PHYTOPHTHORA CINNAMOMI SURVEY OF THE LEXIA ENVIRONMENTAL MONITORING AREA AND RECOMMENDATIONS FOR MANAGEMENT.

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GLOSSARY

Armillaria luteobubalina
A native wood rotting fungus that attacks the sapwood of living plants.

Autonomous disease spread
The natural movement of infective motile spores in saturated soils and growth of mycelium between connecting root systems.

Cambium
The layer of conductive tissue between the wood and outer bark of vascular plants.

Canker fungi
A group of fungi associated with twig, branch and upper trunk deaths.

Chlamydospore
A thick walled spore approximately 0.04 mm in diameter produced vegetatively by the rounding up of cells. Can tolerate drier conditions than zoospore.

Cryptic disease
The situation in which a host plant is infected with a pathogen but there are no visible symptoms.

Dieback
In Western Australia, the term is specifically used to describe the disease in native vegetation caused by the *Phytophthora cinnamomi* fungus. The term is also generally used to describe any progressive deterioration of tree crowns.

Disease
The decline in plant health as a result of the presence of a pathogen and environmental conditions favourable to the pathogen.

Impact
The effect of disease on plant health.

Inoculum
Infective propergules capable of causing disease.

Keystone species
A plant species in an ecosystem that provides conditions pivotal for the survival of other flora and fauna.

Mycelium
A mass of fungal hyphae forming the body of a fungus.

Non-susceptible species
Plant species that do not display secondary symptoms of *Phytophthora cinnamomi* infection when exposed to the pathogen. They may display primary symptoms of infection including the death and discolouration of root tissue and lesion development.

Phytophthora
A genus of microscopic fungi responsible for widespread damage in native vegetation of Western Australia.

Sporangium
An oval or ellipsoid spore sac approximately 0.057 x 0.033 mm that produces zoospores within a cell wall.

Susceptible species
Plant species that will develop secondary symptoms of *Phytophthora cinnamomi* infection when exposed to the pathogen. Secondary symptoms include crown decline and death of the host.

Vectored inoculum spread
The spread of infective propergules through the movement of infected soil or vegetative material. Agents include vehicles and machinery.

Vegetation associations
A group of similar plants that grow in a uniform environment that contains one or more dominant species.

Zoospore
A motile spore approximately 0.01 mm in diameter produced within a sporangium.

1. BACKGROUND

The plant disease known in Western Australia as "dieback" or "Jarrah dieback" is caused by an introduced, microscopic, soil-borne fungus of the genus *Phytophthora.* The most destructive and widespread species is *Phytophthora cinnamomi* Rands, which has caused irreversible decline of susceptible species from Eneabba in the north to Cape Arid on the south coast (Shearer & Tippett, 1989).

The *P. cinnamomi* fungus is highly invasive and will infect the roots of a large range of plant species. The primary symptom of infection is the death and discolouration of root tissue. The secondary symptoms are crown decline and/or the death of the infected plant. Plant species that are partially resistant and do not develop secondary symptoms are classified as "non-susceptible" hosts, and species that develop secondary symptoms are regarded as "susceptible" hosts. There are few native plant species that have been found to be completely resistant to dieback and able to inhibit fungal growth at the point of entry.

P. cinnamomi mycelial strands spread through the root system of an infected plant and under certain environmental conditions develop sporangia. The sporangia release zoospores into the soil where they spread through water movement and, to a lesser degree, through self-propulsion. People and animals can also spread the spores through the movement of infected soil or plant material.

P. cinnamomi has been inadvertently spread throughout the coastal sand plains and infected many areas. The impact that *P. cinnamomi* will have in native vegetation communities is determined by a complex interaction between the host species, the *P. cinnamomi* fungus and environmental factors. The Banksia woodlands of the Swan Coastal Plain are especially at risk as they contain many susceptible species.

Until recently, the only method of disease control was to implement hygiene measures designed to minimise vectored inoculum spread. There was no effective method of controlling autonomous spread within infected areas, or protecting susceptible plant communities in high conservation value areas. Several trials undertaken by the Department of Conservation and Land Management (CALM) have shown that foliar spraying and stem injection of phosphorous acid gives excellent control of *P. cinnamomi* in a range of susceptible hosts. In a report to the Western Australian Minister for the Environment, phosphorous acid treatment is identified as an effective measure for the protection of threatened flora (Podger, James & Mulcahy, 1996).

2. SUMMARY

The 16 monitoring sites within the Lexia Project Area and the adjoining segment of the Melaleuca Project Area cover a total area of 3 997 hectares. There are 2 806 hectares of native Banksia woodlands and Melaleuca wetlands that are uninfested and in very good to pristine condition. There are 790 hectares that are uninterpretable due to a lack of susceptible species, mainly through clearing and plantation establishment. There are 401 hectares of Banksia woodlands and Melaleuca wetlands that are infested with *P. cinnamomi*, with infestations range in size from spot infestations 40 metres in diameter to large expanses in excess of 50 hectares.

From the size and shape of the infestations, it was possible to estimate the time and mode of inoculum vectoring. Evidence indicates that viable inoculum vectoring has not been occurring for the past 20 years, with all infestations being associated with high-risk activities many decades ago. Activities such a vehicle access for bore monitoring are considered low risk and do not require stringent hygiene measures. Autonomous disease spread from existing infestations presents a considerable threat and will result in the death of many native species. This will have a negative impact on the populations of dependent animal species as well as the aesthetic and intrinsic values of the native plant community.

3. INTRODUCTION

The project brief states that "The Water and Rivers Commission is committed to implementing appropriate environmental monitoring programs as part of the Gnangara and East Gnangara Water Resources Allocation and Management Projects. A commitment outlined in the East Gnangara Groundwater Resource (PER), includes monitoring for the presence of dieback at sites accessed for the Environmental Monitoring Program undertaken by the Water and Rivers Commission".

This survey was commissioned as part of the environmental monitoring program with the following objectives:

- To conduct a disease survey of the nominated area and specific sites and assess changes in disease distribution since the previous survey.
- Provide explanations for any changes in disease distribution.
- Determine the potential risks associated with bore monitoring.
- Formulate a hygiene management plan to minimise the potential for disease spread.

Field assessment commenced on 20 March 2000 and was completed 29 May 2000. The method of disease assessment was the systematic examination of susceptible species for secondary symptoms of *P. cinnamomi* infection, supported by soil and root sampling. Assessment was also made for the predicted impact of *P. cinnamomi* in the vegetation associations, disease distribution and impact, site disturbance and potential inoculum vectors, and comparison to the 1996 assessment.

4. METHOD OF DISEASE SURVEY

4.1 Probability survey

Prior to the tendering of the contract, approval was given by the CALM Disease Standard Officer for the use of the probability survey procedure. The procedure targets areas where there has been potential for inoculum vectoring such as roads and tracks, and areas with a high probability of inoculum survival and propagation such as creeks and wetlands. Elevated/dry sites with no apparent inoculum vectors are considered at a very low risk of infestation and mapped as uninfested.

Roads, tracks and wetland areas were identified within the survey area on the "Lexia Area Dieback 1996" map (Hart, Simpson & Associates, 1996) and CALM 1:20 000 map sheet. The open roads and tracks were assessed by driving at walking pace and examining the adjacent susceptible native plant species for secondary symptoms of fungal infection. Secondary symptoms include dead and dying leaves, crown decline and death.

Where secondary symptoms indicative of *P. cinnamomi* infestation were detected, the site was assessed for chronological disease pattern development and evidence of agents other than *P. cinnamomi* (such as fire, drought, lightning, other fungi and mechanical damage). At sites where only a few susceptible species deaths were present, the plants were examined for primary symptoms such as lesion development in the roots and stem cambium.

Wetlands and potential inoculum vectors that could not be accessed by vehicle were traversed on foot. This included overgrown tracks, rehabilitated tracks, fire breaks and horse/motor cycle trails. The method of disease detection was the same as for roads and tracks.

4.2 Broad scale assessment

Broad scale assessment is a comprehensive survey method that involves assessing the entire area by traversing transects on foot or aerial photography interpretation. A dry upland area with isolated infestations and no apparent inoculum vectors was identified

from the Lexia Area Dieback 1996 map (Hart, Simpson & Associates, 1996) and targeted for broad scale assessment on foot. This was done to determine the inoculum vectors of the mapped infestations and determine whether more infestations existed.

A base line with a 50 metre transect interval was established on Warbrook Road between Saint Patrick Road and Walton Road. Transects were extended south to an unnamed track and examined on foot for the presence of secondary symptoms and potential inoculum vectors. Where secondary symptoms indicative of *P. cinnamomi* infestation were detected, the site was assessed for chronological disease pattern development and evidence of agents other than *P. cinnamomi*.

