BEST PRACTICE GUIDELINES

Management of *Phytophthora* Dieback in Extractive Industries

Dieback
WORKING GROUP

Foreword

The death of thousands of different native plants caused by the introduced pathogen, *Phytophthora cinnamomi*, is devastating Western Australia's valuable bushland and has the potential to make a number of rare plant species become extinct. The spread of *Phytophthora* Dieback in native vegetation is a biological disaster of global significance and a major problem for the Extractive Industry. It is also a significant problem in horticulture, forestry, mining, nurseries, domestic gardens, nature recreation and tourism based industries.

Phytophthora Dieback is readily spread through the use of infected soil, sand and gravel during construction activities. The Extractive Industry can positively influence the rate of spread of *Phytophthora* Dieback by taking steps to minimise its role in acting as a vector for the transfer of the pathogen. The process of extracting basic raw materials requires the movement of large volumes of soil and pathogen transfer may occur both on-site (e.g. during extraction operations) and off-site (eg during transportation of materials won).

Since its establishment the Dieback Working Group has worked very hard to show that 'combating dieback is not a lost cause'. The disease is widespread in the south-west of the State but there are large areas of bushland known to be free of the disease. By implementing simple and effective management procedures the spread to dieback-free areas can be greatly curtailed. In my involvement with the bauxite mining industry – where 6 million cubic metres of soil are moved a year – I have seen that simple management procedures can be effective. I am confident that the adoption of the guidelines in this document by the Extractive Industry will be similarly effective.

These guidelines are a show of commitment by the Extractive Industry to manage *Phytophthora* Dieback. The publication is intended to be advisory, educational and encourage a strong environmental ethic within industry. It is not intended to be regulatory or encroach on any other areas of legislative responsibility.

The guidelines have been prepared collaboratively with the help of the industry, the Dieback Working Group and Chamber of Commerce and Industry of Western Australia. In preparing these guidelines I believe the Extractive Industry recognises the vital role that it plays in managing *Phytophthora* Dieback through both on-site and off-site activities.

I commend this publication to you and would like to thank those involved in its production.

Dr Ian Colquhoun
Chair
Dieback Working Group

Natural Heritage Trust
Helping Communities Helping Australia
An Australian Government Initiative

CCI
CHAMBER OF COMMERCE
AND INDUSTRY
WESTERN AUSTRALIA

Extractive Industries Committee

shire of kalamunda

The Dieback Working Group

Background

The Dieback Working Group was formed in 1996 by local government authorities in the Perth metropolitan area, community groups and state government agencies concerned with the management of *Phytophthora* dieback. In 1998, the group obtained funding from the Natural Heritage Trust to appoint a project coordinator. The role of this coordinator was to facilitate the adoption of this policy document within local government, and to raise awareness of dieback within local government and the wider community.

Since its formation, the Dieback Working Group has sought to:

- increase awareness and understanding about *Phytophthora* dieback,
- encourage the adoption of *Phytophthora* dieback prevention and management policies, and
- encourage the implementation of management procedures to minimise the spread and impact of the fungus.

Membership

City of Armadale
City of Bunbury
City of Canning
City of Cockburn
City of Fremantle
City of Gosnells
City of Joondalup
City of Nedlands
City of Melville
City of South Perth
City of Stirling
City of Swan
City of Wanneroo
Shire of Capel
Shire of Busselton
Shire of Bridgetown-Greenbushes
Shire of Denmark
Shire of Esperance
Shire of Kalamunda
Shire of Mundaring
Shire of Serpentine Jarrahdale
Town of Kwinana
Eastern Metropolitan Regional Council
Centre for Phytophthora Science & Management
Department of Conservation & Land Management
Department of Environmental Protection
Department of Land Information
Department of Planning and Infrastructure
Conservation Council
Friends of Ellis Brook Valley
Roleystone Dieback Action Group

Acknowledgments

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1. Introduction

1.1 Background

The impact of the plant pathogen *Phytophthora cinnamomi* is a significant and serious environmental problem in native plant communities in Western Australia (WA). The pathogen has the capacity to invade and destroy the root systems of a vast array of plants. The slow moving epidemic of destructive root disease caused by the pathogen in native vegetation in Australia is often referred to as dieback (CALM, 2000).

Activities involved in moving soil (e.g. road construction and forestry) are thought to have contributed to the rapid spread and wide distribution of *Phytophthora* Dieback in WA resulting in a mosaic of infested and uninfested bushland. However, without any human vectors, the pathogen will continue to invade new areas through autonomous spread from all its established disease fronts.

The spread of *Phytophthora* Dieback is best managed through control of human-vectoring and strategic applications of a systemic fungicide known as phosphite. Control of human vectors can be achieved by applying rigorous hygiene practices (CALM, 2000).

1.2 Purpose of the Manual

This manual provides the Extractive Industry with a single source document on:

- Information about the pathogen *Phytophthora cinnamomi* and diseases it causes.
- The objectives for the management of *Phytophthora* Dieback by operators involved in the extractive industry.
- Best practice management guidelines for the extraction and transport of basic raw materials.
- Information relating to staff training and management.
- Contacts for further information.

2. Terminology

2.1 Glossary of Common Words

Basic raw materials

Sand (including silica sand), clay, hard rock, limestone and gravel, and other construction or road building materials.

Disease

The combinations of pathogen, host and correct environmental conditions that result in disease symptoms or death of a host.

Environment

The sum of all external factors which act on an individual organism during its lifetime.

Extractive process

The process used to remove basic raw materials, including transportation of the product to the consumer.

Extractive industries

For this purpose of this document 'extractive industries' is defined as, those operations participating in the recovery or processing of low value commodities, often construction materials, such as crushed rock aggregates, road bases, sands, clays and dimension stones.

Host

The plant which is invaded by a pathogen and from which the pathogen derives its energy.

Hyphae

A singular tubular filament of a fungus. The hyphae together comprise the mycelia.

Infested areas

Areas that an accredited interpreter has determined have plant disease symptoms consistent with the presence of the pathogen *P. cinnamomi* or areas where *P. cinnamomi* has been isolated.

Pathogen

Any organism or factor causing disease within a host plant.

***Phytophthora* Dieback occurrence map**

This is the main map produced by interpreters. It shows *P. cinnamomi* occurrence, *P. cinnamomi* free areas, uninterpretable areas, and may show unprotectable areas.

***Phytophthora* Dieback hygiene plan**

The document that describes how human access to uninfested areas is to be managed, so that the role of humans as vectors in establishing new centres of infestation will be reduced to the lowest possible level.

***Phytophthora* species**

Eight different *Phytophthora* species are known to occur in Western Australia, these include: *P. cinnamomi*, *P. citricola*, *P. megasperma var. megasperma*, *P. megasperma var. sojae*, *P. drechsleri*, *P. cryptogea*, *P. nicotianae var. nicotianae*, *P. nicotianae var. parasitica* and *P. cactorum*. *P. cinnamomi* is by far the post pathogenic and widespread.

Uninfested areas

Areas that an accredited interpreter has determined to be free of plant disease symptoms thereby indicating the absence of the pathogen, *P. cinnamomi*.

Uninterpretable

Indicator plants are absent or too few to determine the presence or absence of disease caused by *P. cinnamomi*.

3. The Biology of *Phytophthora cinnamomi*

The common names of 'Dieback' and 'Jarrah Dieback' have contributed to a number of misconceptions about the pathogen. For example, there are many other causes of plant decline, such as water table related issues, chemical drift, insect attack and other fungal pathogens. In the eastern states plant death attributed to these other causes is often also termed 'Dieback'. For these reasons the disease caused by *Phytophthora cinnamomi* will be referred to as *Phytophthora* Dieback.

The information contained below has been adapted from CALM (2000).

3.1 Description of *Phytophthora cinnamomi*

P. cinnamomi is a soil-borne pathogen that kills a wide range of plant species in the southwest of WA by destroying their root systems. There are over fifty species *Phytophthora* that occur worldwide. Although all *Phytophthora* species can cause plant disease, *P. cinnamomi* is the most frequently isolated *Phytophthora* species from natural plant communities in WA.

There are another seven *Phytophthora* species that have been isolated in southwest WA. These include: *P. citricola*, *P. megasperma var. megasperma*, *P. megasperma var. sojae*, *P. drechsleri*, *P. cryptogea*, *P. nicotianae var. nicotianae*, *P. nicotianae var. parasitica* and *P. cactorum*. *P. citricola* is the second most common species, however, it only appears to be destructive under certain circumstances. *P. megasperma var. megasperma* is common in the northern sandplains and the south east region of WA. Other species, such as *P. nicotianae*, *P. drechsleri* and *P. cactorum* are only commonly found in nurseries.

For the purpose of this document the plant disease *Phytophthora* Dieback will be used to describe the disease caused by *P. cinnamomi*. However, much of the biology and management principles discussed are also applicable to these other *Phytophthora* species.

P. cinnamomi causes disease in a range of vegetation communities through out the southwest of WA and affects a diverse range of plants. It has a wide distribution in areas with an annual rainfall above 500 mm in the southwest of WA *(Figure 3.1)*. The pathogen will only cause disease in areas with 400-500 mm rainfall in water accumulating sites. Native plant communities particularly at risk from *P. cinnamomi* include those dominated with Banksia species and other Proteaceae.

