Ecoscape (Australia) Pty Ltd

AGR2013058 – State Barrier Fence Esperance Extension

Phytophthora Dieback occurrence assessment – Version 2.0

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This report has been prepared in accordance with the scope of work agreed between the Client and Glevan Consulting and contains results and recommendations specific to the agreement. Results and recommendations in this report should not be referenced for other projects without the written consent of Glevan Consulting.

Procedures and guidelines stipulated in various Department of Environment and Conservation and Dieback Working Group manuals are applied as the base methodology used by Glevan Consulting in the delivery of the services and products required by this scope of work. These guidelines, along with overarching peer review and quality standards ensure that all results are presented to the highest standard.

Glevan Consulting has assessed areas based on existing evidence presented at the time of assessment. The Phytophthora pathogen may exist in the soil as incipient disease. Methods have been devised and utilised that compensate for this phenomenon; however, very new centres of infestation, that do not present any visible evidence, may remain undetected during the assessment.

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Note on version numbering:

0.1 – 0.∞	*Internal documents*
1.0 – 1.∞	*First draft and iterations to Client.*
2.0	*Final document.*

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1 Summary

1.1 Background

The State Barrier Fence (the Fence) currently extends from the coastal Zuytdorp cliffs, north of Kalbarri to approximately 25km east of Ravensthorpe. The Fence provides protection to the majority of the agricultural areas of Western Australia's South West but does not protect the more recently developed land to the east of Ravensthorpe. Concern has been raised about areas that are inadequately protected and the Western Australian state government has responded by proposing an extension of the Fence in this region. The proposed extension is approximately 640km in length.

The State Barrier Fence, Esperance Extension will be located within a fence reserve to be vested with DAFWA. The Fence extension will extend from the current termination near Ravensthorpe, north east toward Salmon Gums and then south east where it will terminate approximately 100km east of Esperance.

Under the guidance of the Esperance Extension Reference Group (EERG), a Project Scoping Study was undertaken to identify project constraints associated with several potential fence alignments. The Scoping Study assessed a range of potentially constraining issues including the potential for impacting on threatened and priority flora and fauna, threatened ecological communities (TEC's) and also the possible impact of Phytophthora Dieback.

To satisfy the deliverables of this project, Glevan Consulting was contracted by Ecoscape Australia Pty Ltd (Ecoscape) to undertake the required Phytophthora Dieback survey for all areas of potentially susceptible vegetation either intersecting, or influencing the proposed project area.

Phytophthora Dieback is the common name for the observable disease result of interaction between the pathogen (*P. cinnamomi*) and the vegetation hosts (susceptible plant species within vulnerable areas). All land with an annual average rainfall of more than 400 millimetres and suitable soil composition is considered vulnerable to Phytophthora Dieback. This large area stretches approximately from Perth, Bunbury and Augusta in the west to Narrogin, Ravensthorpe and Esperance in the east, and as far north as Kalbarri (Department of Parks and Wildlife, 2013).

The *P. cinnamomi* pathogen requires suitable environmental conditions to survive, and cause disease in susceptible vegetation communities. The environmental conditions across the project area suggest that large areas would be suitable for disease expression, if *P. cinnamomi* was present.

1.2 Assessment

The assessment for the disease caused by Phytophthora Dieback is based on interpreting the vegetation for symptoms which can be ascribed to the disease presence. These observable factors must be present during the assessment period. Management recommendations may be included if it is considered that the disease may be cryptic, or the project area displays evidence of activities that are considered a high risk of introducing the disease.

The assessment was conducted by Evan Brown of Glevan Consulting in June and September 2014. Mr Brown is accredited by the Department of Parks and Wildlife (DPaW) in the detection, diagnosis and mapping of the Dieback disease. Mr Brown has conducted many surveys in the region of this project, in Ravensthorpe and Esperance.

1.3 Results

The vegetation associated with the proposed barrier fence extension has been assessed for the presence of Phytophthora Dieback, and has resulted in the majority of the area being categorised as Uninterpretable due to inadequate rainfall or an insufficient coverage of reliable indicator species. Even within the section of the study area identified as being vulnerable to Phytophthora Dieback (areas receiving more than 400 mm of annual rainfall, and other sections receiving significant summer rainfall), much of the vegetation is actually uninterpretable. This is because the amount of reliable indicator species present is simply not adequate to make a confident and accurate diagnosis of the Dieback status. Only 42% of the vulnerable area was observed to interpretable.

Phytophthora Dieback (disease caused by *P. cinnamomi*) was not observed in the vegetation within or immediately adjacent to the project area. The disease was observed at locations in proximity to the project area, including previously recorded infestations along South Coast Highway east of Ravensthorpe, and at sites in Cape Arid and Cape Le Grand National Parks.

At each site, the disease was expressing in multiple deaths of *Xanthorrhoea platyphylla* and *Banksia speciosa* with a reasonable pattern of deaths at each site.