4.3 Sampling

Where there were secondary symptoms and chronological disease pattern development consistent with *Phytophthora cinnamomi* infestation, there was no requirement for sampling and the area was mapped as infested. At sites with a potential inoculum vector and one or a few isolated susceptible species displaying secondary symptoms, the plants were examined for primary symptoms such as lesion development in the roots and stem cambium. It is not possible to conclusively identify *P. cinnamomi* in the field as the fungus is microscopic during all stages of its life cycle. Samples of soil and root material were collected from these sites for laboratory analysis. The sample sites were demarcated in the field with dayglow orange flagging tape and an aluminium identification tag.

The samples were processed by the CALM Vegetation Health Service laboratory. The sample material was divided evenly into two containers and flooded with distilled water containing 15 *Eucalyptus sieberi* cotyledons that had been propagated in sterile conditions. The containers were covered and incubated at 25^0 Celsius for ten days. Cotyledons that changed colour from purple/green to brown were plated on antibiotic agar plates selective for *Phytophthora*. Plated material was left for five days then examined for the development of fungi. Identification of *Phytophthora* species was determined by the structure, size and development of sporangia and hyphae.

4.4 Classification of vegetation

During the disease survey, assessment was made of the vegetation structure and its susceptibility to *P. cinnamomi*. The vegetation was classified into vegetation associations based on the presence of one or more dominant species and the relative abundance of *P. cinnamomi* susceptible species was noted. The response that individual susceptible species will have to *P. cinnamomi* can vary and is dependent upon a complex relationship between the environment, the pathogen and the host. Observations of disease impact within existing infestations were made and used to predict the impact *P. cinnamomi* may have if introduced to uninfested vegetation associations of similar structure.

Segments of native vegetation that had been disturbed by clearing or fire, and areas where the native vegetation had been replaced with plantation could not be assessed for *P. cinnamomi* distribution due to the low representation or absence of susceptible species. These segments were classified as uninterpretable.

4.5 Reassessment of specific monitoring sites

Identification of the specific monitoring sites was attempted by cross referencing map data and text from the report "Water and Rivers Commission. Lexia Area. Dieback" (Hart, Simpson & Associates, 1996). The sites had been annotated on the Lexia Area Dieback 1996 map (Hart, Simpson & Associates, 1996) with a number and listed in the key as "Sites".

It was deduced that the combined 16 monitoring sites covered the entire nominated survey area and were not identifiable as specific monitoring sites within the survey area. Therefore, the nominated survey area was by default a conglomeration of the 16 monitoring sites and no specific surveys could be conducted.

4.6 Mapping and demarcation

A 1:20 000 CALM map sheet was obtained from CALM Como Forest Management Branch. The map displayed roads and road names, cadastral boundaries, the Australian Map Grid (AMG), contours, areas subject to inundation, stream zones and plantations. The map was used to identify target areas for the probability survey and the broad scale survey.

During the survey, areas of native vegetation displaying secondary symptoms and chronological pattern development consistent with *P. cinnamomi* infestation were mapped as infested and sample sites were annotated on the map. The location of disease boundaries and sample sites were mapped with a combination of non-corrected Global Positioning System data (GPS), 1:20 000 aerial photography and the vehicle odometer.

Sites within the survey area that could not be assessed due to a low representation or absence of susceptible species were mapped as uninterpretable, and included sand mines, plantation and areas cleared of native vegetation. The remaining area that had not been classified as infested or uninterpretable was mapped as uninfested.

The 16 specific monitoring sites annotated on the Lexia Area Dieback 1996 map (Hart, Simpson & Associates, 1996) were replicated on the CALM map sheet to provided reference for discussion.

Demarcation of disease boundaries was limited to the points at which infestations intersected uninfested tracks and roads. The demarcation was positioned twenty metres from the infestation in the uninfested vegetation and consisted of a two bands of 50 mm

dayglow orange flagging tape. The tapes were tied to vegetation adjacent to the track with the knots towards the infestation.

The completed map displaying infested, uninfested, uninterpretable, sample sites, monitoring sites and demarcation boundaries was digitised by CALM Como Forest Management Branch. A segment of map information obtained from the adjacent Melaleuca Project Area was appended to the Lexia Project Area to form the "*Phytophthora cinnamomi* Hygiene Management Map" presented in Appendix 1.

5. RESULTS

The native vegetation within the survey area is predominantly Banksia woodland with occasional wetlands in sites subject to inundation. The majority of the flora within the Banksia woodlands is susceptible to *P. cinnamomi* and infested sites were displaying extremely high impact (90% or higher mortality) in the Banksia overstorey and moderate to very high impact (30% to 90% mortality) in the understorey. The majority of the flora within the wetlands is resistant to *P. cinnamomi* and infested wetlands displayed low impact (10% or less mortality) with isolated deaths in scattered susceptible understorey species. Uninfested native vegetation segments are generally in pristine condition with little or no disturbance.

There are many infestations throughout the survey area that are having an extremely high impact in the Banksia woodlands. There is a large infestation east of Saint Patrick Road and north of Warbrook Road (Appendix 1) that appears to have been present for many decades. It is probable that this infestation has been a source of inoculum for some of the smaller infestations radiating along inoculum vectors. The majority of detected infestations are adjacent to inoculum vectors. This is due to the nature of vectored inoculum spread and the design of the probability survey.

Described below are the vegetation associations and there susceptibility to *P. cinnamomi* should the pathogen be introduced, the current disease distribution and impact, site disturbance and potential inoculum vectors, and comparison to the disease distribution mapped in 1996. The monitoring site numbers and site names from Water and Rivers Commission. Lexia Area. Dieback (Hart, Simpson & Associates, 1996) have been used to facilitate direct comparison between the two reports.

Site 1. Neaves Road Transect

From analysis of the text and map within Water and Rivers Commission. Lexia Area. Dieback (Hart, Simpson & Associates, 1996), the monitoring site does not appear to be a transect, but rather a broad area of Banksia woodland and wetland. For this survey the boundary was Neaves Road between Cooper Road and the survey boundary, the survey

boundary between Neaves Road and Seismic Road, Seismic Road between the survey boundary and Cooper Road, and Cooper Road between Seismic Road and Neaves Road.

Vegetation associations

There are two wetlands adjacent to Seismic Road and Cooper Road that constitute approximately 15% of the site. The remaining area is Banksia woodland on undulating sand plain. The wetland vegetation association is an open *Melaleuca rhaphiophylla* (Paperbark) woodland over *Adenanthos cygnorum, Melaleuca spp.* (Tea Tree) *Patersonia spp.* and *Xanthorrhoea preissii.* There are scattered *Banksia attenuata, Banksia ilicifolia* and *Nuytsia floribunda* in the overstorey. The predicted impact of *P. cinnamomi* is negligible in the majority of the vegetation (Melaleuca species) but high in the scattered Banksias.

The Banksia woodland vegetation association is a *Banksia attenuata, Banksia menziesii* woodland with occasional *Banksia ilicifolia, N. floribunda* and *Eucalyptus marginata* (Jarrah) over *A. cygnorum, Patersonia spp.* and *X. preissii.* The predicted impact of *P. cinnamomi* is extremely high in the Banksia overstorey and moderate to very high in the understorey.

Disease distribution and impact

A *P. cinnamomi* infestation was detected adjacent to Neaves Road easement. It is semicircular (due to the roadside clearing to the north of the infestation) with a diameter of approximately 50 metres. The regular semicircular shape and size of the infestation suggests a point source of inoculum approximately 25 to 30 years ago (given an estimated autonomous rate of spread of one metre per annum). Disease impact is extremely high in the Banksia overstorey and moderate in the understorey.

There were multiple deaths in Banksias, Paperbarks and *X. preissii* within the wetland that were attributed to fire. Sample eight was taken from several recent deaths in susceptible *X. preissii* to exclude *P. cinnamomi* as a possible pathogen. The sample returned a negative result (annotated on map, Appendix1).

Site disturbance and potential inoculum vectors

The wetland adjacent to Cooper Road has been subject to a moderate intensity fire an estimated six years ago. The age of deaths and even distribution between both *P. cinnamomi* susceptible and resistant species, and lack of chronological pattern development suggest that fire was the cause of death.

There has been recent scrub rolling within the powerline easement (132kv Northern Terminal to Pinjar) between Cooper Road and Neaves Road. It is unknown whether the operation was completed under hygienic conditions and there appears to have been potential for movement of soil and plant material. Assessment within the easement was difficult due to the disturbance.

All open roads and internal tracks constitute potential inoculum vectors through unhygienic vehicle access.

Comparison to 1996 assessment
The infestation adjacent to Neaves Road was recorded as having been sighted but was not mapped.

Site 2. Dampland 78 and access track

From analysis of the text and map within Water and Rivers Commission. Lexia Area. Dieback (Hart, Simpson & Associates, 1996), the monitoring site was determined to be the wetland south of Quicke Road at AMG coordinates 397 000mE 6 491 750mN, and the access track from the plantation to the wetland.

