high species richness attractive to tourists north of Perth and on the South coast are vulnerable to infection. A high proportion of some areas, such as the Stirling Range National Park and Two Peoples Bay Reserve, are already infected by *P. cinnamomi*. Thus the tourism and wildflower industries could be severely affected by dieback.

Decline in leaf area following *P. cinnamomi* infection can lead to raised water tables and increased stream salinity in salt prone areas (Schofield *et al.* 1989). Additional research and modelling is necessary to improve current understanding of the interactions between impact of *P. cinnamomi* and salinity (Schofield *et al.* 1989).

In the 1940s and 1960s high mortality of jarrah in infected areas increased concerns of the threat of *P. cinnamomi* to timber production. Estimates of past or potential losses is difficult as there has been no adequate assessment of jarrah death over time, or regeneration and growth rates of jarrah in infected

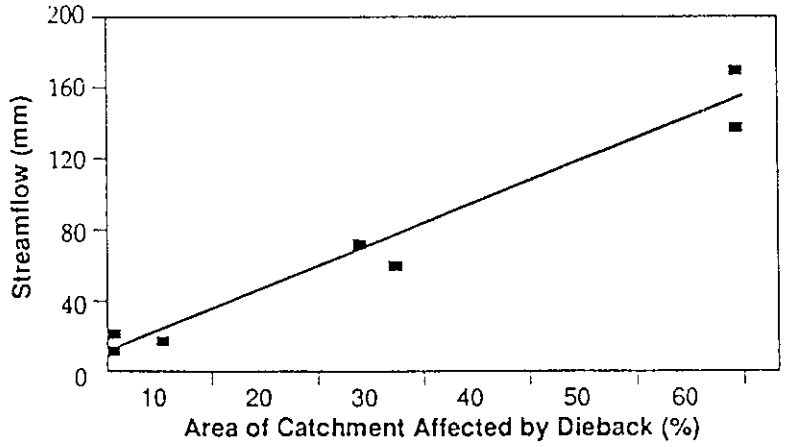


FIGURE 5: Streamflow versus proportion of catchment area affected by dieback for six high rainfall zone catchments in the jarrah forest (Schofield et al. *1989).*

areas. Healthy forest needs to be rated according to the likely hazard of jarrah mortality, should the fungus be introduced.

There have been three studies of the effects of *P. cinnamomi* on the growth of jarrah. Two studies (Podger, 1972; Crombie and Tippett, 1990) have shown that growth rates of jarrah trees surviving on intermediate to high impact dieback sites were reduced substantially compared with apparently healthy jarrah. The third study by Davison and Tay (1988), reported similar or slightly greater growth rates of jarrah on intermediate impact but heterogeneous dieback sites in comparison with uninfected sites. The reduced tree stocking rate in their dieback sites would partly explain the observed greater growth rate in dieback areas. The effects of different levels of infection on jarrah growth requires clarification.

The analysis of the major losses from dieback shows that the inability to put monetary costs to losses from disease does not mean they are unimportant. Many losses are vital to ecosystem dynamics and need quantification. Prevention of potential losses through protection of catchments and healthy communities must be high priority.

Prognosis

Dieback caused by *Phytophthora* species is a greater threat to conservation and resource management in south-western Australia than other more visible agents of land degradation, such as salinity. Many areas are disease free, but vulnerable to infection. Plant communities are under land use pressures that present opportunities for spread and intensification of *Phytophthora* species. Vulnerable shrublands and woodlands are increasingly exposed to disturbances from rural and urban expansion, recreation and mining. Multiple use of forests in terms of recreation, water production, mining and harvesting of forest resource, requires continued diligent research and management.

Table 2: Estimated expenditure on dieback mapping/detection, prevention and research in Western Australia during 1989 by Government Departments and Industries surveyed.

Organisations	Expenditure (millions $) on dieback: Mapping/ Detention	Prevention	Research	
Government[1]	0.31	0.34	0.82	
Industry[2]	0.10	1.35	0.45	
Total (millions $)	0.41	1.69	1.27	3.37

1 Proportion of total expenditure for government departments: Dept. Conservation & Land Management (94%), Water Authority of W.A. (3%), Main Roads (2%), Dept. of Agriculture (1%).