An infestation of *P. rosacearum* was observed adjacent to Bandalup Road, near the intersection of Coujinup Road. The infestation appears restricted to a disused gravel extraction site. A significant infestation of *P. inundata* was identified toward the eastern end of the proposed extension and is having a significant impact on the susceptible vegetation. The infestation is adjacent to farmland and is spreading along the existing firebreak.

Both of these infestations will require hygiene procedures to mitigate any spread of the pathogen from the existing infestation.

Eight samples were taken during the field work component of the assessment. Five samples were taken during the initial assessment in June, while three samples were taken during the September assessment in an attempt to determine the extent of the *P. inundata* infestation.

2 Introduction

2.1 Background

The State Barrier Fence (the Fence) currently extends from the coastal Zuytdorp cliffs, north of Kalbarri to approximately 25km east of Ravensthorpe. The Fence provides protection to the majority of the agricultural areas of Western Australia's South West but does not protect the more recently developed land to the east of Ravensthorpe. Concern has been raised about areas that are inadequately protected and the Western Australian state government has responded by proposing an extension of the Fence in this region. The proposed extension is approximately 640km in length.

The Esperance Extension Reference Group (EERG) was formed, led by the Department of Agriculture and Food WA (DAFWA), to provide direction for undertaking the relevant investigations and approvals processes associated with the proposed construction of the Esperance Extension of the Fence. A Project Scoping Study was undertaken to identify project constraints associated with several potential fence alignments. The Scoping Study assessed a range of potentially constraining issues including the potential for impacting on threatened and priority flora and fauna, threatened ecological communities (TEC's) and also the possible impact of Phytophthora Dieback.

To satisfy the deliverables of this project, Glevan Consulting was contracted by Ecoscape Australia Pty Ltd (Ecoscape) to undertake the required Phytophthora Dieback survey for all areas of potentially susceptible vegetation either intersecting, or influencing the proposed project area. The desktop analysis of the floristic data generated from on-ground flora surveys was undertaken to further review the interpretability of vegetation occurring within the potentially susceptible areas of the proposed alignment. The field assessment was undertaken to identify, demarcate and map the distribution of *Phytophthora* along the proposed alignment.

2.2 Location of Project Area.

The State Barrier Fence, Esperance Extension will be located within a fence reserve to be vested with DAFWA. The Fence extension will extend from the current termination near Ravensthorpe, north east toward Salmon Gums and then south east where it will terminate approximately 100km east of Esperance. The survey corridor is defined as a 100m wide easement following the DAFWA proposed alignment, extending from immediately outside private property boundaries into all Crown Land and various reserves. In most sections this survey corridor follows the existing chained fire breaks within the UCL. The proposed DAFWA alignment is shown in Figure 1.

The proposed alignment traverses many varied geographical landforms with a high degree of ecological variability. Additionally, much of the project area is situated adjacent to remnant vegetation with high conservation value.