It is estimated that more than 2000 species of plants may be affected by *P. cinnamomi* in WA (Wills 1993, Wills and Keighery 1994, Shearer *et al.* 2004). Most species affected belong to four families – Proteaceae, Epacridaceae, Papilionaceae/Fabaceae and Myrtaceae. It is important to note that not all genera within a family are susceptible to the pathogen. The pathogen can also survive and reproduce on some plant species without killing them.

P. cinnamomi grows vegetatively through the infected plant tissue as microscopic-sized filaments called hyphae, which when together in a larger mass are known as mycelia. The pathogen consumes plant tissues causing lesions (areas that appear rotten) in the root system or lower stem. This weakens or kills the host plant by reducing or stopping the movement of water and nutrients within the plant. Once attacked, susceptible plants rarely recover – most succumb to a 'sudden death' syndrome rather than a 'dying-back or dieback' syndrome.

Figure 3.1 *Phytophthora cinnamomi is commonly recovered from areas in the southwest of Western Australia with greater than 400mm rainfall. Source: CALM.*

3.2 Life Cycle

The life cycle of *P. cinnamomi (Figure. 3.2)* depends on moist conditions that favour survival, sporulation and dispersal of the pathogen. The highest levels of the pathogen occur within soils after significant rainfall (greater than 5-10 mm) and remain at high levels for a significant period of time. The exact period of time is unclear and is dependant on a number of variables including soil type, presence of vegetation and temperature.

The pathogen extracts its food from living plant tissue because it is incapable of photosynthesis. Extraction of food is completed by the mycelia, which form the body of the organism and grow through the host tissue. Mycelia will continue to grow in the host tissue when the moisture content is greater than 80%. The transfer of mycelia or diseased plant tissue from one area to another during favourable environmental conditions can start a new infestation.

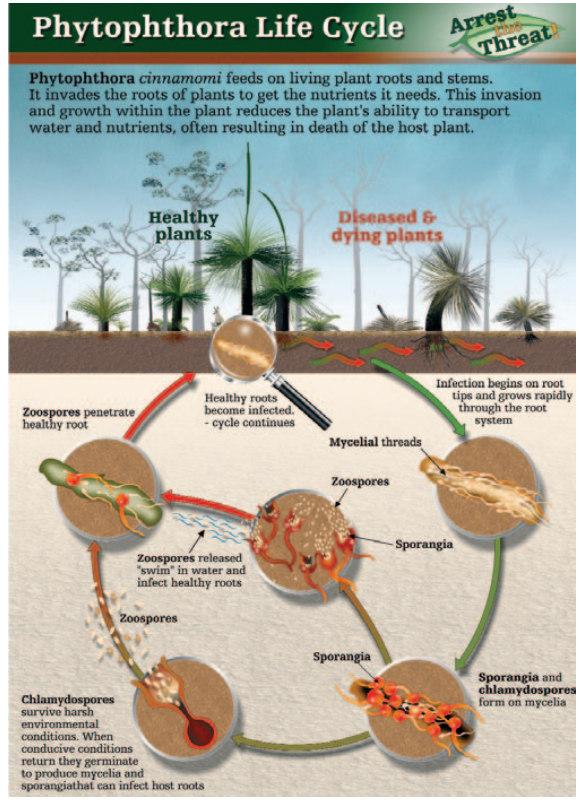


Figure 3.2 *Generalised lifecycle of Phytophthora cinnamomi.*

After infection the pathogen invades root bark and forms lesions that may extend in to the plant's stem collar.

3.2.1 Reproduction

Under ideal environmental conditions, *P. cinnamomi* reproduces vegetatively. It is also capable of producing millions of tiny spores that reproduce the fungus. Two kinds of spores are likely to be found, zoospores and chlamydospores.

3.2.2 Zoospores

These are very small spores that can actively swim short distances using a 'whip-like' tail called a flagellum seeking new hosts to infect. Zoospores are fragile and short-lived and are produced in large numbers under favourable conditions. They can be carried in water over large distances.

3.2.3 Chlamydospores

Chlamydospores are larger than zoospores and are also much tougher and long-lived (within dead plants and soil). They are produced under unfavourable conditions and are the resistant resting phase of *P. cinnamomi*. They can be transported in soil or roots and then germinate to cause a new infection when exposed to favourable conditions. They germinate to produce mycelia and zoospores.

3.3 Disease Triangle

Expression of disease symptoms requires an interaction between the pathogen, host and environment. The absence of one of these factors means that the disease cannot exist at the site *(Figure 3.3)*.

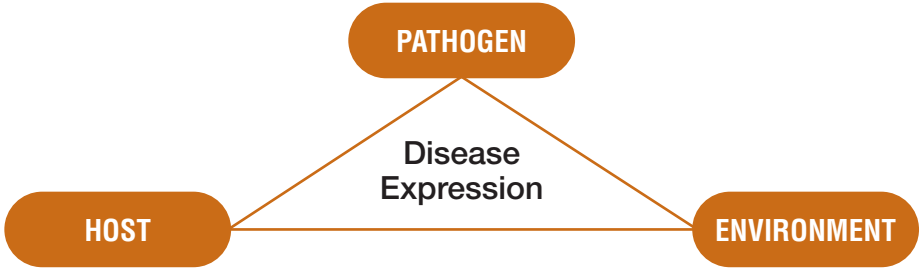


Figure 3.3. *Disease triangle illustrating relationship between pathogen, host and environment.*

4. History of *Phytophthora* Dieback in Western Australia

4.1 History

It is believed that *Phytophthora cinnamomi* was introduced to WA around the time of European settlement in soil around the roots of cultivated plants. In the absence of quarantine measures the importation of exotic soil and plant products would have occurred numerous times at many points around Australia (CALM, 2000).

The first noted observations of the impact associated with *P. cinnamomi* were made in 1921 in the Perth Hills district where increasing number of patches of healthy Jarrah forest were dying. The cause of these plant deaths was the subject of much speculation. It wasn't until 1964 that it was established that *P. cinnamomi* was the agent responsible for these plant deaths in the Jarrah forest.

4.2 Spread

Autonomous spread of the pathogen is generally slow and is achieved through movement of the pathogen along plant root systems. Faster autonomous spread is accomplished through the movement of microscopic spores in surface and sub-surface water flows, and by animals. Autonomous spread up slope and on flat ground is relatively slow (approximately 1m per year) (Shea *et al.* 1983).

Human-related vectors can disperse the pathogen much more quickly and are believed to be the primary reason for the widespread distribution of the pathogen in WA. Any activity that transfers soil and plant material from one location to another is a potential vector. Road construction, earth moving, stock movement, revegetation and four-wheel driving are some examples of activities that can contribute to the spread of the pathogen.

5. Impact of *Phytophthora* Dieback

5.1 Impact

Phytophthora Dieback has had a significant impact on the biodiversity of native plants and animals from WA. Furthermore, the pathogen has had a significant effect on the nursery, horticultural, mining, floricultural and forestry industries in WA.

5.1.1 Biodiversity

Over 2,000 native plant species are susceptible to *P. cinnamomi* in WA. Although significant, the costs of these plant losses to society are difficult to quantify (Wills 1993, Wills and Keighery 1994). According to CALM (2003), a conservative estimate places approximately 15-20% of the Jarrah forest as infected by *P. cinnamomi*. Furthermore, approximately 60% of the shrubland, Banksia woodland and mallee woodland in the Stirling Range National Park are infected by the pathogen. Similarly, 70% of the Shannon and D'Entrecasteaux National Parks are also affected by *P. cinnamomi*.

P. cinnamomi has the potential to significantly alter the structure of various vegetation communities. It has been demonstrated that by altering the structure of vegetation communities, *Phytophthora* Dieback also affects the native fauna that is dependent on the vegetation for habitat and food.

5.1.2 Industry

Plant death from *P. cinnamomi* is not restricted to native plant species. The nursery industry suffers significant losses as a result of *P. cinnamomi*. Horticultural crops such as apricot, peach, kiwi fruit, avocado, pineapple, walnut, chestnut, proteas and macadamia nut are all susceptible to *P. cinnamomi* (Cahill, 1993; Erwin & Ribeiro, 1996). Many ornamental and garden plants are susceptible to *P. cinnamomi*, including Roses, Camellias, Azaleas and Rhododendrons (Erwin & Ribeiro, 1996).

The pathogen is a significant cost to the mining of bauxite and mineral sands in WA. In addition, the forestry and tourism industries are also affected. Hardham (2003) estimated that *P. cinnamomi* causes economic losses in the vicinity of $200 million per annum.

6. Detection and Diagnosis

6.1 Detection and Diagnosis of Phytophthora Dieback

Accredited dieback interpreters are used to determine the presence and distribution of *Phytophthora* Dieback at a site. They undertake a comprehensive survey of the site noting plant deaths and any patterns associated with these deaths. During the assessment of proposed Extractive Industry sites it is important to determine the presence of the pathogen within the quarry area and within areas that haulage/access roads are planned to transect.

A *Phytophthora* survey involves observing the following:

- Death of a plant species that are susceptible to *P. cinnamomi* (indicator species).
- Total deaths – *P. cinnamomi* kills plants completely and quickly.
- An age range in plant deaths, ie old and recent plant deaths.
- Death in a range of susceptible species.
- A vector for the introduction of the pathogen.
- Noting other factors that may have caused plant deaths (e.g. fire, drought, insect attack, other fungal pathogens).