2 Proportion of total expenditure for industries surveyed: Bauxite mining (92%), Forest products (8%).

The occurrence of dieback does not recognize land tenure and effective control depends on the combined efforts of the general public and an assortment of industries, federal, state and local government departments. Individual government departments and industries have committed considerable resources to dieback management (Table 2). However state and national dieback plans would assist all public and private sectors in training, detection, research and management strategies to implement dieback control throughout south-western Australia.

Circumstantial evidence suggests that the *Phytophthora* species other than *P. cinnamomi* have also been introduced into Western Australia. Further research is required to improve the current understanding of the relative behaviour of *Phytophthora* species in the environment of south-western Australia and host susceptibility to infection

The assessment of damage and the monitoring of disease development over time will provide a sound basis for management decisions. Despite many susceptible plant taxa, the changes in understorey composition caused by *Phytophthora* infection are poorly documented for south-western Australia (Shearer and Hill, 1989; Shearer and Tippett, 1989). In particular, a greater understanding is needed on long term changes in plant species richness following infection and the associated affects on fauna. Knowledge of the diversity of shrublands and woodlands, similar to Havel's (1968) site-vegetation analysis of Banksia woodland, is required for the development and application of hazard and risk systems.

Questions about the effects of potential climatic changes on disease development can only be answered confidently by quantifying the relationships between climatic events, site and vegetation water status, water movement within a site, pathogen development and host susceptibility. Greater emphasis needs to be placed on applying information through simple mathematics to help test assumptions and give indications of probable rates of change in disease development under a range of conditions. Long term predictions can then be based on sensitivity analysis to determine how changes in temperature and rainfall distribution between years and seasons affect the intensification of disease.

Most of the information relating environment to disease development has come from research in the high rainfall zone of the northern

jarrah forest. Information is needed on the specific requirements for pathogen survival, sporulation and spread as well as host infection and susceptibility in intermediate-low rainfall and southern jarrah forest, woodlands and shrubland-heaths. Such information is essential for the development of systems to minimize introduction and spread of *Phytophthora* species.

Hazard and risk system development will be an on-going process and modifications made as a result of experience. The hazard rating systems can predict the likely disease outcome only for undisturbed forest areas. An understanding of major factors affecting hazard will help in updating hazard rating systems when management strategies are changed or are applied repeatedly over time. Clarification of the relationships between environmental factors, sporulation, survival, dispersal, infection and host susceptibility will improve the precision of risk rating systems and estimates of how quickly hazard will be expressed.

Significant progress has been made in the development and application of hygiene methods to control dieback. As hygienic procedures are aimed at stopping new infections by preventing or delaying the entry of the pathogen, they are not infallible and most efficient when integrated with rate reducing methods of control. Rate reducing methods, however, require further development and testing before practical application.

Cost effective methods are needed to eradicate the pathogen once established, without causing unacceptable damage to conservation values. Further evaluation of chemicals, biological control and host resistance must be a high research priority to provide managers with as many options as possible to reduce the spread and development of *Phytophthora* species.

Conclusions

The present destruction caused by *Phytophthora* species in south-western Australia highlights the following inescapable conclusions:

- The vulnerability to infection of a wide range of healthy plant communities, especially those occurring in leached sands and the nodes of high endemic plant species richness north of Perth and on the south coast;
- The present devastation caused by *Phytophthora* species in south-western Australia is an exceptional example of introduced pathogens of wide host range causing great damage to diverse plant communities with many susceptible species;
- Humans have been the main agents of dispersal through the movement of infected soil and plant material associated with their activity;
- The cost of protecting healthy plant communities is small compared to the irreversible loss of conservation, resource management and aesthetic values caused by disease.

Recently Shea (1989) concluded *'Phytophthora cinnamomi* has the potential to destroy some of the most diverse and unique plant communities on the South Coast of Western Australia. We need a paradigm shift in our understanding of plant pathology if we are to avoid this tragedy'. Mobilization of the research areas previously outlined with the new innovative areas of molecular biology would provide added impetus to dieback control strategies, but would require more resources than are currently available.