Vegetation associations
The wetland vegetation association is an open Paperbark woodland with occasional *Eucalyptus rudis* over *A. cygnorum, Patersonia spp.,* Tea tree and *X. preissii.* The predicted impact of *P. cinnamomi* is negligible in the majority of the vegetation (Melaleuca species) and would result in some mortality in *A. cygnorum, X. preissii* and *Patersonia spp.*

The wetland vegetation grades into a Banksia woodland vegetation association of *B. attenuata, B. menziesii* woodland with occasional *B. ilicifolia, N. floribunda* and Jarrah over *A. cygnorum, Hibbertia spp.,* and *Patersonia spp..* The predicted impact of *P. cinnamomi* is extremely high in the Banksia overstorey and moderate to very high in the understorey.

Disease distribution and impact
There were no infestations detected within the wetland, the adjacent Banksia woodland, or adjacent to the access track. There are two infestations within the powerline easement (132kv Northern Terminal to Muchea) south east of the monitoring site at AMG coordinates 397 200mE 6 491 300mN and 397 075mE 6 491 100mN.

The northern infestation is oval in shape and approximately 130 metres long by 70 metres wide, suggesting that inoculum was introduced along the easement (as apposed to a point source) approximately 35 years ago. Disease impact is extremely high in both the overstorey and understorey.

The southern infestation is within the powerline easement with only scattered susceptible species present and extending into an uninterpretable clearing within the plantation. The segment that was detectable is semi circular and approximately 100 metres in diameter. It was not possible to determine the vector or time of initial infestation, but it is probable the infestation has been present for many decades.

Site disturbance and potential inoculum vectors
The access track extends into the wetland in a northerly direction and then extends to the south east within the wetland. It appears that the track is used for bore monitoring within

the wetland as bore sites were located adjacent to the track. There has been vehicle access associated with illegal Tea Tree cutting/extraction activities. The two infestations south east of the monitoring site constitute a potential source of inoculum that may be vectored by vehicles accessing the site.

Comparison to 1996 assessment
The infestation at AMG coordinate 397 075mE 6 491 100mN was not detected in the previous survey. The northern infestation was mapped considerably smaller.

Site 3. EPP wetland 173 and access

From analysis of the text and map within Water and Rivers Commission. Lexia Area. Dieback (Hart, Simpson & Associates, 1996), the monitoring site was determined to be the wetland and surrounding Banksia woodland between the AMG grid line 401 000mE and the eastern survey boundary.

Vegetation associations
The wetland vegetation association is an open Paperbark woodland with occasional *E. rudis* over *A. cygnorum, Patersonia spp.,* Tea tree and *X. preissii*. The predicted impact of *P. cinnamomi* is negligible in the majority of the vegetation and would result in some mortality in *A. cygnorum, Patersonia spp.* and *X. preissii*

The wetland vegetation grades into a Banksia woodland vegetation association of *B. attenuata, B. menziesii* woodland with occasional *B. ilicifolia, N. floribunda* and Jarrah over *A. cygnorum, Hibbertia spp., Patersonia spp.* and *X. preissii*. The predicted impact of *P. cinnamomi* is extremely high in the Banksia overstorey and moderate to very high in the understorey.

There is a segment of open *Corymbia calophylla* (Marri) and Jarrah woodland over *B. attenuata, B. ilicifolia,* and *B. menziesii* on the northern boundary of the wetland. The predicted impact of *P. cinnamomi* is extremely high in the Banksia understorey and moderate in the overstorey (as Marri is non-susceptible).

Disease distribution and impact
There is an infestation in the north eastern corner of the monitoring site that extends beyond the survey boundary into private property. The size and shape of the infestation could not be accurately defined due to uninterpretable areas within the private property. Evidence suggests the infestation exceeds several hectares in size. It was difficult to determine the south western boundary within the wetland due to sparse distribution of susceptible species. Chronological pattern development indicates the disease is moving autonomously in a south westerly direction through the monitoring site. The Banksia woodland fringing the western, southern and eastern wetland riparian zone is uninfested, indicating the majority of the wetland is uninfested.

Within the infestation, disease impact is high to extremely high in the Banksia woodland

overstorey, and low to moderate in the understorey, reducing to low impact in the wetland. The *P. cinnamomi* susceptible *X. preissii* were not readily displaying secondary symptoms and were not useful in determining the disease boundary.

There is an infestation on the southern boundary of the monitoring site at AMG coordinates 401 425mE 6 491 350mN. The infestation is extensive in the adjacent private property and has spread autonomously into the survey area. The infestation is approximately 20 metres in diameter and consists of scattered deaths in Banksia.

Site disturbance and potential inoculum vectors
There is one access track adjacent to the private property boundaries from Cooper Road in the north to the natural gas pipeline easement. The track is within the survey area and within five metres of the boundary fences. It traverses three infestations and presents a possible inoculum vector. There are no internal tracks within the wetland or surrounding Banksia woodland.

Comparison to 1996 assessment
The entire wetland was mapped as infested in the previous survey. The infestation at AMG coordinates 401 425mE 6 491 350mN was not detected in the previous survey.

Site 4. Amarante Road

From analysis of the text and map within Water and Rivers Commission. Lexia Area. Dieback (Hart, Simpson & Associates, 1996), the monitoring site was determined to be the road easement and vegetation adjacent to a segment of Amarante Road from Centre Way extending 4.5 km to the west. The section of Amarante Road between Centre Way and Silver Road could not be located in the field and did not appear on the CALM map. As this section was uninterpretable plantation, the survey was confined to the section of Amarante Road to the west of Silver Road.

Vegetation associations
From Silver Road to 1.2 km west of Silver Road, the vegetation is plantation and partially cleared wetland. From 1.2 km to the western survey boundary, the vegetation to the south of Amarante Road is also plantation. These areas have very few susceptible species remaining and could not be assessed for disease (uninterpretable).

From 1.2 km west of Silver Road there is a 40 metre wide strip of partially cleared Banksia woodland north of, and parallel to, Amarante Road. The remnant vegetation extends 500 metres to the west. The vegetation association is a modified open Banksia woodland of occasional *B. menziesii*, *B. attenuata* over *A. cygnorum, Lomandra spp., Hibbertia spp,* and *Patersonia spp.*. The predicted impact of *P. cinnamomi* is extremely high in the sparse Banksia overstorey and moderate in the understorey.

At the western end of the native vegetation strip (approximately 1.7 km from Silver Road), the vegetation changes to a broad strip (250 metres wide) of Banksia woodland.

The vegetation association is *B. attenuata, B. menziesii* woodland with occasional *B. ilicifolia* and *N. floribunda* over *A. cygnorum, Patersonia spp.* and *X. preissii*. The predicted impact of *P. cinnamomi* is extremely high in the Banksia overstorey and moderate to very high in the understorey.

Disease distribution and impact
There were no infestations detected within the monitoring site. At the eastern end of the narrow roadside strip of remnant native vegetation there were suspicious deaths in susceptible *A. cygnorum* and *Stirlingia latifolia*. There was a slight radial pattern development, but also evidence of a low intensity fire. Sample nine was taken from several dead plants and returned a negative result (annotated on map, Appendix1).

Site disturbance and potential inoculum vectors
The reason for an absence of Banksia overstorey within the roadside strip of remnant native vegetation was not obvious. It is possible that it was partially cleared some time in the past and has not regenerated, or was subject to a fire of high intensity during adjacent clearing operations. The strip of remnant native vegetation and Banksia woodland are bordered by open tracks and one internal track (within the Banksia woodland) that constitute possible inoculum vectors.

Comparison to 1996 assessment
The disease distribution is the same, with no infestations detected during both surveys.

Site 5. Centre Way north of Warbrook Road

From analysis of the text and map within Water and Rivers Commission. Lexia Area. Dieback (Hart, Simpson & Associates, 1996), the monitoring site was determined to be the powerline easement between Warbrook Road and Underwood Road (combined 132kv Northern Terminal to Muchea and 132kv Northern Terminal to Pinjar), and the powerline easement from Underwood Road to 500 metres north east of Bustard Road (132kv Northern Terminal to Muchea)

Vegetation associations
The majority of the easement has been cleared or partially cleared of native vegetation and is uninterpretable. There are three segments of remnant native vegetation within the uninterpretable area consisting of Banksia woodland vegetation association of *B. attenuata, B. menziesii* woodland with occasional *B. ilicifolia*, and *N. floribunda* over *A. cygnorum, Hibbertia spp,* and *Patersonia spp.*. The segments between Galah Road and Underwood Road are partially infested and displaying extremely high impact in the Banksia overstorey.

There is a wetland vegetation association of Paperbark and *E. rudis* woodland over occasional *B. attenuata, B. ilicifolia* and *B. menziesii*, approximately 600 metres south of Underwood Road. The predicted impact of *P. cinnamomi* is extremely high in the Banksia understorey and negligible in the non-susceptible overstorey and shrub layer.

Disease distribution and impact
The four infestations between Galah Road and Underwood Road are linked beyond the eastern survey boundary in remnant native vegetation. The infestation is continuous and extensive, exceeding 50 hectares in size. The infestation is contiguous with uninterpretable cleared areas and plantation, with the precises disease boundary being indeterminate. It is probable that there were multiple points of inoculum introduction along the open tracks and powerline easement many decades ago, which have spread autonomously and through inoculum vectoring to form the large infestation. The disease impact is extremely high in the Banksia overstorey and moderate to high in the understorey.