An interpreter may also decide to take soil and tissue samples back to the laboratory to confirm their observations. A sample can be used to prove the presence or absence of *P. cinnamomi* at a site. It is important to note that a negative sample does not indicate that the pathogen is absent at a site, rather it means that the pathogen was not recovered from the sample. As a result of the survey and sample analysis, the subject site is then classified into three categories; these are:

1. Infested
2. Uninfested
3. Uninterpretable

Extreme care must be taken when sampling an extraction or stockpile site for the presence of *Phytophthora* Dieback. A study conducted Davison and Tay (2003) found that areas lacking native vegetation, such as stockpiles and areas cleared of natural vegetation, were very difficult in determining their disease free status. In many cases, the number of samples required to be statistically confident that the site is *Phytophthora* Dieback free was not economically feasible given a processing cost of $100 per sample. Therefore, if a company wishes to establish a new quarry that is to be certified as free of *Phytophthora* Dieback, a bushland site with sufficient vegetation coverage for interpretation would be essential.

6.2 Disease Syndromes

Four distinct disease syndromes have been recognised in the native plant communities from WA. The first two closely follow the advancing disease front of the pathogen, while the third, most clearly recognised in the Jarrah forest, is only expressed years later in the plant community that has replaced the original forest. It is important to understand that variable impact in native vegetation is common. Not all *P. cinnamomi* infestations are typified by tree 'graveyards'.

6.2.1 Syndrome 1

Most highly susceptible plant species are killed in heathlands, Banksia woodlands and in the understorey of a number of forest types, including the Jarrah forest. Disease progression is uniformly destructive of the most susceptible species, is relatively insensitive to site conditions where rainfall is greater than 800 mm and is usually clearly visible.

6.2.2 Syndrome 2

Generally restricted to Jarrah forest, this syndrome is characterised by the death of overstorey Jarrah trees. The extent and frequency of these deaths is highly variable, being sensitive to site conditions, particularly when they affect drainage on the site. There may be near complete mortality in overstorey and understorey plant species, commonly known as mass collapse, creating 'graveyards' of dead trees.

6.2.3 Syndrome 3

Where the Banksia understorey and most Jarrah trees have been long dead and the former forest has been replaced by woodland of resistant Marri *(Corymbia calophylla)* and Parrotbush *(Dryandra sessilis)*. At this stage *P. cinnamomi* behaves as an endemic (native) pathogen, attacking the Parrotbush in wet years, but with little or no obvious impact on the Marri.

6.2.4 Syndrome 4

No apparent disease at all. This applies to those areas of Karri *(Eucalyptus diversicolor)* and Wandoo *(Eucalyptus wandoo)* forest, which contain no floristic elements of the dry sclerophyll forest type and to plant communities on the Spearwood Dune System of the Swan Coastal Plain, and pedogenically related landscapes.

7. Western Australia's Basic Raw Materials Extractive Industry

7.1 Industry Overview

The quarry industry provides earth materials such as sand, gravel, crushed rock and clay (collectively these are termed basic raw materials) that are processed into raw material inputs for buildings and construction, road construction, agriculture and industrial processes.

Quarry operators range from large multi-national companies operating throughout Australia in metropolitan and regional areas to small family-owned quarries and municipal quarries servicing regional and local needs.

In Australia, about 400,000 tonnes of aggregates are required each day[1]. The quarry industry directly employs in excess of 7,000 people working in over 2,500 quarries. Approximately 25% of quarries produce about 75% of the total aggregates[2].

There are no accurate statistics for quarrying in WA. The WA State Government only compiles quarrying statistics for those quarries operating on mining tenements and does not include operations that occur on freehold land. Local governments administer extractive quarry licences for basic raw materials won from freehold land.

For a description on how development applications may be processed by local governments please see *Figure 7.1*. The recording of quarry output is sporadic and it is therefore difficult to determine the amount of raw materials quarries in WA. Accurate figures on the extractive industry from WA are a little difficult to find. However, the Quarrying Institute of Australia estimates that there are approximately 200 quarries in WA, employing about 800 people.

The Department of Industry and Resources (DoIR) (2003) estimated extraction on State Crown Land in the Swan region to be worth $20.5 million during 2003. *Table 7.1* outlines the different basic raw materials extracted during this time as described by the DoIR.

[1]Source: Australian Quarrying Institute, http://www.quarry.com.au/profile01.html
[2]Source: Australian Quarrying Institute, http://www.quarry.com.au/profile02.html

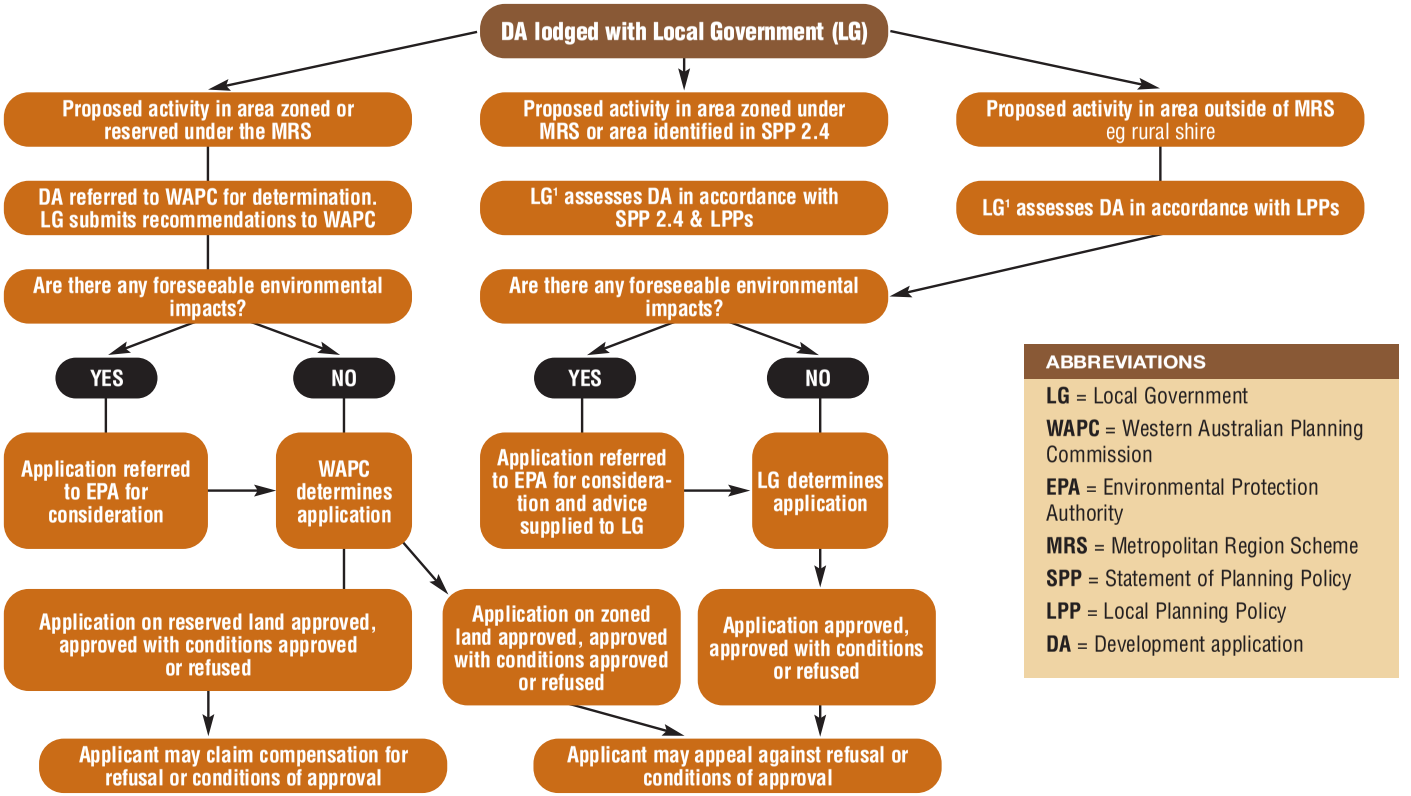


Figure 7.1. Process to assess development applications (DA) for the extractive industry. 1Local governments (LG) are required to refer DA to the Western Australian Planning Commission (WAPC) for land zoned or reserved in the MRS. Thanks to Nick Leong for his assistance (DPI).

Description	Production (million tonnes)	Production ($ million)
Limestone/lime sand	2.4	10.3
Sand	1.0	5.2
Silica Sands	0.4	4.4
Gravel and Sandstone	–	0.6
TOTAL	3.8	20.5

Table 7.1 *Value of production in Extractive Industries for the Swan region in Western Australia (Department of Industry and Resources, 2003).*

7.2 Extraction Methods

Although the different raw materials are extracted using different methods there are a number of similarities. Essentially, all extractive industry operations include the following stages:

1. **Surveying the site**

   Proposed sites are usually surveyed prior to excavation to determine the profitability of the site. The ratio of overburden to raw material is used as a guide of the profitability of the operation. Often this is achieved by removing samples or soil cores. Initial testing often comprises a series of drill holes 50-100 m apart. Vacuum rotary drills are often used so not to contaminate the sample. Hydrological, botanical & faunal surveys and environmental impact assessments may be conducted at this time.