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APPENDIX 10

HAZARD RATINGS

10. Hazard Ratings

Hazard ratings have been prepared from detailed field observation and measurements over many years. They cover a range of climate and locations and are our best available predictions of the end expression of dieback disease at present. Research is ongoing and improvements to these predictions will eventuate as our knowledge of the disease and site factors increases. Environmental Protection Branch would be pleased to hear of any marked difference between hazard ratings given and observations in the field.

In some locations more than one hazard mapping system is available eg., Shearers Hazard rating in the Northern jarrah forest, Havels vegetation mapping of the Northern jarrah forest, Strelein's vegetation mapping of the Southern Jarrah forest, Landform (System 6) mapping of the Northern and Central Forest Regions. The area of coverage where each system can be applied varies. The most applicable system for each operation must be determined and used for each 7-Way Test.

10.1 Northern Jarrah Forest

Vegetation Type	Dieback Hazard
A	Low
B	High-Very High
C	High
E	High
W	Low-Moderate
C	Low-Moderate
F	Low
J	High
H	Low-Moderate
P	High-Very High
Z	Low-Moderate
S	Moderate-Very High - Wide range

Vegetation Type	Dieback Hazard
T	Low-Moderate
U	Low
R	Low-Moderate
Q	Low
M	Low
L	Very Low
Y	Very Low
O	Low-High - wide range

Landform Types	Dieback Hazard
Yarragil	Low (swamp) Very High (Fringes)
Dwp/High rainfall/Well drained	Moderate-High
Dwp/High rainfall/Concreted Laterite	Very High
Dwp/Low rainfall/Yalangee	Low
Helena/Murray	Low
Monadnocks	Low (High localised)
Williams/Micchibin	Low
Pindalup/Goonapin/Coolakin	Low-Moderate
Collie/Cardiff/Muja	Moderate-Very High

10.2 Southern Jarrah Forest

Landform	Vegetation Type	Hazard
Hester	P,R	High
Hester	S	Low-High
Dwellingup	P,S	High
Ellis	P	High
Mungardup	A,B	High
Caldyanup	F,B,J	High
Trent	P	High
Bevan	K	Low

Landform	Vegetation Type	Hazard
Crowea sand	P	Moderate - High
Crowea yellow		Low
Crowea laterite	P	Moderate - High
Crowea brown	T,S	Low
Collis yellow	P	High
Collis yellow	I,S,T,	Low
Collis shallow	N	High
Major valleys		Low
Mattaband yellow (lateritic duricrust)	P	High
Mattaband shallow & duplex		Low - High
Keystone yellow (shallow soils)		High
Keystone brown	P	High
Keystone brown	K	Low
Stream	Various	Low - High

10.3 Sunklands

McCutcheon Soil Type	Brief Description	Hazard
1	Lateritic sand	Low - Moderate*
2	Sand over laterite 50cm	Low - Moderate*
3	Yellow-Brown sand 50cm	Low - Moderate*
4	Light-Greyish Brown sand 50cm	Low - Moderate*
5	Yellow-Brown Sandy loam	High - Very High
7	Alluvial soils	Moderate - High

* some ares exhibit high impact where an impeding layer is present.

Landform	Hazard
Balingup	Low - Moderate
Hester	Moderate - High
Ellis (Grimwade)	High - Very High
Dwellingup	Moderate - High
Wilga	Moderate
Catterick	Low - Moderate
Yarrigal	Low - Moderate
Goonaping	Low
Bassendean	Low - High
Yoongarillup	Low
Kingia	High - Very High
Preston	Low - Moderate
Pindalup	Low
Coolakin	Low
Minchibin	Low
Jarrahwood	High - V. High
Cartis	High - V. High
Mungardup	High - V. High

10.4 South Coast

Community Types	Hazard
Forest:	
Karri	Very Low
Jarrah/Marri	Moderate - Very High
Low forest (< 10m):	
Jarrah	Moderate
Bullich	Low
River yate	Very low