The infestation immediately north of Underwood Road was detected in regrowth Banksias within, and adjacent to, the powerline easement. The boundary was difficult to determine due to the low representation of susceptible species, with the infestation estimated to be 30 metres in diameter. It is probable that inoculum was introduced at least 15 years ago. The overall impact is moderate due to the absence of a susceptible overstorey (through clearing).

The infestation at the northern boundary of the survey area has been described in Site 2. The infestation is within the powerline easement with only scattered susceptible species present and extending into an uninterpretable clearing within the plantation. The segment that was detectable is an arc approximately 50 metres in diameter. It is estimated that the infestation has been present for 25 years or more.

Site disturbance and potential inoculum vectors
There are tracks within, and adjacent to, the uninfested remnant native vegetation segments that present potential inoculum vectors. The well-used tracks traverse the adjacent infestations that present a potential source of inoculum.

Comparison to 1996 assessment
The infestation immediately north of Underwood Road and the infestation on the northern survey boundary were not detected in the previous survey. The shape and size of the mapped areas of uninfested remnant native vegetation vary between the 1996 map and the current map.

Site 6. Unnamed road north of Krake Road

From analysis of the text and map within Water and Rivers Commission. Lexia Area. Dieback (Hart, Simpson & Associates, 1996), the monitoring site was determined to be the road easement and vegetation adjacent to the unnamed east/west road between Saint Patrick Road and the powerline easement (Site 5).

Vegetation associations
Approximately 95% of the site is within plantation and is uninterpretable due to the lack

of susceptible species. There is a segment of remnant wetland vegetation on the western survey boundary common to both Site 5 and Site 6. The wetland vegetation association is Paperbark and *E. rudis* woodland over occasional *B. attenuata, B. ilicifolia* and *B. menziesii* over Tea Tree. The predicted impact of *P. cinnamomi* is extremely high in the Banksia understorey and negligible in the non-susceptible overstorey and shrub layer.

The road bisects a small segment of remnant wetland vegetation 200 metres west of Payne Road, that was considered too small to map (less than one hectare). The wetland vegetation association is Paperbark and *B. attenuata* over sedges. The predicted impact of *P. cinnamomi* is high in *B. attenuata* and negligible in the paperbark and sedges.

Disease distribution and impact
Both the wetland on the western survey boundary and the wetland 200 metres west of Payne Road are partially infested. The pattern of susceptible species deaths indicates that the uninterpretable areas surrounding the wetland are infested and the disease is spreading autonomously into the wetlands. The infested areas are displaying high impact in the Banksias, and no impact in the non-susceptible species.

Site disturbance and potential inoculum vectors
The uninfested wetland vegetation has had little disturbance and was assessable for disease presence. The remaining area (approximately 95%) has been cleared of susceptible species and is not assessable. There has been considerable potential for inoculum vectoring through plantation activities such as clearing, roading and harvesting. Vectoring of inoculum on the unnamed road and intersecting tracks is probable due to the large source of inoculum within the adjacent infestation (Site 5).

Comparison to 1996 assessment
The remnant wetland vegetation (and associated infestation) 200 metres north of Payne Road was not described in 1996.

Site 7. Walton Road Block

It was not possible to determine the monitoring site boundary from analysis of the text and map within Water and Rivers Commission. Lexia Area. Dieback (Hart, Simpson & Associates, 1996). The boundary for this assessment (that may match the original perimeter) was Galah Road between Saint Patrick Road and the eastern survey boundary, the eastern survey boundary between Galah Road and Warbrook Road, Underwood Road between Warbrook Road and Saint Patrick Road, Saint Patrick Road between Underwood Road and Galah Road.

Vegetation associations
The vegetation within the monitoring site has been graded in to two primary vegetation associations of wetlands and Banksia woodlands. There are relatively small vegetation segments within the site with slightly varied floristic compositions that have not been described individually.

There are extensive wetlands in the north west quadrant of the survey area, with a broad drainage feature extending across Warbrook Road to the eastern boundary. The vegetation association is open *X. preissii* scrubland with occasional Paperbark and *E. rudis* over *A. cygnorum, Patersonia spp.* and Tea Tree. The wetlands have been infested for many decades.

The vegetation association on undulating sandy rises is a B. *attenuata, B. menziesii* woodland with occasional *B. ilicifolia, N. floribunda* and Jarrah over *A. cygnorum, Hibbertia spp., Patersonia spp.* and *X. preissii.* The predicted impact of *P. cinnamomi* is extremely high in the Banksia overstorey and moderate to very high in the understorey. There are extensive *P. cinnamomi* infestations within the Banksia woodlands that have modified the floristic structure, primarily through total loss of the Banksia overstorey.

Disease distribution and impact

There is a large *P. cinnamomi* infestation (approximately 150 hectares) occupying the majority of the northern half of the site. The wetlands are completely infested and the disease has spread rapidly through the riparian zone to the adjacent Banksia woodlands. Impact is extremely high in the Banksia woodland overstorey and negligible in the wetland. It is probable that there were susceptible species within the wetlands that have been eradicated by disease.

There are three infestations approximately 60 metres in diameter within the underground gas pipeline easement. The size and radial shape suggests a point source of inoculum approximately 30 years ago. Disease impact is extremely high in the Banksia overstorey and moderate in the understorey.

There is an infestation on a track on the eastern survey boundary, 300 metres north of Galah Road. The infestation is oval in shape with an length of 200 metres and width of 70 metres, suggesting inoculum was spread along the track approximately 35 years ago. Disease impact is extremely high in the Banksia overstorey and high in the understorey.

There are eight infestations south of Warbrook Road that have no apparent inoculum vector. The two infestations adjacent to Warbrook Road and the two infestations to the east of Walton Road may be associated with the roads, although the disease pattern development suggest alternative inoculum vectors. The infestations are all radial in shape and 40 metres to 100 metres in diameter, suggesting point sources of inoculum 20 to 50 years ago. Disease impact within all infestations is extremely high in the Banksia overstorey and moderate to high in the understorey.

Soil and root tissue samples were taken from isolated susceptible species deaths adjacent to roads and tracks at sample sites four, five, six and seven. All samples returned negative results (annotated on map, Appendix 1).

Site disturbance and potential inoculum vectors

There are many roads and tracks that traverse infested and uninfested areas that present

possible inoculum vector. All roads and tracks appear to be regularly accessed by vehicles. Several incidences of illegal dumping of domestic garden waste (including soil) were noted.

Comparison to 1996 assessment
The majority of mapped infestations are similar in size, shape and location for both surveys. Four infestations were mapped that had not been detected in the previous survey.

Site 8. Warbrook Road east of the Walton Road Block, Sawpit Road, Maralla Road and the Dunstan property

From analysis of the text and map within Water and Rivers Commission. Lexia Area. Dieback (Hart, Simpson & Associates, 1996), the monitoring site was determined to be the road easement and vegetation adjacent to Warbrook Road between Underwood Road and Sawpit Road, Sawpit Road between Warbrook Road and Maralla Road, and Maralla Road between Sawpit Road and Halden Road.

Vegetation associations
Warbrook Road and Sawpit Road are within cleared or partially cleared farmland and are uninterpretable. The exception to this is 400 metres of wetland and Banksia woodland at the western end of Warbrook Road. The wetland has been partially cleared to an open *E. rudis* woodland over Paperbark, *A. cygnorum, Patersonia spp.,* Tea Tree and *X. preissii*. The wetland is infested and is displaying very low impact.

The Banksia woodland has been partially cleared of overstorey and understorey species and consists of a *B. attenuata, B. menziesii* open woodland over scattered A. *cygnorum, Hibbertia spp.,* and *Patersonia spp.*. The predicted impact of *P. cinnamomi* is extremely high in the Banksia overstorey and moderate in the understorey.

The vegetation in private property to the south of Maralla Road is intact and consists of a *B. attenuata, B. menziesii* woodland with occasional *B. ilicifolia* and *N. floribunda* over *A. cygnorum, Hibbertia spp., Patersonia spp.* and *X. preissii*. There are remnant segments of this vegetation extending into partially cleared private property on the northern side of the road. The predicted impact of *P. cinnamomi* is extremely high in the Banksia overstorey and moderate to very high in the understorey.

Disease distribution and impact
The wetland at the western end of Warbrook Road and the wetland at the intersection of Sawpit and Maralla Road are infested and displaying very low impact. The infestations extend beyond the survey boundary and no assessment was made of the total area. It is probable that the wetlands have been infested for many decades.

There is a disease front parallel to and 60 metres south of Maralla Road for the majority of the road easement. Evidence suggests that inoculum was introduced along the road easement or adjacent fire break approximately 30 years ago. Disease impact is extremely

high in the Banksia overstorey and moderate in the understorey.