2. **Clearing of site**

   Clearing to the site prior to excavation involves the removal of trees, shrubs, boulders and structures (usually with a bulldozer) allowing the excavation equipment easy access to the topsoil, overburden and raw material. A large number of extractive industries in WA operate on previously cleared pastoral or privately owned land and require minimal clearing prior to excavation. It is recommended that some form of useful disposal of wood from clearing be found, for example, lumber or mulch. Many operators use bunding or trees around the edge of the excavated area to reduce the visual impact, noise or dust problems resulting from the quarry. Logs, boulders, vegetation fragments should be removed with the intent on replacing them during the rehabilitation process to help provide seed sources and habitats.

3. **Stripping, Stockpiling and Excavation**

   Stripping operations are used to remove the topsoil and overburden to expose the raw material of interest. The topsoil is stockpiled on the side of the site for use later in the rehabilitation of the site. The waste overburden is usually placed away from the topsoil stockpile. The composition of the overburden varies significantly depending on the nature of the raw material being excavated. In many cases the overburden is used to create a bunding around the site of excavation. Once the overburden has been removed, excavation of the raw material can begin.

   The depth of excavation varies depending on the nature of the raw material being excavated. For example, hard rock can be taken from soil depths up to 100 m. In contrast, gravel and sand are usually taken from soil depths of 5-10 m. Quarrying is not allowed to extend within 2.5 m of the highest known water table in accordance with the requirements of the Water Corporation. Stripping, stockpiling and excavation are usually conducted using a variety of equipment, including scrapers, dozers, backhoes and loaders. The type of equipment used to extract the basic raw materials depends on the water table, amount of overburden and distance the overburden has to be transported. The excavation of some raw materials (e.g. hard rock) often requires controlled blasting.

4. **Processing of raw materials**

   Any processing of the raw materials is usually conducted on site. For example, hard rock (e.g. granite, basalt) is usually crushed on site and the aggregate graded into uniform sizes prior to being transported to the customer. Occasionally, sand and hard rock may be washed on site to remove contaminants, such as dust. Under some circumstances processing of raw materials (e.g. the production of lime) may occur off-site.

5. **Transporting**

   Due to the low value of the raw materials extracted from quarries the cost of transport can significantly impact on the profitability of the business. As such, many quarries are located close to major transport routes and the construction of haulage roads is often avoided.

6. **Site rehabilitation**

   After the excavation of the raw materials the stockpiled overburden is re-distributed by scrapers and dozers over the excavated area before the topsoil is replaced. Pit floors may be ripped if necessary to assist the infiltration of rainwater. The excavated area is then rehabilitated to the standard stipulated by the landowners (private owners, local government). The rehabilitation process may occur in stages or all at once, depending on the size of the quarry and the period of extraction.

7.3 Scope for Managing *Phytophthora* Dieback

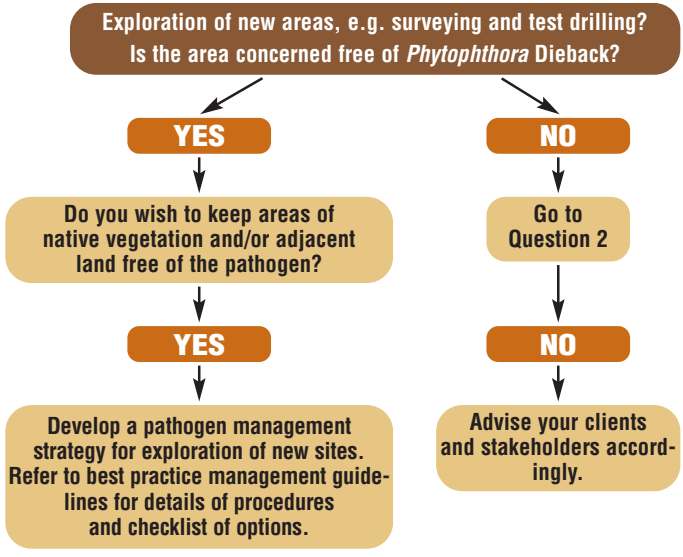
The movement of large volumes of soil is a significant risk in terms of spreading *P. cinnamomi*. The extractive industry has the opportunity to reduce the rate of spread of *P. cinnamomi* by taking steps to minimise the accidental spread of the pathogen. Operations responsible for the extraction of basic raw materials in the >500 mm rainfall zone are at greatest risk of spreading the pathogen *(see Figure 3.1)*. In particular, operations occurring near native plant communities dominated with *Banksia* species and other Proteaceae are at high risk.

Different types of extracted materials have their different levels of inherent risk with regards to the likelihood of being infested with *Phytophthora* Dieback and therefore these differences need to be taken into account when preparing management plans. For example, sand and gravel are easily infested with *Phytophthora*, where limestone and hard rock aren't.

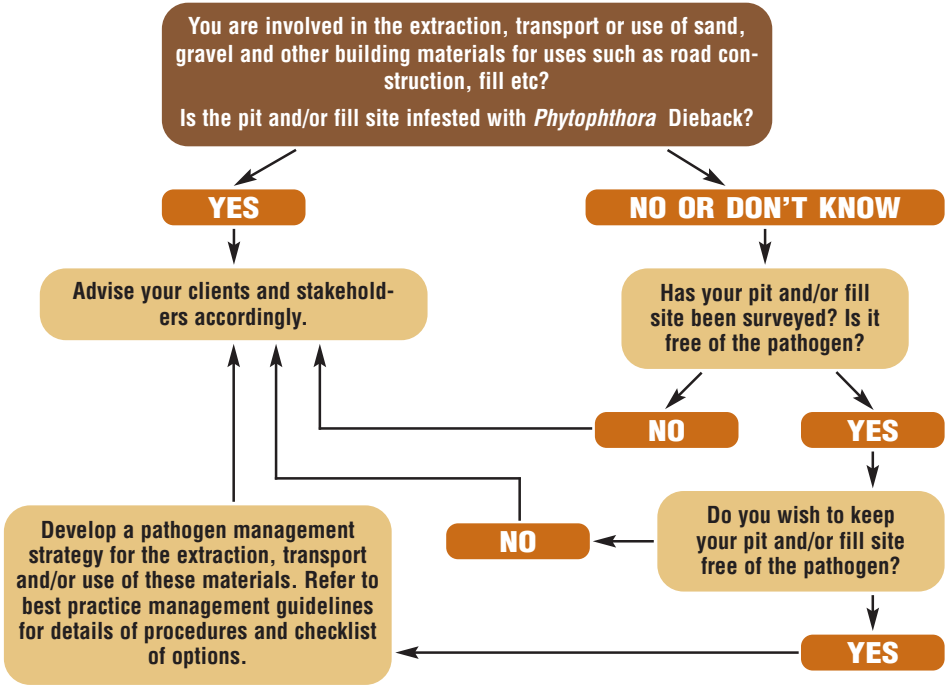
The best practice management techniques contained within this document are examples of management procedures available to quarry operators to minimise the risk of their operations in acting as a vector for the transfer of the pathogen. The methods described here are by no means an all-encompassing list. Other techniques may be available or developed.

The preparation of management guidelines for the removal of basic raw materials by the extractive industry reflects industry commitment in managing the pathogen. Operators aiming for improved environmental performance can implement the relevant techniques to managing this pathogen in the best available and practical measures. Two flow charts have been inserted below to assist quarry operators in deciding if they need to take further action to manage *P. cinnamomi*.

Question 1



Question 2



8. Best Practice Management Techniques

The focus of managing *Phytophthora* Dieback should be to minimise the spread of the pathogen during the extraction, processing and transportation of the basic raw materials. The tools and techniques described below can assist operators in attaining this objective.

8.1 Guidelines for Exploration

Once the operator has established that they wish to manage *Phytophthora* Dieback, it is necessary to survey the subject site to determine its disease status. However, it is not always feasible to conduct a *Phytophthora* Dieback survey prior to exploration. In these instances it essential that all exploration equipment/vehicles are cleaned *(see page 34)* prior to entering the exploration site and between each exploration site. Given a *Phytophthora* Dieback survey has been conducted a number of scenarios may arise. The site may be:

1. Entirely infested with *Phytophthora* Dieback.
2. Entirely free from *Phytophthora* Dieback.
3. Partially infested and uninfested of *Phytophthora* Dieback.
4. Uninterpretable due to absence of indicator species or recent disturbance (e.g. fires, cleared for agriculture).

The management strategy for exploration will vary according to the relevant scenario. Each scenario will be dealt with in turn.

8.1.1 Guidelines for a site entirely infested with *Phytophthora* Dieback

No hygiene considerations are required to enter the site. However, wash down of equipment/vehicles on exit is essential if moving into a bushland area that is determined to be free from *Phytophthora* Dieback or a site where the *Phytophthora* Dieback status of adjacent vegetation is unknown. Wash down of equipment/vehicles on exit is not essential when moving to another adjoining infested area. Refer to information contained in Section 8.5 for guidelines relating to the cleaning of equipment/vehicles and footwear and the sterilisation of water.