Community Types	Hazard
Riverine/Lacustrine Low Forest:	
Paperbark (fresh)	Low
Paperback (salt)	Very low
Banksia seminuda	?
Sclerophyll Woodland:	
E. newbey	Low
E. platypus	Very low
E. wandoo	Very low
E. loxophelba	Very low
E. occidentalis	Very low
Allocasuarina huegeliana	?
All other sclerophyll woodlands including E. salmonophoia, E. rudis, E. oleosa, E. flacktaniae, E. annulate, E. transcontinentalis, E. longicorns	Very low
Low Woodlands (< 5m):	
Jarrah; Jarrah/Sheoak	Moderate - High
E. staeri	Moderate - High
Agonis flexuosa	Low
E. dicipiens	Very low
Shrublands:	
Ravensthorpe range Thicket	High
Barren Ranges Thicket	High
Stirling ranges Thicket	High
banksia shrublands.heath (incl. B. speciosa, B. media)	High - Very high
Agonis flexuosa/E. angulosa Broomebush Thicket	Very low

Community Types	Hazard
i) Allocasuarina campestris, Thrytomene, melaleuca	Very low - Moderate
ii) Allocasuarina/Melaleuca/Acacia	Very low
iii) Allocasuarina/Melaleuca/ Calothamnus	Very low
Mallee/Marlock: usually 1 layer duplex soils:	
E. stoatei	Moderate
E. annulata	Low
E. conglobata	Low
Other communities dominated by } E. nutans, E. gardneri, E. anglosa } E. dicipiens, E. cornuta or } E. lahmaniona }	Very low
Scrub/heath (2 layers)	
Mixed Proteaceae/Myrtaceae	Moderate
Agonis flexuosa	Low
Melaleuca Communities on Clay:	
M. thyoides/M. parviflora	Very low
Malee Heath:	
Jarrah	Moderate
E. tetragona	Low
Mixed	Low
E. incrassata	Moderate - High

Heath:	
Myrtaceae/Proteaceae	Moderate - High
Community Types	**Hazard**
Coastal heath (Scaevola/Olearia)	Low
Casuarina heath (A. campestris)	Moderate - Very High
Heath with scattered Nuytsia	
Nuytsia floribunda	?
Reed Swamps	Very low
Halophytic communities	Very low
Low scrub on granite	Low - Very High
Moss swards	Low - Very High
Mosaics of Mallee	?
Heath/Woodland	

<u>South Coast Region Landforms</u>

Torndirrup:

Gg - podsols on slops of granite outcrops with dense heath, many proteaceae, Thickets of Mallee in gullies.	High
Mp Mf - posdols over calcareous sands. Woodlands of Agonis, Banksias and Eucalypts.	Moderate
Mc Mp Mf - calcareous soils, limestone Outcrop, low coastal heath, agonis.	Low

Two Peoples bay:

Gg - As for Torndirrup.	High
Mp Mf as above. Some Mf podsols on interdune plain with banksia.	High

Community Types	Hazard
Mc Mp on limestone substrate as for Torndirrup.	Low
OW - Thicket, heath, reeds.	Low
S6 - S7 podsols and duplex soils	Moderate - High
DC sands and laterites - JM woodland	Low - Moderate
West Cape Howe:	
Mp Ms strong calcareous influence.	Low
Ks - dieback present on podsol teatree heath and J. woodlands.	?
William Bay:	
M series - mostly calcareous origin	Low
Some Mf podsols within range	Moderate
Millbrook:	
Dc sands and laterites, JM forest.	Moderate
R yellow duplex soils, JM forest.	Moderate
S7 podsols and duplex soils.	High
Bakers Junction:	
DC sands and laterites.	
JM Forest.	Moderate
S6 - S7 see above	High

Community Types	Hazard
Many Peaks:	
TK - mostly cleared, some evidence on	Moderate
road verges, duplex JM heaths.	High
Yate in depressions	Low
Podsols and Banksia woodland,	Moderate - High
DC see above	Moderate
Gs - sands and podols Hakea sp.	High
S7 - broad valley, low J. scrub	High
BAg - granite outcrops.	Moderate - High on fringes
North Sister: (Lake Pleasant View)	
Bo - Yate melaleuca swamps.	Low
Podsols J, B, scrub.	Moderate - High on fringes
South Sister:	
BAf - duplex soils JM sheoak.	Moderate

10.5 Northern Sand Plan

Not yet available (as per Mt Lesueur report)

10.6 Wheatbelt

Not yet available.