Site disturbance and potential inoculum vectors
The entire site is within public road easements and adjacent private property with a range of levels of disturbance. The uninfested Banksia woodland to the south of Maralla Road is in pristine condition and some small remnant wetlands on Sawpit Road are relatively intact. The roads, road easements and cleared private property displayed a high level of disturbance and are uninterpretable.

There is high potential for soil movement and associated potential inoculum vectoring within private property. Activities that were noted included fire break establishment, cropping and turf farming. It is probable that there is some degree of cryptic infestation within the uninterpretable areas, providing a source of inoculum.

Comparison to 1996 assessment
The mapped disease boundaries south of Maralla Road vary between the 1996 map and the current map.

Site 9. Extension of Galah Road east of Centre Way

From analysis of the text and map within Water and Rivers Commission. Lexia Area. Dieback (Hart, Simpson & Associates, 1996), the monitoring site was determined to be road easement and vegetation adjacent to Galah Road between Centre Way and Saint Patrick Road.

Vegetation associations
Approximately 80% of the site is within plantation and is uninterpretable due to the lack of susceptible species. There is a segment of Banksia woodland west of Payne Road that has been included in Site10, and is not described here.

There is a segment of Banksia woodland north of Galah Road between Payne Road and Saint Patrick Road consisting of *B. attenuata, B. menziesii* woodland with occasional *B. ilicifolia*, and *N. floribunda* and over *A. cygnorum, Patersonia spp.* and *X. preissii.* The predicted impact of *P. cinnamomi* is extremely high in the Banksia overstorey and moderate to very high in the understorey.

Disease distribution and impact
There are extensive infestations in the Banksia woodland between Payne Road and Saint Patrick Road. The size and shapes of the infestations suggests that there has been multiple points of inoculum introduction many decades ago, followed by autonomous disease spread that has joined some infestations. The infestations are displaying extremely high impact in the Banksia overstorey and moderate to very high in the understorey.

A soil and root tissue sample (sample 2) was taken from scattered susceptible species deaths at the intersection of Galah Road and Saint Patrick road. The sample returned a negative result (annotated on map, Appendix 1).

Site disturbance and potential inoculum vectors
Approximately 80% of the site is within plantation cleared of susceptible species and is uninterpretable. There has been considerable potential for inoculum vectoring through plantation activities such as clearing, roading, planting and harvesting. Galah Road, Payne Road and Warbrook Road are regularly accessed by vehicle traffic and present possible inoculum vectors.

Comparison to 1996 assessment
The mapped infestations are similar in size, shape and location for both surveys.

Site 10. Warbrook Road between Centre Way and Walton Road Block

From analysis of the text and map within Water and Rivers Commission. Lexia Area. Dieback (Hart, Simpson & Associates, 1996), the monitoring site was determined to be road easement and vegetation adjacent to Warbrook Road between Centre Way and Galah Road. For this survey, the northern site boundary was extended from Warbrook Road to Galah Road to include a segment of Banksia woodland.

Vegetation associations
Approximately 70% of the site is plantation and is uninterpretable due to the lack of susceptible species. There is a segment of Banksia woodland north of Warbrook Road, extending to Galah Road of *B. attenuata, B. menziesii* woodland with occasional *B. ilicifolia*, and *N. floribunda* and over *A. cygnorum, Patersonia spp.* and *X. preissii.* The predicted impact of *P. cinnamomi* is extremely high in the Banksia overstorey and moderate to very high in the understorey.

There are two segments of wetland vegetation south of Warbrook Road that extend into the survey site. The wetland vegetation association is open Paperbark woodland over *Patersonia spp.,* Tea Tree and *X. preissii.* The predicted impact of *P. cinnamomi* is very low.

Disease distribution and impact
There were no infestations detected within the Banksia woodland or wetlands. The wetlands are bordered by plantation and Warbrook Road, with no fringing Banksia woodland vegetation to express disease symptoms. As it is possible that cryptic infestation may exist within the wetlands, they were classified as uninterpretable.

Site disturbance and potential inoculum vectors
Approximately 70% of the site has been cleared of susceptible species and is uninterpretable. Segments of the Banksia woodland have been burnt approximately three

years ago, reducing the reliability of the disease assessment (as disease symptoms may be masked).

There has been considerable potential for inoculum vectoring through plantation activities such as clearing, roading, planting and harvesting. Warbrook Road is a major access road and presents a possible inoculum vector.

Comparison to 1996 assessment
There were no infestations detected in this survey or the previous survey.

Site 11. Saint Patrick Road Block

It was not possible to determine the monitoring site boundary from analysis of the text and map within Water and Rivers Commission. Lexia Area. Dieback (Hart, Simpson & Associates, 1996). The boundary for this assessment (that may match the original perimeter) is Galah Road between Saint Patrick Road and the eastern survey boundary, the track at the eastern end of Galah Road to a point due east of Tick road, from this point to Tick Road, 500 metres along Tick Road to the plantation/Banksia woodland boundary, and along approximately 7.5 km of plantation/Banksia woodland boundary to Galah Road.

Vegetation associations
The monitoring site is approximately 500 hectares in size and primarily Banksia woodland on undulating sandy rises with one minor wetland. There are relatively small vegetation segments within the site with slightly varied floristic compositions that have not been described individually. There is a active sand mine north of Bell Road and a clearing east of Barlow Lane that were uninterpretable due to clearing of susceptible species.

The vegetation association on undulating sandy rises is a B. *attenuata, B. menziesii* woodland with occasional *B. ilicifolia, N. floribunda* and Jarrah over *A. cygnorum, Hibbertia spp., Patersonia spp.* and *X. preissii*. The predicted impact of *P. cinnamomi* is extremely high in the Banksia overstorey and moderate to very high in the understorey.

The wetland is adjacent to Saint Patrick approximately 500 metres south of Galah Road. The vegetation association is an open Paperbark woodland with occasional *E. rudis* over *A. cygnorum, Patersonia spp.*, Tea Tree and *X. preissii*. The predicted impact of *P. cinnamomi* is low.

Disease distribution and impact
There are seven infestations adjacent to Saint Patrick Road. The infestations are circular or semicircular in shape and 40 metres to 80 metres in diameter. The semicircular infestations suggest a point source of inoculum on only one side of the road that has not spread across or under the road. The circular infestations (bisected by the road) suggest inoculum was introduced on both sides of the road simultaneously. The size of the

infestations suggests inoculum was introduced 20 to 40 years ago. Impact is extremely high in the Banksia overstorey and moderate to high in the understorey within all infestations.

There are two infestations within the underground gas pipeline easement. The infestation north of Bell Road is a collection of scattered Banksia deaths with only a slight pattern development. It is possible that there are multiple infestations associated with relatively recent inoculum introduction (less than ten years ago). The infestation south of Bell Road is circular in shape and approximately 60 metres in diameter, suggesting a point source of inoculum approximately 30 years ago. Disease impact is extremely high in the Banksia overstorey and low in the understorey.

There is an infestation on Bell Road 250 metres east of the underground gas pipeline easement. The infestation is circular in shape and approximately 70 metres in diameter, suggesting a point source of inoculum approximately 35 years ago. Disease impact is extremely high in the Banksia overstorey and moderate in the understorey.

There is an infestation on the eastern boundary track 700 metres north of Bell Road. The infestation is circular in shape and approximately 100 metres in diameter, suggesting a point source of inoculum approximately 50 years ago. Disease impact is extremely high in the Banksia overstorey and moderate in the understorey.

There is an infestations on an unnamed track due west of the sand mine at AMG coordinates 399 600mE 6 486 500mN. It appears that the infested site was the location of a tower or mast that has since been removed. The infestation is circular in shape and approximately 100 metres in diameter, suggesting a point source of inoculum approximately 50 years ago. Disease impact is extremely high in the Banksia overstorey and high in the understorey

There is an infestations on an unnamed track at AMG coordinates 398 900mE 6 486 500mN. The infestation is circular in shape and approximately 70 metres in diameter, suggesting a point source of inoculum approximately 35 years ago. Disease impact is extremely high in the Banksia overstorey and low in the understorey

There is an infestations adjacent to Possum Road, extending north east for 400 metres. The infestation is linear in shape and approximately 50 metres in wide, suggesting inoculum was spread along the associated tracks 25 to 40 years ago. Disease impact is extremely high in the Banksia overstorey and high in the understorey

There are two infestations adjacent to Tick Road that have been included in monitoring site 13.

A soil and root tissue sample (sample 3) was taken from scattered susceptible species deaths within the underground gas pipeline easement 300 metres south of Galah Road. The sample returned a negative result (annotated on map, Appendix 1).

Site disturbance and potential inoculum vectors
The sand mine north of Bell Road and a clearing east of Barlow Lane were uninterpretable due to clearing of susceptible species. The plantation adjacent to the monitoring site is also uninterpretable due to a lack of susceptible species.