8.1.2 Guidelines for a site free of *Phytophthora* Dieback

'Clean on entry' is essential if the operator wishes to maintain the disease free status of the site. All equipment and vehicles are to be free of mud and soil prior to entering the site.

8.1.3 Guidelines for a site partially infested with *Phytophthora* Dieback

Sites that are partially infested by *Phytophthora* Dieback require special management if the spread of the pathogen is to be minimised within the site.

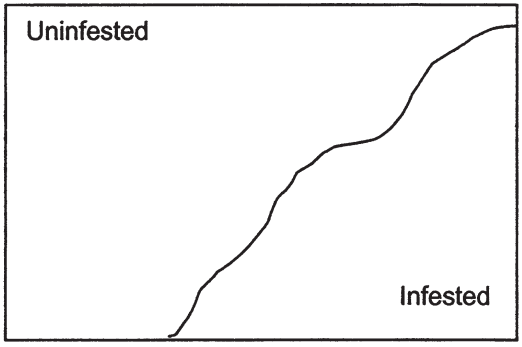


Figure 8.1 *Theoretical subject site showing partial infestation.*

The preferred approach to the situation depicted in *Figure 8.1* would be enter the uninfested section subject site with 'clean' equipment/vehicles/footwear *(Section 8.5)* to conduct exploratory works within that section. Once exploration is completed in the uninfested section, equipment and vehicles can then be shifted across the hygiene boundary without cleaning. If equipment and vehicles need to recross into the uninfested area they will require cleaning crossing the boundary.

8.1.4 Guidelines for a site that is uninterpretable

Sites that are deemed uninterpretable due to the absence of indicator species or due to recent disturbances such as fire, should be treated using the precautionary principle, and as such hygiene guidelines should be implemented prior to entry of the site and again upon leaving the site. If time permits, susceptible plant species (e.g. *Banksia grandis*) could be planted into uninterpretable sites. These plants would then be monitored for symptoms of *Phytophthora* Dieback over a two-year period. Any plants displaying *Phytophthora* Dieback symptoms could then be sampled to confirm the presence or absence of the pathogen. The results of the sampling could then be used to confirm the presence of the pathogen.

8.2 Guidelines for Extraction

Once the operator has established that they wish to manage *P. cinnamomi*, it is essential to conduct a survey to determine the distribution of the pathogen across the subject site. The results of the disease survey may indicate a number of scenarios, the site may be:

1. Entirely infested with *Phytophthora* Dieback.
2. Entirely free from *Phytophthora* Dieback.
3. Partially infested and uninfested of *Phytophthora* Dieback.
4. Uninterpretable due to absence of indicator species or recent disturbance.

The management strategy for extraction will vary according to the relevant scenario. However, it is recommended that the operator's customers be advised of this decision as it may have implications for the use of the materials.

8.2.1 *Phytophthora* Dieback present across entire site

If the subject site is entirely infested with *Phytophthora* Dieback, the site operator/manager can prevent further off-site spread by implementing the following:

Action Description	Rationale
Training	Train all staff about *Phytophthora* Dieback, its impact and management.
Signage	Inform personnel entering the site that *Phytophthora* Dieback is present and that precautions need to be taken to ensure that *Phytophthora* Dieback is not spread from the site.
Containment of surface water on-site	Surface water is an efficient means for the spread of *Phytophthora* Dieback. Furthermore, increases in soil moisture can greatly increase the impact of the pathogen on surrounding native vegetation.
Hard, well drained stockpile area	Increased moisture increases the survival of *Phytophthora* Dieback. Run-off from stockpiles may contain *Phytophthora* Dieback and therefore should be contained in an evaporation pond and not be allowed to enter sensitive areas or nearby watercourses. Limestone makes an ideal material for use in construction of the stockpile area due to its high pH being very suppressive of *Phytophthora* Dieback.
Wash-down facility	Clean-on-exit. All vehicles should be washed down prior to exiting the site if the materials are being driven through sensitive area e.g. bushland. Workers should wash equipment and foot wear prior to exiting the site.
Rehabilitate using resistant plant species	Use of resistant plant species in rehabilitation will increase success of rehabilitation. Purchase plants from accredited nurseries. Improved drainage and use of topsoil that is free of the pathogen will significantly improve the success of the rehabilitation.
Customer notification	Advise potential customers that the material is likely to be infested with *Phytophthora* Dieback.
Secure site	Secure the site using fencing to prevent uncontrolled access. Consider having a split phase operation to isolate loading from excavation, thus reducing the need to washdown loading trucks.

Hygiene procedures during the extraction of materials are not essential. However, particular care should be taken to not spread the pathogen during the transportation of the infested materials.

8.2.2 Phytophthora Dieback not present at site

A site determined by an accredited interpreter to be free from *Phytophthora* Dieback is a valuable resource, particularly for consumers that require materials for use in sensitive areas such as conservation reserves and horticultural applications. Extractive Industry sites can only be certified as being free of *Phytophthora* Dieback under the following circumstances (CALM, 2004).

- Where a new site is located in an undisturbed area, where sufficient indicator plants are available for a *Phytophthora* Dieback assessment to be made.
- An existing site that has records confirming that it was originally free of *Phytophthora* Dieback and that sufficient evidence exists that an effective system of hygiene has been maintained to ensure the site has remained free of the pathogen.
- Where basic raw materials are being extracted from deep pit quarries, and where this is no obvious source of inoculum (e.g. mixing of top-soil and plant material, sub-surface water flow from adjacent infested areas or unhygienic entry of vehicles/ machinery into the site).

Pathogen Management Strategy

A pathogen management strategy outlines the procedures essential for ensuring *Phytophthora* Dieback is not introduced to the subject site. It may be a part of a broader environmental management plan, or a stand-alone document. The format for the pathogen management strategy may vary. However, a checklist is provided in Section 8.7 to ensure that the relevant components have been considered and/or included.

The pathogen management strategy must identify the position of the resource, and in doing so devise locations for the following:

- Extraction and processing areas
- Roads, including haul roads
- Turn around points
- Vehicle/equipment hygiene points
- Storage/stockpile areas
- Water source/s

Quarantine

The subject site should be treated as a quarantine area. Unauthorised and/or unhygienic entry must not be permitted. This may be achieved via restrictive fencing, and provision of parking areas outside of the 'quarantine area'. Similarly a boundary fence around the site will minimise the risks associated with boundary breaches. All vehicles or equipment entering the compound are to be 'clean on entry', and therefore are required to be washed down prior to entering the site. Once clean, vehicles and equipment can move around within the site without hygiene restrictions. All footwear should also be clean on entry to the site. A split phase operation is recommended that separate the loading and excavation areas. This would eliminate the need for loading trucks to be washed down.

The table below lists a number of Dieback management strategies available for sites free of the pathogen and the rationale for their inclusion.

Action Description	Rationale
Training	Train all staff about *Phytophthora* Dieback, its impact, management and the value of *Phytophthora* Dieback free materials.
Signage	Inform personnel entering the site that it is free of *Phytophthora* Dieback and the need to washdown any equipment/vehicles/foot wear that enter the quarantined area.
Wash-down facility	Clean-on-entry. All vehicles should be washed down prior to entering the site. Quarry workers should wash foot wear prior to entry on the site.
Quarantine area	Restrictive fencing surrounding the site and provision of parking areas outside the site. Establish a split phase operation to separate loading and excavation areas. Limestone makes an ideal material for use in construction of the loading area due to its high pH being very suppressive of *Phytophthora* Dieback.
Containment of surface water on-site	Surface and sub-surface water are an efficient means for the spread of *Phytophthora* Dieback. To ensure the pathogen would not be spread around the site if accidentally introduced it is important to contain any surface water. Ensure drainage does not enter the site from surrounding areas.
Water management	Ideally water used on site (e.g. to reduce dust) should be either from main's supply or a deep bore. If the water is from a dam or creek it is essential to sterilise the water prior to its use.
Rehabilitation using *Phytophthora* Dieback free materials	Only bring in certified *Phytophthora* Dieback free materials (e.g. soil, mulch and compost). Purchase plants from accredited nurseries. Consider direct seeding rather than planting seedlings.
Customer notification	Advise customers that the material is free of *Phytophthora* Dieback.
Regular testing of the stockpile and extraction area	Regular testing can be used as evidence that the dieback-free status of the quarry and its extracted materials is maintained.

During the planning and establishment of the quarry it is important to determine the placement of roads, turn around points and wash down facilities. Soil and water collected from the wash-down facility should be sterilised *(Section 8.5)*. Surface and sub-surface water are an efficient means for the spread of *Phytophthora* Dieback. To ensure the pathogen would not be spread around the site if accidentally introduced it is important to contain any surface water. Where possible the construction of roads and turn around points should occur in dry soil conditions, for example, November to May and postponed following rain (particularly if greater than 5-10 mm of rain has fallen within 24 hours. The exact period of time to postpone is variable and is dependant on a number of factors including soil type, presence of vegetation and temperature.

It is important to use signage to clearly indicate the areas that have been shown to be free of *Phytophthora* Dieback. Furthermore, fencing should be used to designate areas for loading, quarantine, vehicle wash-down facilities and to exclude non-work areas. Extracted raw materials should be stockpiled and stored either on-site or at another area known to free of *Phytophthora* Dieback.