APPENDIX 11.

INDICATOR SPECIES COMMONLY USED IN *PHYTOPHTHORA* DIEBACK INTERPRETATION

Indicator species commonly used in *PHYTOPHTHORA* DIEBACK INTERPRETATION.

The reliability of these indicators varies from location to location within the zones identified. *P. cinnamomi* has been recovered from the species listed by root sterilization.

Note that the order in which plants are listed IS NOT meant to imply a ranking in terms of their reliability as indicators. The list is presented only as a guide and is not necessarily complete. It will be reviewed with each update of the manual. In addition, there is likely to be considerable overlap of species between these broad communities, i.e. they are not necessarily confined to the vegetation type as shown.

1. SWAN COASTAL PLAIN

FAMILY	SPECIES	COMMON NAME
Dasypogonaceae	*Lomandra odora*	Tiered Mat Rush
Dilleniaceae	*Hibbertia hypericoides*	Yellow Buttercups
	Hibbertia subvaginata	
Epacridaceae	*Andersonia heterophylla*	
	Andersonia lehmanniana	
	Astroloma xerophyllum	
	Conostephium pendulum	Pearl Flower
	Leucopogon conostephioides	
Iridaceae	*Patersonia occidentalis*	Purple Flag
	Patersonia rudis	Hairy Flag
	Patersonia xanthina	Yellow Flag
Myrtaceae	*Melaleuca scabra*	Rough Honey Myrtle
	Scholtzia involucrata	Spiked scholtzia
	Verticordia nitens	Morrison feather flower
Papilionaceae	*Bossiaea eriocarpa*	
	Jacksonia floribunda	Holly Pea
Proteaceae	*Adenanthos serivea*	
	Adenanthos cygnorum	Woolly Bush

	Banksia attenuata	Slender Banksia
	Banksia grandis	Bull Banksia
	Banksia illicifiolia	Holly-leaved Banksia
	Banksia littoralis	Swamp Banksia
	Banksia meaziessii	Menzies Banksia
	Banksia prionotes	Acorn Banksia
	Banksia sphaerocarpa	Fox Banksia
	Conosperma stoechadis	Smoke bush
	Dryandra carduacea	Pingle
	Dryandra nivea	Couch Pot Dryandra
	Dryandra sessilis	Parrot Bush
	Isopogon formosus	Cone Flower
	Petrophile linearis	Pixie mops
	Stirlingia latifolia	Blue Boy
	Synaphea petiolaris	Synaphea
Xanthorrhoeaceae	*Xanthorrhoea spp*	Blackboys
Zamiaceae	*Macrozammia riedlei*	Zamia palm

2. NORTHERN JARRAH FOREST

FAMILY	SPECIES	COMMON NAME
Casuarinaceae	*Allocasuarina fraseriana*	Sheoak
Dasypogonaceae	*Lonandra odora*	Tiered Mat Rush
Epacridaceae	*Leucopogon capitellatus*	
	Leucopogon nutans	
	Leucopogon propinquus	
	Leucopogon verticillatus	Tassel flower
	Styphelia tenuiflora	
Iridaceae	*Patersonia occidentalis*	Purple Flag
	Patersonia rudis	Hairy Flag
Myrtaceae	*Eucalyptus marginata*	Jarrah
Proteaceae	*Adenanthos barbigera*	Hairy Jugflower
	Adenanthos obovata	Basket Flower
	Adenanthos cygnorum	Woolly Bush
	Banksia grandis	Bull Banksia
	Banksia littoralis	Swamp Banksia
	Banksia sphaerocarpa	Fox Banksia

	Dryandra armata	Prickly Dryandra
	Dryandra carduaceae	Pingle
	Dryandra sessilis	Parrot Bush
	Isopogon axillaris	
	Isopogon sphaerocephalus	Drumstick Ispogon
	Persoonia elliptica	
	Persoonia longifolia	Snoddy gobble
	Petrophile linearis	Pixie mops
Xanthorrhoeaceae	*Xanthorrhoea gracilis*	Slender blackboy
	Xanthorrhoea nana }	John Forrest N. Pk
	Xanthorrhoea reflexa }	
	Xanthorrhoea preissii	Blackboy