There are many roads and tracks that traverse infested and uninfested areas that present possible inoculum vector. All roads and tracks appear to be regularly accessed by vehicles. The access road to the sand mine appears to have traversed an infestation mapped in 1996. It is not known whether the road construction was completed hygienically.

Comparison to 1996 assessment
The majority of mapped infestations are similar in size, shape and location for both surveys. Six infestations were mapped that had not been detected in the previous survey. An infestation mapped in 1996 could not be relocated and appears to have been excavated/cleared during road construction for the sand mine access road.

Site 12. Mount Lawley Block

From analysis of the text and map within Water and Rivers Commission. Lexia Area. Dieback (Hart, Simpson & Associates, 1996), the monitoring site was determined to be approximately 400 hectares of private property on the eastern survey boundary. The monitoring site boundary is the eastern survey area boundary south from Maralla Road to the plantation, the plantation boundary west for 1.8 km to an unnamed track, the unnamed track 2.3 km north to Maralla Road, and Maralla Road east to the eastern survey area boundary.

Vegetation associations
The monitoring site is a mosaic of Banksia woodland on undulating sandy rises with extensive wetlands in broad swales. There are relatively small vegetation segments within the site with slightly varied floristic compositions that have not been described individually.

The vegetation association on undulating sandy rises is a B. *attenuata, B. menziesii* woodland with occasional *B. ilicifolia, N. floribunda* and Jarrah over *A. cygnorum, Hibbertia spp., Patersonia spp.* and *X. preissii.* The predicted impact of *P. cinnamomi* is extremely high in the Banksia overstorey and moderate to very high in the understorey.

The wetlands vegetation association is an open sedge land with occasional Paperbark, *B. attenuata* and *B. ilicifolia,* fringed with Paperbark woodland over A. *cygnorum, Patersonia spp.,* Tea Tree and *X. preissii.* The predicted impact of *P. cinnamomi* is low.

Disease distribution and impact
There is an extensive infestation in the wetland and fringing Banksia woodland on the eastern survey boundary, occupying approximately 60 hectares. It is probable that initial

inoculum vectoring was many decades ago and associated with the track forming the eastern survey boundary. Disease impact in the wetland is low, with deaths in the sparse Banksias only. Disease impact in the fringing Banksia woodland is extremely high in both the overstorey and understorey.

There is an infestation 300 metres south west of the infestation described above in Banksia woodland, spreading autonomously into a wetland. The southern boundary of the infestation was difficult to determine due to a recent fire (the firebreak bisects the infestation), and the infestation was approximated to be oval in shape with an length of 150 metres width of 80 metres. The size and shape of the infestation suggest inoculum was vectored along a transect approximately 40 years ago. Disease impact in the Banksia woodland is extremely high in both the overstorey and understorey, particularly adjacent to the wetland.

There is an infestation within a wetland in the north west corner of the site at AMG coordinated 401 200mE 6 487 350mN. The infestation is approximately 120 metres in diameter with no recognisable inoculum vector and has been present for many decades. Disease impact is low in the wetland and extremely high in the fringing Banksia woodland.

There is an infestation 200 meters south west of the infestation described above. The infestation is partially within monitoring site 11, and is described there.

A soil and root tissue sample (sample 1) was taken from scattered susceptible species deaths adjacent to Maralla Road. The area had been previously mapped as infested, yet the current symptoms did not indicate *P. cinnamomi*. The sample returned a negative result (annotated on map, Appendix 1).

Site disturbance and potential inoculum vectors

The south eastern corner of the survey site was uninterpretable due to a moderate intensity wild fire approximately one year ago. There were many fire-related deaths in the Banksia overstorey and loss of most understorey species. It was possible to detect large infestations, whereas smaller infestations may have been missed.

There were vehicle wheel tracks in several of the wetlands, and tracks traversing infested and uninfested areas. All open roads and tracks present possible inoculum vectors. The recent construction of the firebreak that bisects the southern most infestation may have resulted in the vectoring of inoculum.

Comparison to 1996 assessment

Sample site one was mapped as infested during the previous survey. The area is now mapped as uninfested.

Site 13. Tick Road

From analysis of the text and map within Water and Rivers Commission. Lexia Area. Dieback (Hart, Simpson & Associates, 1996), the monitoring site was determined to be the road easement and vegetation adjacent to Tick Road between Centre Way and a point 200 metres west of Walton Road.

Vegetation associations
Approximately 98% of the site is within plantation and is uninterpretable due to the lack of susceptible species. At 700 metres east of Centre Way there is a small segment of remnant Banksia woodland common to both Site 11 and Site 13. The Banksia woodland vegetation association is *B. attenuata, B. menziesii* woodland with occasional *B. ilicifolia, N. floribunda* and Jarrah over *A. cygnorum, Hibbertia spp., Patersonia spp.* and *X. preissii.* The predicted impact of *P. cinnamomi* is extremely high in the Banksia overstorey and moderate to high in the understorey.

Disease distribution and impact
There are infestations in the Banksia woodland north and south of Tick Road. The northern infestation is on the boundary of the plantation and approximately 150 metres long by 30 metres wide. The southern infestation is approximately 50 metres in diameter. It is probable that inoculum was introduced during establishment of the plantation. Disease impact is extremely high in the Banksia overstorey and moderate in the understorey.

Site disturbance and potential inoculum vectors
The remnant Banksia woodland is relatively undisturbed and was assessable. The remaining area (approximately 98%) has been cleared of susceptible species and is not assessable. There has been considerable potential for inoculum vectoring through plantation activities such as clearing, roading and harvesting.

Comparison to 1996 assessment
The remnant Banksia woodland and associated infestation were not mapped in 1996.

Site 14. Trainor Road

From analysis of the text and map within Water and Rivers Commission. Lexia Area. Dieback (Hart, Simpson & Associates, 1996), the monitoring site was determined to be the road easement and vegetation adjacent to Trainor Road between Centre Way and Gaskel Avenue. The site includes two segments of remnant native vegetation south of Trainor Road between the Barlow Lane intersection and Euro Road intersection.

Vegetation associations
Trainor Road and the associated easement is within plantation and is uninterpretable due to the lack of susceptible species. There is approximately six hectares of remnant native vegetation south of the Barlow Lane intersection, consisting of a Jarrah, Marri tall woodland over *B. attenuata, Banksia grandis, B. menziesii* and *N. floribunda.* Encompassed within the woodland is a segment of wetland vegetation of open Paperbark

woodland over sedges. The predicted impact of *P. cinnamomi* is moderate in the Jarrah/ Marri overstorey, extremely high in the Banksia understorey and negligible in the wetland vegetation.

There is approximately three hectares of remnant Banksia woodland west of Nursery Road consisting of a *B. attenuata, B. menziesii* woodland with occasional *B. grandis* and *B. ilicifolia* over *Hibbertia spp., Patersonia spp.,* Tea Tree and *X. preissii.* The plantation extends through the Banksia woodland, with many mature pine trees through out the area. The predicted impact of *P. cinnamomi* is extremely high in the Banksia understorey and moderate to high in the understorey.

Disease distribution and impact

There is an infestation in the Jarrah/Marri woodland adjacent to the Trainor Road/Barlow Lane intersection. The infestation is semi circular (adjacent to uninterpretable) and approximately 40 metres in diameter, suggesting a point source of inoculum approximately 20 years ago. Disease impact is extremely high in the Banksia understorey.

Site disturbance and potential inoculum vectors

The Jarrah/Marri woodland is relatively undisturbed and was assessable. The Banksia woodland under plantation species was relatively intact and assessable. The remaining area of the monitoring site has been cleared of susceptible species and is not assessable. There are tracks both on the perimeter and within the remnant vegetation areas that present potential inoculum vectors. There has been considerable potential for inoculum vectoring through plantation activities such as clearing, planting and roading.

Comparison to 1996 assessment

The remnant native vegetation segments were not mapped in their entirety in 1996. The infestation adjacent to the Trainor Road/Barlow Lane intersection was not detected 1996.

Site 15. Bentley Road, Gaskel Avenue and Wetherell Road

It was not possible to determine the monitoring site boundary from analysis of the text and map within Water and Rivers Commission. Lexia Area. Dieback (Hart, Simpson & Associates, 1996). The boundary for this assessment (that may match the original perimeter) is the survey boundary from Tick Road to Trainor Road, the survey boundary from Trainor Road to Gaskel Avenue, the survey boundary from Gaskel Avenue to Wetherell Road, the survey boundary from Wetherell Road to the unnamed track at AMG coordinates 401 100mE 6 485 300mN, the unnamed track to a point due east of Tick Road, from this point to Tick Road.

There is a segment of native vegetation west of the monitoring site that was not assessed in 1996 or during this survey.

Vegetation associations

The monitoring site is approximately 300 hectares in size and consists of Banksia woodland on undulating sandy rises with one wetland. Approximately half of the site has been cleared of native vegetation for sand mining or plantation.

The vegetation association on undulating sandy rises is a *B. attenuata, B. menziesii* woodland with occasional *B. ilicifolia, N. floribunda* and Jarrah over *A. cygnorum, Hibbertia spp., Patersonia spp.* and *X. preissii*. The predicted impact of *P. cinnamomi* is extremely high in the Banksia overstorey and moderate to very high in the understorey.