8.2.3 Site partially infested with *Phytophthora* Dieback

If a site is partially infested and uninfested with *Phytophthora* Dieback it is important to minimise the further spread of pathogen within the site. To facilitate this it is necessary that areas free of the pathogen are quarantined using fencing or some form of delineation from infested areas and that these different areas are clearly signed.

The site operator should extract the materials from areas determined to be free of the pathogen prior to extracting in non-infested areas. Segregation of the excavation activities is another other option, but movement of water and soil needs to be controlled. Vehicles and equipment should be washed down prior to entering *Phytophthora* Dieback free areas within the site.

Once the extraction of the materials is completed in the uninfested section, equipment and vehicles can then be shifted across the hygiene boundary without cleaning. If equipment and vehicles breach the hygiene boundary, they will require cleaning before being able to return back to the uninfested area. Surface water should be contained within the different areas (uninfested, infested) within the site.

8.2.3 Site partially infested with *Phytophthora* Dieback – *continued*

Action Description	Rationale
Containment of surface water on-site	Surface and sub-surface water are an efficient means for the spread of *Phytophthora* Dieback. Furthermore, increases in soil moisture can greatly increase the impact of the pathogen on surrounding native vegetation.
Signage	Inform personnel entering the site areas that are infested with *Phytophthora* Dieback and areas that are non-infested.
Wash-down facility	Clean-on-entry. Vehicles, equipment and footwear should be washed down prior to entering non-infested areas. Clean-on-exit. Vehicles, equipment and footwear should be washed down prior to exiting infested areas.
Hard, well drained stockpile area	Increased moisture increases the survival of *Phytophthora* Dieback. Run-off from stockpiles may contain *Phytophthora* Dieback and therefore run-off should be contained in an evaporation pond and not enter sensitive areas or nearby watercourses. Stockpiles of *Phytophthora* Dieback infected materials should be stored away from stockpiles of *Phytophthora* Dieback free materials. Limestone makes an ideal material for use in construction of the stockpile area due to its high pH being very suppressive of *Phytophthora* Dieback.
Soil management	Topsoil from infected and non-infected areas to be stored separately in dry higher areas. Soil from the infected area to only be used for rehabilitation within that area and will not be used to rehabilitate *Phytophthora* Dieback free areas. Infected topsoil to only be used in drier sites where the rate of spread will be reduced. Where possible topsoil from the infected areas will be buried underneath the over burden.
Work up slope	By excavating the area up-slope there is reduced risk of spreading the pathogen into non-infested areas of the quarry.
Water management	Ideally water used on site (e.g. to reduce dust) should be either from main's supply or a deep bore. If the water is from a dam or creek it is essential to sterilise the water prior to its use. Bunds to be established to prevent excessive runoff into bushland. Drainage to be constructed to minimise the amount of surface water crossing roads within quarry area.
Rehabilitate using non-susceptible plant species	Use of non-susceptible plant species in rehabilitation will increase success of rehabilitation within infested areas.

8.2.3 Site partially infested with *Phytophthora* Dieback – *continued*

Action Description	Rationale
Rehabilitate using *Phytophthora* Dieback free materials in *Phytophthora* Dieback free areas	Only bring in certified *Phytophthora* Dieback free materials (e.g. soil, mulch and compost) into the areas free of the pathogen. Purchase plants from accredited nurseries. Consider direct seeding rather than planting seedlings. Suspect or non-certified materials can be used in *Phytophthora* Dieback infested areas.
Customer notification	Advise potential customers that the material may be infested with *Phytophthora* Dieback.
Training	Train all staff about *Phytophthora* Dieback, its impact and management.
Secure site	Secure the site using fencing to quarantine areas free of the pathogen and to prevent uncontrolled access.

8.2.4 Site that is uninterpretable

Sites that are deemed uninterpretable should be treated using the precautionary principal and as such hygiene guidelines (signage, vehicle/ equipment wash down, footbaths and containment of surface water) should be applied. In some instances, uninterpretable sites may be easier to be considered as dieback infected and emphasis should be placed on management of the topsoil.

8.2.4 Site that is uninterpretable – *continued*

The table below lists a number of Dieback management strategies available for uninterpretable sites and the rationale for their inclusion.

Action Description	Rationale
Containment of surface water on-site	Surface and sub-surface water are an efficient means for the spread of *Phytophthora* Dieback. Furthermore, increases in soil moisture can greatly increase the impact of the pathogen on surrounding native vegetation.
Signage	Inform personnel entering the site may be infested with *Phytophthora* Dieback.
Wash-down facility	Clean-on-entry and Clean-on-exit. Vehicles, equipment and footwear should be washed down prior to entering site and before exiting the site.
Hard, well drained stockpile area	Increased moisture increases the survival of *Phytophthora* Dieback. Run-off from stockpiles may contain *Phytophthora* Dieback and therefore run-off should be contained in an evaporation pond and not enter sensitive areas or nearby watercourses. Limestone makes an ideal material for use in construction of the stockpile area due to its high pH being very suppressive of *Phytophthora* Dieback.
Rehabilitate using *Phytophthora* Dieback free materials in *Phytophthora* Dieback free areas	Only bring in certified *Phytophthora* Dieback free materials (e.g. soil, mulch and compost). Purchase plants from accredited nurseries. Consider direct seeding rather than planting seedlings.
Customer notification	Advise potential customers that the material may be infested with *Phytophthora* Dieback.
Work up slope	By excavating the area up-slope there is reduced risk of spreading the pathogen into non-infested areas of the quarry.
Water management	Ideally water used on site (e.g. to reduce dust) should be either from main's supply or a deep bore. If the water is from a dam or creek it is essential to sterilise the water prior to its use.
Training	Train all staff about *Phytophthora* Dieback, its impact and management.
Secure site	Secure the site using fencing to the excavation quarantine area and to prevent uncontrolled access.

8.3 Loading and Transportation

Split phase operations would be a useful method for preventing the spread of *Phytophthora* Dieback *(Figure 8.2)*. The aim of a split phase operation is to have vehicles, machinery and equipment enter non-infected areas only when they have been cleaned. Extraction vehicles and machinery can then move freely within the quarantined area. Trucks and machinery used for stockpiling and loading are kept separate from the extraction (quarry) area.

In many cases any processing or stockpiling of the extracted material should occur on the border of the extraction and loading designated areas. Light and non-essential vehicles should be restrained to a defined parking area adjacent to the access road and should not have access to the transport or excavation area at any time. By careful planning the need to clean equipment can be minimised.

To ensure the pathogen is not introduced or spread during the construction of haulage/access roads it is important that *Phytophthora* Dieback management procedures are used. For example, *Phytophthora* Dieback-free construction materials should be used. Limestone makes an ideal material for use in construction of the stockpile and loading areas due to its high pH being very suppressive of *Phytophthora* Dieback.

Where possible the construction of roads and turn around points should occur in dry soil conditions (November to April and postponed following rain, particularly if rainfall is greater than 5-10 mm within 24 hrs). The exact period of time to postpone is variable and is dependant on a number of factors including soil type, presence of vegetation and temperature. Sealing roads with asphalt can significantly reduce the chance of accidentally introducing the pathogen into the native plant communities that the haulage/access roads dissect.

Trucks carrying loads of *Phytophthora* Dieback infected materials should be washed down after the delivery is complete. This will ensure that other subsequent materials loaded into the truck are not contaminated. However, washdown is not necessary if the truck is dedicated to carrying *Phytophthora* Dieback infected materials.

8.4 Rehabilitation

After the extraction of the raw materials is complete the rehabilitation process can begin. To ensure good drainage is essential to rip the excavated area prior to commencing the rehabilitation process. In many cases the extraction process removed impeding rock layers and leads to vastly improved drainage. The excavated area should be ripped to a depth of at least 800 mm in a cross pattern at 1 m by 2 m intervals. Once the ripping is complete the overburden and topsoil can begin to be replaced.

Phytophthora Dieback free soils are the most valuable resource available for rehabilitation and should be used in areas with the greatest benefit. It is important that infected and *Phytophthora* Dieback free topsoils are kept segregated during the extraction process. *Phytophthora* Dieback free topsoils should be applied to areas that are least likely to become infected, for example areas up slope from infected areas.

Rehabilitation of a *Phytophthora* Dieback infected area aims to establish the naturally occurring vegetation to the site. It is therefore important that *Phytophthora* Dieback areas within the site are clearly designated. The infection and death of highly susceptible plant species can increase the levels of the pathogen in the soil, thereby increasing the impact of the pathogen. Therefore, highly susceptible plant species should not be used to rehabilitate sites infested with *Phytophthora*. Susceptible plant species can be planted into areas that have used *Phytophthora* Dieback free topsoils.

It is important that the rehabilitation process of a non-infested site does not actually lead to the pathogen being introduced. Phytophthora species have been regularly isolated from plant stock originating from nurseries in WA. Therefore, it is important that all plants are purchased from nurseries with Nursery Industry Association wholesale accreditation, or nurseries with excellent hygiene standards.

Direct seeding can often be preferred as the chance of accidentally introducing the pathogen is vastly reduced. Direct seeding should be conducted either during autumn or winter to allow the plants to be established with the autumn-to-spring rainfall. The use of mulch is not recommended unless the mulch has been well composted (the heating of the mulch during the compost process will kill *Phytophthora* Dieback).