3. CENTRAL FOREST REGION

3.1 JARRAH FOREST

FAMILY	SPECIES	COMMON NAME
Epacridaceae	*Leucopogon capitellatis*	
	Leucopogon propinguus	
	Leucopogon verticellatus	Tassel flower
Iridaceae	*Patersonia spp.*	Flag Flowers
Myrtaceae	*Eucalyptus marginata*	Jarrah
Podocarpaceae	*Podocarpus drouyniana*	Emu Bush
Proteaceae	*Adenanthos barbigera*	Hairy Jugfloer
	Adenanthos obvata	Basket Flower
	Banksia grandis	Bull Banksia
	Isopogon sphaeracephalus	Drumstick Isopogon
	Persoonia longifolia	Snoddy gobble
	Xylomelum occidentale	Woody Pear
Xanthorrhoeaceae	*Xanthorrhoea gracilis*	Slender Blackboy
	Xanthorrhoea preissii	Blackboy

4. SOUTHERN FOREST REGION

4.1 JARRAH FOREST

FAMILY	SPECIES	COMMON NAME
Casuarinaceae	*Allocasuarina fraseriana*	Sheoak
	Allocasuarina humilis	Scrub sheoak
Dasypogonaced	*Dasypogon bromeliifolius*	
	Dasypogon hookeri	Pineapple Bush
Epacridaceae	*Leucopogon australis*	
	Leucopogon capitellatus	
	Leucopogon propinguus	
	Leucopogon verticillatus	Tassel Flower
Iridaceae	*Patersonia occidentalis*	Purple Flag
	Patersonia umbrosa	
Myrtaceae	*Eucalyptus marginata*	Jarrah
Podocarpaceae	*Podocarpus dronyniana*	Emu Bush
Proteacea	*Adenanthos barbigera*	Hairy Jugflower
	Adenanthos obovata	Basket flower
	Banksia grandis	Bull Banksia
	Banksia ilicifolia	
	Banksia quercifolia	
	Banksia sphaerocarpa	
	Dryandra bipinnatifida	
	Dryandra nivea	Couchpot Dryandra
	Dryandra sessilis	Parrot Bush
	Hakea prostrata	Harsh hakea
	Isopogon sphaerocephalus	Drumstick Isopogon
	Persoonia elliptica	
	Persoonia longifolia	Snoddy gobble
	Petrophile diversifolia	
	Petrophile linearis	Pixie mops
	Xylomelum occidentale	Woody Pear
Xanthorrhoeaceae	*Xanthorrhoea gracilis*	Slender Blackboy
	Xanthorrhoea preissii	Blackboy
Zamiaceae	*Macrozamia reidlei*	Zamia Palm

4.2 KARRI FOREST

FAMILY	SPECIES	COMMON NAME
Epacridaceae	*Leucopogon spp.*	
Iridaceae	*Patersonia xanthina*	Yellow Flag
Proteaceae	*Adenanthos spp*	
	Banksia attenuata	Slender banksia
	Banksia grandis	Bull Banksia
	Banksia littoralis	Swamp Banksia
	Banksia seminuda	
	Hakea oleifolia	
	Personnia elliptica	
	Persoonia longifolia	Snoddy gobble
Xanthorrhoeaceae	*Xanthorrhoea spp*	Blackboys
Zamiaceae	*Macrozamia reidlei*	Zamia palm

4.3 COASTAL AREAS (additional species)

FAMILY	SPECIES	COMMON NAME
Papilionaceae	*Jacksonia horrida*	
Proteaceae	*Banksia occidentalis*	Red Swamp Banksia

5. SOUTH COAST REGION

5.1 JARRAH FOREST (additional species)

FAMILY	SPECIES	COMMON NAME
Proteaceae	*Adenanthos cuneata*	
	Dryandra serra	
	Petrophile squamata	