The wetland is bisected by the northern extension of Gaskel Avenue and consists of open sedgelands fringed by an open Paperbark woodland with occasional *E. rudis* over *A. cygnorum, Patersonia spp.*, Tea Tree and *X. preissii*. The predicted impact of *P. cinnamomi* is low.

Disease distribution and impact

There are two infestations within the underground gas pipeline easement north of Bentley Road. The southern infestation is rectangular in shape and approximately 300 metres long by 30 metres wide. It is probable that the infestation extended further to the east prior to the area being cleared and mined. The northern infestation is rectangular in shape and approximately 600 metres long by 50 to 80 metres wide. The location, shape and size of the infestations suggests inoculum was introduced along the easement 25 to 40 years ago. Disease impact is extremely high in the Banksia overstorey and high in the understorey.

There is an infestation 70 metres west of Walton Road and 300 metres south of Tick Road. The infestation is oval in shape and approximately 120 metres long by 70 metres wide, suggesting inoculum was introduced along a transect approximately 35 years ago. Disease impact is extremely high in the Banksia overstorey and moderate in the understorey

There are three infestations north of Bentley Road adjacent to the northern extension of Gaskel Avenue. The infestations are semicircular or oval in shape and 60 metres to 100 metres in diameter. The two northern infestations have been partially cleared by the road construction. The size and shape of the infestations suggest inoculum was introduced 30 to 50 years ago. Impact is extremely high in the Banksia overstorey and moderate to high in the understorey within all infestations.

There is an infestation 200 metres south of Bentley Road that has been bisected by northern extension of Gaskel Avenue. The infestation is in Banksia woodland on the northern perimeter of the wetland and evidence indicates that the wetland is partially infested. The lack of symptoms in Banksia woodland fringing the western and eastern perimeter of the wetland indicates that the wetland is not completely infested. It was not possible to determine the size of the infestation and it is probable that it has been present for many decades. Disease impact is extremely high in the Banksia overstorey and moderate in the understorey, and negligible in the wetland vegetation.

There is an infestation 120 metres to the east of the infestation described above in Banksia woodland. The infestation is circular and approximately 80 metres in diameter, suggesting a point source of inoculum approximately 40 years ago. Disease impact is extremely high in the Banksia overstorey and high in the understorey.

There is an infestation north of Machado Road at AMG coordinates 399 500mE 6 482 650mN. The infestation is circular and approximately 40 metres in diameter, suggesting a point source of inoculum approximately 20 years ago. Disease impact is very high in the Banksia overstorey and low in the understorey.

There is an infestation south of Machado Road at AMG coordinates 399 400mE 6 482 150mN. The infestation is in remnant Banksia woodland surrounded by cleared uninterpretable areas and it was not possible to determine the extent of the infestation. Disease impact is extremely high in the Banksia overstorey and high in the understorey.

Site disturbance and potential inoculum vectors

Approximately half of the site has been cleared of native vegetation for sand mining or plantation and could not be assessed due to the lack of susceptible species. There has been considerable road works associated with the Gaskel Road northern extension and eastern section of Tick Road. The Gaskel Road northern extension crosses four infestations and it is not known if the extensive road works were completed hygienically.

During the survey, a large water main was being installed along the eastern side of Gaskel Road to Tick Road. The operation involved considerable soil movement through infested and uninfested areas with no apparent hygiene.

There has been considerable potential for inoculum vectoring through plantation activities such as clearing, planting and roading, and vehicle use of tracks and roads.

Comparison to 1996 assessment

The disease distribution within the underground gas pipeline easement, Saint Patrick Road and Gaskel Avenue vary significantly between the 1996 map and current map.

Site 16. Dowdell property, Gnangara Road

From analysis of the text and map within Water and Rivers Commission. Lexia Area. Dieback (Hart, Simpson & Associates, 1996), the monitoring site was determined to be Lake Yakine at the intersection of Gnangara Road and West Swan Road.

Vegetation associations

The majority of the site is inundated or has been cleared of native vegetation. There are segments of remnant wetland vegetation fringing Lake Yakine consisting of an *E. rudis*, Paperbark woodland over *Melaleuca spp, Pteridium esculentum* (Bracken fern) and

sedges.

There is a small segment of Banksia woodland north of the site consisting of a *B. attenuata* woodland with occasional Marri over Bracken fern and *X. preissii*. The predicted impact of *P. cinnamomi* is etremely high in the Banksia overstorey and low in the understorey.

Disease distribution and impact
The site is uninterpretable due to a lack of susceptible species. The Banksia woodland north of the site was not displaying symptoms of infestation.

Site disturbance and potential inoculum vectors
The monitoring site is in private property and has been predominantly cleared of native vegetation, which has been replaced with annual grasses. There are tracks within the site that present possible inoculum vector that may result in cryptic infection.

Comparison to 1996 assessment
The site was mapped as uninterpretable in 1996.

6. DISCUSSION

The principle aims of *Phytophthora* management are to minimise the risk of increasing the occurrence of disease through vectored inoculum spread, and to minimise the impact of existing infections (Shearer and Tippett, 1989). The following discussion illustrates the issues that have been considered in analysing these risks and the potential impact of vectored and autonomous spread of disease within the survey area.

6.1 Estimations of the age of infestations and mode of inoculum vectoring

It was possible to make estimations of the time and mode of inoculum vectoring in existing infestations based on the size and shape of the infestation. Within infested Banksia woodlands on elevated sandy rises, the current rate of autonomous disease spread is approximately one metre per annum. This was determine by observation of the decay of Banksia stags (dead trees) and their position in relation to the active disease front. Rates of disease spread in Banksia woodland adjacent to wetlands were more rapid and as high as 10 metres per annum.

There is a significant range of rates of mycelium spread in Banksia roots from as low as 20 centimetres per annum to several metres per annum (Shea & Dillon, 1980). The rate of autonomous disease spread is dependent on soil type, geology, vegetation structure, soil moisture and temperature. It is possible that the rate of spread may have varied in the past with fluctuations in soil moisture and temperature. Based on experience and field

observations of the infestations, it is probable that the rate of spread on elevated sandy rises has been relatively constant at one metre per annum.

From the initial point of inoculum introduction, *P. cinnamomi* propagates through mycelium spread in susceptible species roots and under certain climatic conditions will produce motile spores (Zoospores). The relatively uniform distribution of Banksias and vertical drainage within the sandy soils results in a continuous disease front with consistent rates of spread in all directions. Infestations that are circular in shape indicate inoculum was introduced at a central point and the disease has propagated equally in all directions. Infestations that are oval or rectangular in shape indicate that there has been multiple points of inoculum introduction along a transect.

6.2 Disease distribution and inoculum vectoring

From the disease distribution mapped during this survey, estimations have been made about the time and mode of past inoculum vectoring and the potential for future vectoring.

The majority of infestations are adjacent to roads, tracks, gas pipeline easements, powerline easements and plantations. The size of the infestations indicates inoculum vectoring occurred decades ago and was probably associated with the initial establishment of the road, easement or plantation. High-risk activities such as importation of soils and use of soil moving machinery would have taken place.

There are isolated infestations in Banksia woodland with no evidence of the inoculum vector. The isolated infestations have been present for at least 25 years and it is probable that the inoculum vector has been obscured by time. It is possible that inoculum may have been vectored during wild fire control by soil moving machinery and use of water from infested wetlands/soaks.

All detected infestations have been present for at least 20 years, with no infestations less than 40 meters in diameter. During the survey, isolated and scattered deaths in susceptible species adjacent to roads and tracks were sampled to determine if new infestations are being established. All eight samples returned a negative result. Evidence indicates that vehicle use of the roads and tracks is not resulting in the establishment of infestations.

As there is regular vehicle access without hygiene constraint, it is probable that there is soil movement during moist soil conditions. The reasons for inoculum not being viably vectored to uninfested areas are beyond the scope of this report, but may include low levels of inoculum in infested soils, the type of inoculum (mycelium, zoospores, chlamydospores), low levels of infested soil movement, no survival of vectored inoculum, or a combination of these factors.

6.3 Predicted impact of autonomous disease spread and inoculum vectoring

The Banksia woodland vegetation associations that occupy the majority of the survey area are extremely susceptible to *P. cinnamomi*. Infestations are displaying extremely high impact, with total loss of the Banksia overstorey and moderate to very high impact in the understorey. Many Banksias are keystone species (Shearer, Wills & Stukely, 1991), providing a food source for insects, birds and mammals. The loss of these keystone species will have a negative impact on the populations of dependent animal species as well as the aesthetic and intrinsic values of the native plant community.