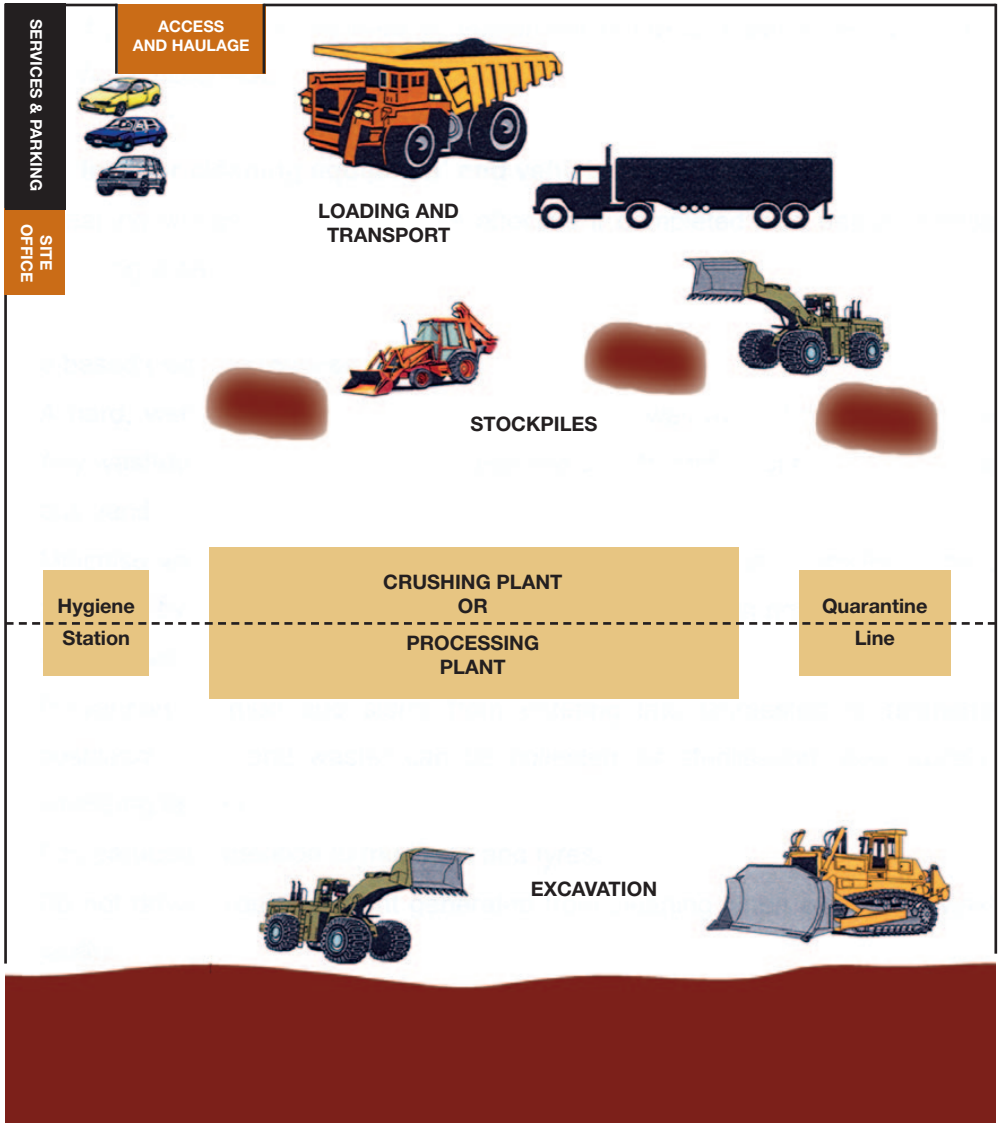


Figure 8.2. An example of a split phase operation that separates the excavation and loading/processing activities within a quarry (Noel Eddington).

8.5 Hygiene

Hygiene is essential to any operation aiming to minimise the spread of *Phytophthora* Dieback. Below are some guidelines applicable to the cleaning of vehicles, equipment and footwear. Also included are some points about sterilisation of water, equipment and footwear. Companies may need to seek professional advice about the sterilisation of water in open cut dams. Where practical it is preferable to use the dry cleaning methods (air compressor, brushes) rather than cleaning with water as it has a significantly lower chance of accidentally spreading the pathogen. It should be noted that dust and grime on vehicles or equipment is not a threat in terms of spreading *Phytophthora* Dieback.

Guidelines for cleaning equipment and vehicles

- Cleaning will be easier and more effective if completed at a depot or designated cleaning area.

Field-based cleaning requires:

- A hard, well-drained surface (e.g. road) that is well away from native vegetation. Any washdown effluent should be collected on-site and must not be allowed to drain bushland.
- Minimise water use to remove soil and mud from equipment/vehicles. This can be achieved by preferentially dry cleaning techniques e.g. stiff brushes.
- Washdown on ramps if possible.
- Prevention of mud and slurry from entering into uninfested or uninterpretable bushland. Soil and waster can be collected for sterilisation (see guidelines for sterilising below).
- Pay particular attention to mudflaps and tyres.
- Do not drive through effluent generated from cleaning when exiting the washdown facility.

Guidelines for cleaning footwear

- Try to remove mud and soil when it is dry. Remove as much mud and soil as possible with a stiff brush or stick and minimise the amount of water used.
- Collect all mud and soil removed and place in a bucket or bag for later disposal at a site that is infested with *P. cinnamomi* or that contains no native vegetation.

Guidelines for sterilising

- Sterilisation of equipment, footwear and vehicle tyres can be used to take an extra precaution. Sterilisation of nursery equipment using steam is common practice, however the use of steam is not practical in the field. The following sterilisation methods can be used in the field.
- Spray methylated spirits on small hand tools and footwear covering all surfaces and allowing a few minutes for it to soak into all soil material.
- Spray diluted bleach (sodium hypochlorite) onto equipment and footwear allowing a few minutes before rinsing the bleach off using water. Dilute bleach so that solution contains 1% active ingredient sodium hypochlorite. Be sure to follow any of the manufacturer's safety instructions provided on the bleach container.
- Spray Phytoclean® can be used in footbaths, washdown facilities and during the cleaning of equipment. See the manufacturer's details for directions.

8.6 Monitoring and Reporting

Monitoring during the exploration, extraction and rehabilitation processes is essential to determine the effectiveness of the *Phytophthora* Dieback management plan. It may be an on-going requirement of the licence to provide regular reports on the success of the environmental management plans, including the *Phytophthora* Dieback management plan. Regardless, reports should be regularly generated outlining any successes or failures of managing the pathogen. It is important to note any areas of the plan that could be used to improve the effectiveness and practicality of the management plan.

8.7 Documentation

A pathogen management strategy is an important document outlining the necessary steps required for implementation to minimise the spread and impact of *P. cinnamomi*. A pathogen management strategy should contain the following information:

- Devise locations for extraction, processing, turn around points, washdown areas, stockpile areas, water sources and water collection areas.
- Determine where to place entry point to the site and within different areas within the site, fencing and appropriate signage.
- Detail rehabilitation process to reduce the future impact of the pathogen on the site.

8.8 Staff Education

If the *Phytophthora* Dieback management plan is to succeed its essential that all employees are made aware of pathogen and understand the importance of the management procedures. It only takes one mistake by one employee to accidentally introduce the pathogen to an uninfested area, thereby making all the resources spent on a pathogen management strategy void! The Dieback Working Group regularly run a free training course on the management of *Phytophthora* Dieback. The covers a background of the pathogen, its impact in WA and common techniques used in the management of the disease. The course can be tailored for an individual company needs to make it as relevant to their operations as possible. Contact the Dieback Project Coordinator (Chapter 9) to discuss this course further.

8.9 Consumer Notification

The Dieback status (infested, uninfested, maybe infested) of the extracted material can have consequences for its intended use. Therefore, its essential that all companies in the Extractive Industry notify their customers of the *Phytophthora* Dieback status of the extracted material, particularly when its the material is likely to be infested. In 2000, the Dieback Working Group released a document titled *'Managing Phytophthora Dieback – Guidelines for Local Government'* which encouraged the use of '*Phytophthora* free' materials. Therefore, it is a considerable marketing advantage for a company to be able to provide raw materials (e.g. gravel, sand) that are known to be free of *Phytophthora* Dieback.

9. Case Studies

The following case studies were compiled to provide the extractive industry with examples from leading companies or government departments that have been successfully managing *Phytophthora* Dieback in WA. The case studies highlight their diversity in their application of different management techniques to different scenarios. Essentially, interested extractive industry companies need to review the suggested techniques described in Chapter 8 and determine which apply for their operations. The examples provided should not be interpreted as being infallible or complete, rather they aim to demonstrate real management approaches and should help assist companies in developing management practices for their own operations.

9.1. Alcoa World Alumina Australia

The jarrah forest in WA is the location of one of the largest and most productive bauxite mining operations in the world. Alcoa World Alumina Australia supplies 16% of the world's alumina from two mine sites in the jarrah forest, Huntly and Willowdale. Alcoa has been a leader in the development of techniques for managing *Phytophthora* Dieback. In particular, the application of strict hygiene/access protocols, intensive use of disease mapping and world class rehabilitation practices have lead to very low rates of spread by their operations and excellent survival rates in *Phytophthora* Dieback infected rehabilitation areas.