5.2 KARRI FOREST

FAMILY	SPECIES	COMMON NAME
Epacridaceae	*Leucopogon spp.*	
Iridaceae	*Patersonia xanthina*	Yellow Flag
Proteaceae	*Adenanthos spp*	
	Banksia attenuata	Slender banksia
	Banksia grandis	Bull Banksia
	Banksia littoralis	Swamp Banksia
	Banksia seminuda	
	Hakea oleifolia	
	Personnia elliptica	
	Persoonia longifolia	Snoddy gobble
Xanthorrhoeaceae	*Xanthorrhoea spp*	Blackboys
Zamiaceae	*Macrozamia reidlei*	Zamia palm

5.3 COASTAL AREAS

FAMILY	SPECIES	COMMON NAME
Proteaceae	*Banksia attennata*	Slender Banksia
	Banksia baueri	Wooly banksia
	Banksia baxteri	Baxter's Banksia
	Banksia coccinea	Scarlet Banksia
	Banksia grandis	Bull Banksia
	Banksia nutans	Nodding Banksia
	Banksia speciosa	Showy Banksia
Proteaceae	*Dryandra baxteri*	
	Dryandra formasa	Showy Dryandra
	Dryandra pteridifolia	Tangled Honeypot
	Dryandra senecifolia	
	Dryandra sessilis	Parrot Bush
	Hakea baxteri	
	Hakea crassifolia	
	Hakea cucullata	Wedge-leaved Dryandra
	Hakea trifurcata	

APPENDIX 12.

MOTORBIKE USE AND SAFETY

MOTORBIKE USE:

1. All personnel using motor bikes must possess a current, valid L class drivers licence.

2. Bikes must be cleaned down regularly to avoid moving disease innoculum.

3. Bikes must only be used off track inside a cell under dry soil conditions. Use as transport inside a cell must satisfy the requirements of a 7-Way test.

4. Creeks and wet areas must not be crossed when it is likely that soil will adhere to the bike and be transported elsewhere.

5. Bikes should only be used when it is likely that time will be saved interpreting the cell. The time taken to load and unload bikes, any risks associated with the use of motorbikes and the added plant costs should be considered.

6. Bikes must be used only as transport in the field. No disease detection and mapping should be attempted while riding a bike. It is dangerous and leads to inaccuracy.

MOTORBIKE SAFETY

Loading and unloading:

1. Motor bikes **must never** be ridden on and off trailers or utes.

2. Motorbikes must be loaded and unloaded by **two** people.

3. Motorbikes must be loaded front first onto the ute or trailer. One person is required to step onto the vehicle while the other holds the bike then both proceed to complete the loading operation.

4. Motorbikes must be secured to the transporter by "tiedown" straps on both sides of the bike at the front and rear of the machine. The tiedowns should be tight enough to take up the travel in the shock absorbers.

5. Unloading is to be done by two people and is the reverse procedure to that of loading.

RIDING:

1. **ALWAYS** wear helmet, long trousers and boots when riding. Riders are also encouraged to wear gloves and eye protection.

2. **ALWAYS** ensure the bike is well maintained.

3. **ALWAYS** ride with the light on on public roads.

4. **ALWAYS** allow sufficient distance between riders to allow time to react and maintain visibility in dusty conditions.

5. **ALWAYS** be alert to track conditions, overhanging vegetation, obstacles and your own capabilities; adjust your speed accordingly.

6. **DO NOT** ride alone.

7. **DO NOT** ride two abreast. Ride one behind the other and allow sufficient distance between bikes to accommodate evasive action if necessary.

8. **DO NOT** ride too fast. Track conditions, terrain and the riders capability should determine the speed of travel.

9. **DO NOT** attempt to detect and plot disease from a moving bike. The bike must be stationary and the interpreter proceed with the task on foot.

10. **DO NOT** exceed your capabilities. Every rider should know his or her own capability. Be prepared to stop and proceed on foot when the conditions get too tough.

11. **DO NOT** attempt to ride bikes over large logs. If it is not possible to ride around the log safely then proceed on foot.

12. **DO NOT** carry heavy loads in packs or boxes on the rear of the bike. Heavy loads can alter the handling characteristics of the bike considerably.

THINK SAFETY AT ALL TIMES!!

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