P. cinnamomi is spreading autonomously in the Banksia woodlands at a rate of approximately one metre per year. With more than 20 kilometres of active disease front within the survey area, over two hectares will be infested each year. This annual rate of infestation will increase as the perimeter of infestations increases. The autonomous spread of *P. cinnamomi* can be reduced with the application of phosphorous acid (a cheap, biodegradable and non-toxic chemical) that has been found to be very effective as both a curative and protectant against *P. cinnamomi* in a range of susceptible hosts (Kormorek, Shearer, Smith & Fairman, 1997).

There is no evidence of infestation due to inoculum vectoring within the last twenty years. It is possible that there may be cryptic infestation from inoculum vectoring in the recent past, although sample evidence suggests that this is unlikely. Activities with a demonstrated high risk of viable inoculum vectoring are occurring within the survey area. The construction of the Gaskel Road northern extension, scrub clearing within powerline easements, construction of the water main from Tick Road, and road maintenance are examples of recent high risk activities.

6.4 Variations in disease distribution between this survey and the 1996 survey

There are variations in the size, shape and locations of infestations mapped by Heart, Simpson and Associates in 1996 and infestations mapped during this survey. The variations are attributed to the different methods of mapping used and not to autonomous disease spread or inoculum vectoring. The scale of the maps and the variations due to mapping techniques does not allow calculation of the rate of autonomous disease spread. Disease fronts were not demarcated in the field during the 1996 survey, resulting in an absence of a point of reference for calculation of autonomous disease spread.

A total of 16 infestations were detected during this survey that were not detected in 1996. The infestations have been present for several decades and have not been established since the 1996 survey. The infestations are adjacent to roads and tracks and the reason for them not being detected is unknown.

An infestation was mapped on the northern boundary of monitoring site 12 in 1996 that has now been mapped as uninfested. The site was sampled in 1996 and again during this survey, returning a negative result both times. The symptoms are not consistent with *P.*

cinnamomi infestation and are more consistent with *Armillaria luteobubalina* (discrete and discontinuous). There were traces of macroscopic mycelium within stem and root cambium of affected plants, but identification was not conclusive.

6.5 Variations in interpretation of results between this survey and the 1996 survey

There are significant differences in the interpretation of results from the two surveys. Water and Rivers Commission. Lexia Area. Dieback (p15, Hart, Simpson & Associates, 1996) states that "Most of the area is extremely or highly vulnerable to infection because of the unrestricted public access, off road vehicle use, rubbish dumping, firebreak maintenance and other activities", " It is clear that there is enormous potential for the existing infections to be disseminated", and that there is "Clearly a need for rigorous (hygiene) measures to be adopted by the (Water and Rivers) Commission".

This does not correlate with the results of the 1996 survey or this survey. There is no evidence to indicate that unrestricted public access, off road vehicle use, rubbish dumping, or firebreak maintenance have resulted in the establishment of infestations within the past 20 years. Evidence indicates that the infestations were caused by higher risk activities more than 20 years ago.

There is no demonstrated need for rigorous hygiene measures to be adopted by the Water and Rivers Commission for bore monitoring. Activities with a high potential for soil movement such as bore establishment, installation of water mains or development of access tracks will require hygiene measures in uninfested areas.

7. RECOMMENDATIONS FOR MANAGEMENT

It is recommended that a protocol is introduced to reduce the possibility of vectored inoculum spread to uninfested areas during bore monitoring. It is evident that the risk is very low and the resources commitment should be commensurate. The proposed protocol is:

- Monitoring vehicles should be free of soil from outside the survey area. This may involve a wash down at the depot prior to departure.
- During dry periods of no soil movement, there is no further hygiene requirement.
- During wet periods when soil is adhering to tyres and vehicle underbodies, uninfested sites should be visited first, followed by infested and uninterpretable sites. If this is not practical, the best compromise should be implemented (ie. visit most of the uninfested sites first).
- When travelling between uninfested sites during wet periods, avoid traversing infestations with a high potential for soil adhesion (ie. infested wetlands).

It is recommended that activities with a higher risk of viable inoculum vectoring such as bore establishment, road construction and water mains construction are assessed individually. The assessment should include:

- Mapping and field demarcation of disease distribution within the operational area.
- Determination of the areas at risk, based on vegetation structure and the CALM "Protectable Areas" protocol.
- Development of hygiene procedures to prevent infested soil and plant material being introduced to protectable areas.
- A post operational survey to determine the effectiveness of operational hygiene.

It is recommended that the viability of a strategic phosphorous acid application program is investigated. Such a program could have input from agencies with interests in the survey area such as Alinta Gas, CALM, Water and Rivers Commission, Western Power Corporation and community interest groups.

8. REFERENCES

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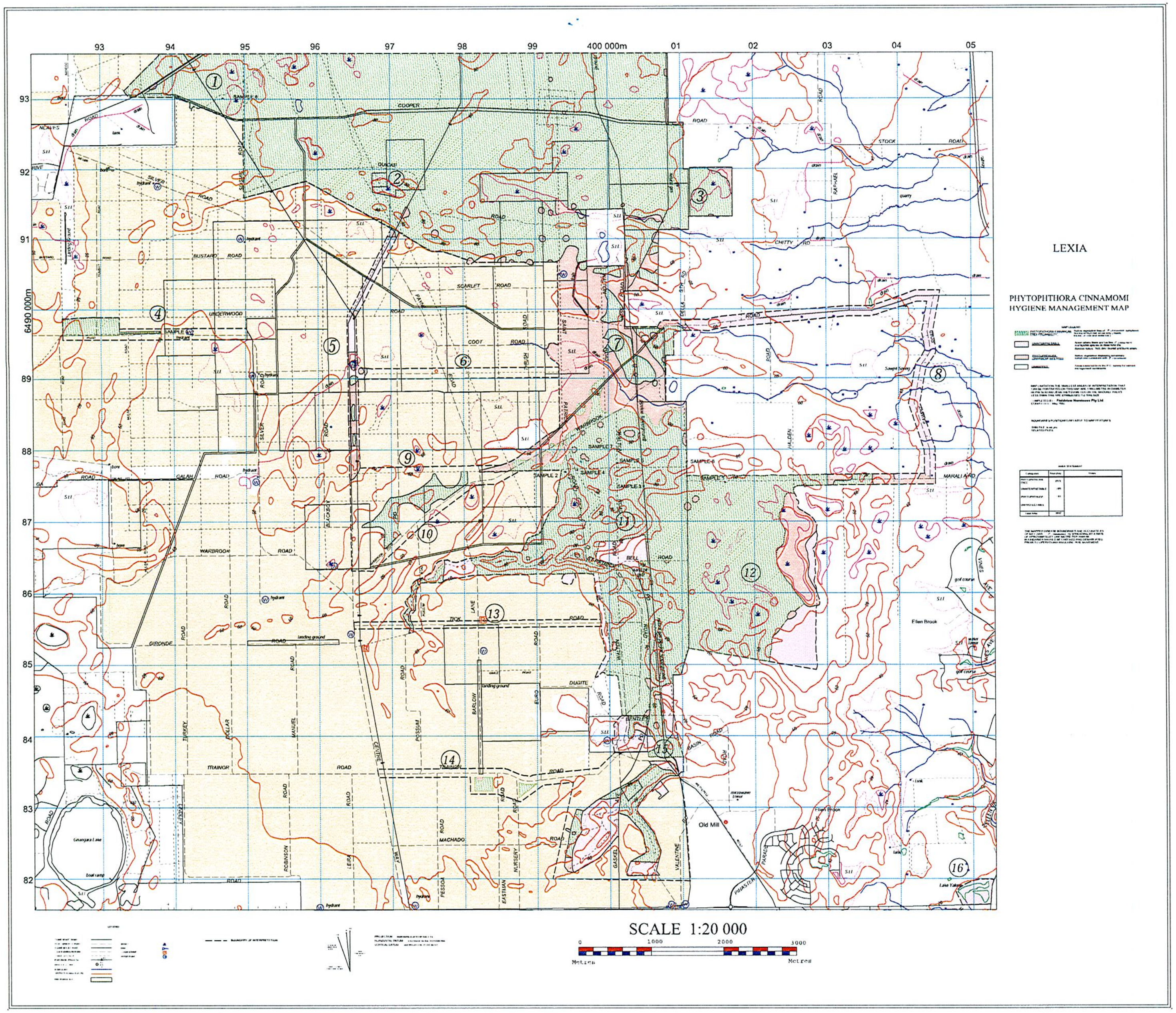

LEXIA
PHYTOPHTHORA CINNAMOMI
HYGIENE MANAGEMENT MAP
SCALE 1:20 000
Metres
400 000m
6490 000m
COOPER
ROAD
STOCK
CHITTY
SCARLETT
UNDERWOOD
RUSTARD
COOT
GALAH
WARBROOK
GIRONDE
TICK
LANE
BARLOW
DUGITE
TRAINOR
MACHADO
PESSOA
NURSERY
EASTIAN
ROBINSON
VALENTINE
MAHALI
Ellen Brook
Old Mill
Lake Yakine
Gnangara Lake
landing ground
hydrant
SAMPLE 1
SAMPLE 2
SAMPLE 4
SAMPLE 5