The list of control, measures used by Alcoa to manage *Phytophthora* Dieback include:

- Mapping, detection and demarcation.
- Scheduling of high risk operations during low-risk periods of the year.
- Restricting vehicle movements between infested areas to Phytophthora Dieback free areas.
- Clean vehicles before entering Phytophthora Dieback free areas. This includes providing washdown facilities at entrance to the minesites.
- Don't mix uninfested and infested soil.
- Train all field staff and planners.
- A range of excellent rehabilitation practices including the improvement of drainage, use of *Phytophthora* Dieback free and the use of Phytophthora Dieback resistant Jarrah's *(Eucalyptus marginata)*.

Alcoa has also developed a number of innovative approaches to managing *Phytophthora* Dieback. For example, the creation of a procedure for eradicating

P. cinnamomi and *P. citricola* from unsealed roads by heaping wood produced from clearing activities and burning it on the road. The wood heaps were approx. 30 m long by 10 m wide by 6 m high. The heaps are burnt for 3-4 days. Subsequent sampling reported that the pathogen had been eradicated from the road surface. Extractive Industry companies interested in using similar techniques would need to seek approval from the relevant authorities.

Another example of an innovative management approach is a method Alcoa have developed to test the *Phytophthora* Dieback status of an unsealed road by planting out susceptible *Banksia grandis* seedlings. Once established the B. grandis plants were then surveyed regularly for signs of *Phytophthora* Dieback infection (e.g. chlorosis, wilting, collar rot or death). Plants showing symptoms of *Phytophthora* Dieback were sampled to determine the presence of the pathogen. The later approach would have broad applications in the extractive industry when determining the *Phytophthora* Dieback status of uninterpretable areas (e.g. quarry sites on pastoral land or old quarry sites that have long been cleared).

Interestingly, Alcoa investigated the use of disinfectants (copper sulphate, quaternary compounds, substituted phenol compounds) and concluded that there is still no disinfectant capable of meeting the needs of mining operations while overcoming economic and environmental concerns.

9.2. Main Roads Western Australia

In 1992 Main Roads Western Australia (MRWA) released an Environmental Management manual for the management of *Phytophthora* Dieback during there construction activities (Hart, Simpson and Associates, 1992). The manual focused on four main sections, including policy, organisational procedures, techniques and performance assessment. In particular, the manual emphasised a range of Dieback management techniques, including:

- Clean gravel used in forested areas.
- Vehicle washdown and adding copper sulphate in washdown water.
- Demarcation of infested and non-infested areas.
- Education and training.
- Contract requirements for contractors to remove any suspect infected soil that may have been inadvertently moved into a healthy area.
- Drainage management.
- Conduct work when possible during dry conditions.
- Phosphite treatment.

The following case studies demonstrate two different scenarios in which MRWA had to work within the presence of *Phytophthora* Dieback. The second case study is particularly interesting given it deals with a construction site that is infected by a different *Phytophthora* species other than *P. cinnamomi*, called *P. citricola*.

MRWA Case Study 1

This case study refers to the contract for the construction of a dual carriageway during 1990 in Bunbury. The contract included the construction of one side of dual carriageway road to a length of 11.3 km. *Phytophthora* Dieback was identified in a creek over which the road passed and an infection area of 360 m was demarcated. The following is a summary of the steps taken and the clauses included in successful contractors contract.

1. CALM consulted at planning stage.
2. *Phytophthora* Dieback infection mapped and then the boundaries were marked with written signs for the duration of the project.
3. *Plant management.* All equipment was cleaned prior to beginning on site. Machinery in the demarcated area was cleaned prior to leaving the infected area.
4. *Washdown bay specified.* This included details of fungicide quantities, requirement to replace fungicide daily and a provision for a sump to collect overflow and waste fluids. However, in the end this was not constructed, rather the contractor set up a simple washdown pad on the edge of the infected area. Water and overflow were then drained directly into the already infected creekline.
5. *Soil management.* Cleared vegetation to be retained in the area and burnt. Topsoil removed from designated area to be buried under any embankment construction within the area. Imported embankment material to be backed in from the edge of the designated area so that it forms a "clean" pad on which to work.

Overall the project was a success. There was no evidence of up-hill spread and the contractor reported that the conditions on the contract did not deleteriously impact on operational activities.

MRWA Case Study 2

This case study refers to the contract for the construction of a passing lane during 1990 at Bindoon Hill. Passing lanes were constructed leading up to the summit of Bindoon Hill on Great Northern Hwy over a distance of 3.7 km. *P. citricola* was identified in the top of the hill in a bushland area and the associated drainage system of the road. A pit and gravel stockpile on adjoining land and the water source for the job were designated free of *Phytophthora* Dieback by CALM. It is important to note that in contrast to

P. cinnamomi, *P. citricola* doesn't always cause obvious disease and therefore it can be difficult to determine Dieback free status without intensive sampling. The following is a summary of the clauses were included in the contract specification.

1. *Plant management.* All equipment to be cleaned down prior to entering the job site or any of the gravel pits. Cleandown requirements were specified. Plant to be washed down in accordance with *Table 9.1*.
2. *Water treatment.* All water used for construction, haul roads and other works to be treated with fungicide (amounts and renewal times were specified).
3. *Cleandown bay specified.* This included the provision to two such sites, details of fungicides, dimensions and provisions of a sump.
4. *Plant movement.* Trucks used to cart water from water source to the storage site were separate from those used to cart water from the storage site to the construction area. The area around the storage site was constructed and managed in a way that the trucks carting from the source to storage site will not pick up any soil or mud.
5. *Material handling.* No material to be removed from the job site without the approval to the supervisor.

Table 9.1. Plant washdown requirements for passing lane construction by Main Roads Western Australia in 1990 at Bindoon Hill.

Item of plant	Moving from job site to pits	Moving from job site to water source	Moving offsite
Water trucks	Washdown	Washdown	Washdown
Water carting trucks	No washdown*	No washdown*	Washdown
Trucks	No washdown*	Washdown	Washdown
Construction machinery	Washdown	Washdown	Washdown
Vehicles	No washdown*	Washdown	No washdown*

**except as directed by supervisor*

9.3. Conservation and Land Management

The Department of Conservation and Land Management (CALM) have an extensive experience when managing *Phytophthora* Dieback in the entire range of their operation activities. Batini (1992) described the following approaches that CALM use when managing Dieback in their forestry activities.

- Dieback mapping, classification and demarcation of site.
- Road building and maintenance, in particular taking care with site selection, maintenance and gravel sources.
- Washdown/cleandown to minimise accidental spread. The cleaning of equipment/vehicles is achieved using a number of different methods including blowing down equipment with compressors and cleaning heavy machinery with stiff dry brooms.
- Split phase logging that separates the different components of the operation.
- Maximising activities such as log stockpiling during the driest time of year.
- Access control.
- Training and education.

Many of CALM's operation require the use of *Phytophthora* Dieback free gravel. Borrow pits can only be certified as being *Phytophthora* Dieback free if it's a new pit located in an undisturbed area where sufficient indicator plants are available for an assessment, or for an existing pit that records confirm it was originally free of the pathogen and sufficient evidence exists to prove an effective system of hygiene has been maintained. Existing gravel pits without a known history that can be placed into quarantine and kept free of all living and dead plant material for a period of three years may have their status reviewed.

During exploration and extraction of quarrying gravel within CALM managed land the following management guidelines apply:

- *Phytophthora* Dieback mapping, classification and demarcation of site.
- *Hygiene. Clean on entry.* Particular care is to be taken when moving across between infested and uninfested areas.
- *Use of barrier systems (split phase operations)*. This ensures that the clean equipment within the uninfested area does not come into contact with infested soil or unclean equipment operating outside the uninfested area.
- *Limiting and controlling access.* This includes limiting entry periods to the quarry when the soil is not moist enough to be picked up and moved by equipment/vehicles.
- Controlling drainage to ensure it doesn't move from infested to uninfested areas.

10. Contacts and Further Information

Dieback Interpretation Services

- GLEVAN Dieback Consultancy Services (Evan Brown). Phone (08) 9496 3336.
- Department of Conservation and Land Management, Swan Region (Abe van de Sande). Phone (08) 9368 4399.

Laboratories for Testing Soil and Plants for *Phytophthora cinnamomi*

- Department of Conservation and Land Management – Vegetation Health Service. Phone (08) 9334 0309.
- Murdoch University, Plant Pathology, Giles Hardy. Phone (08) 9360 6000.
- Curtin University, Elaine Davison. Phone (08) 9351 3106.
- Agriculture WA, Peter Wood. Phone (08) 9368 3693.

Dieback Treatment Contractors

- Dieback Treatment Services, Glenn Tuffnell. Phone (08) 9496 0311.

For Further Information

- The Environment Officer or Parks Officer at your local Council.
- Dieback Project Coordinator, Dieback Working Group, c/o Shire of Kalamunda. Phone (08) 9257 9937 or 0438 044 488 – www.dwg.org.au
- Extractive Industries Committee, Chamber of Commerce and Industry of Western Australia, 180 Hay Street, East Perth Phone (08) 9365 7537 www.cciwa.com

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Dieback
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