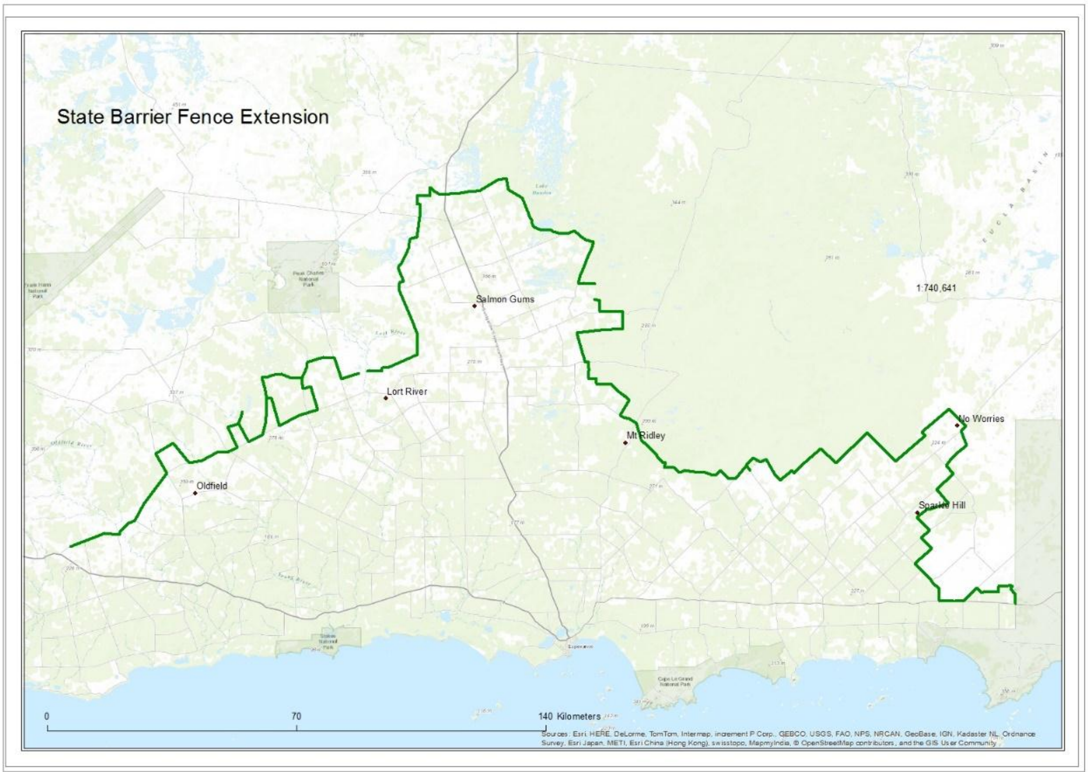

Figure 1 - Project Area

2.3 Study team

The assessment was conducted by Evan Brown of Glevan Consulting in June and September 2014. Mr Brown is accredited by the Department of Parks and Wildlife (DPaW) in the detection, diagnosis and mapping of the Dieback disease. Mr Brown has conducted many surveys in the region of this project, in Ravensthorpe and Esperance.

3 Phytophthora Dieback

The pathogen *Phytophthora cinnamomi* is an agent of environmental disease found in vulnerable areas of Western Australia. Phytophthora Dieback is the common name for the observable disease result of interaction between the pathogen (*P. cinnamomi*) and the vegetation hosts (susceptible plant species within vulnerable areas). The environment conditions of the site significantly affect the pathogens ability to survive or flourish and spread over time.

All land with an annual average rainfall of more than 400 millimetres and suitable soil composition is considered vulnerable to Phytophthora Dieback. This large area stretches approximately from Perth, Bunbury and Augusta in the west to Narrogin, Ravensthorpe and Esperance in the east, and as far north as Kalbarri (Department of Parks and Wildlife, 2013). This vulnerable area has many different bioregions, having specific characteristics formed by climate and geology. These two factors are highly significant in determining the pathogen's effectiveness and resulting disease impact levels.

3.1 The Pathogen

Phytophthora cinnamomi is a microscopic water mould. It belongs to the class Oomycetes and belongs in the Kingdom Stramenopila. It is more closely related to brown algae than to true fungi. Oomycetes organisms occupy both saprophytic and pathogenic lifestyles however *P. cinnamomi* is considered parasitic. It behaves largely as a necrotrophic pathogen causing damage to the host plant's root tissues because of infection and invasion.

The life cycle of *Phytophthora cinnamomi* is a continuous circle of infection, sporulation and further infection and is readily vectored by animals and human activity allowing for rapid invasion into new areas.

3.2 Host

A population of hosts is made up of susceptible, infected and immune or resistant individuals. The infection of host plants is an unseen activity happening constantly beneath the soil at an infested site.

The environmental conditions favouring or disfavouring the pathogen may change at a critical point during disease development, temporarily changing the rates of infection and invasion. This can be observed symptomatically after soil temperature change through winter months.

The plant host is a highly variable component of the disease development. Sites may range from having no susceptible host. Within vulnerable areas, three main family groups are regarded as highly susceptible to Phytophthora Dieback disease, being:

- Proteaceae
- Ericaceae
- Xanthorrhoeaceae.

There is however a continuum of susceptibility within different species in each family, from highly susceptible to resistant to Phytophthora Dieback.

3.3 Environment

Two fundamental environmental characteristics influencing Phytophthora Dieback disease are rainfall and soil. Areas vulnerable to Phytophthora Dieback are defined as native vegetation which occur west and / or south of the 400 millimetre rainfall isohyet. The correlation of increased Phytophthora Dieback impact with increased annual rainfall is generally applicable.

Certain soil properties influence Phytophthora Dieback disease development within the vulnerable areas:

1. Moisture is critical for *Phytophthora cinnamomi* to survive in the soil and for sporangia production.
2. Soil pH affects the growth and reproduction of the pathogen. The calcareous sands closest to the coast are alkaline and hostile to *Phytophthora cinnamomi,* but are favourable to *P. multivora.*
3. Fertile soils are less favourable to Phytophthora Dieback because the richness of nutrients aids strong host resistance, good soil structure allows water movement and drainage, and high organic matter provides antagonistic microflora.
4. Coarse-textured soils have larger pore spaces which favour dispersal of spores.
5. The optimum temperature for *Phytophthora cinnamomi* sporulation is 21 to 30°C, peaking at 25°C., but some sporangia can still be produced at temperatures as low as 12°C. The optimum growth range is 15 to 30°C and temperatures lower than 5°C or

greater than 35°C are unfavourable for the persistence of survival of spores and the vegetative mycelia of *P. cinnamomi.*

4 Methods

4.1 Pre survey desktop study

Known databases of *Phytophthora* locations retained by Glevan Consulting and Vegetation Health Services (DPaW) were searched to determine previous recoveries of *Phytophthora* within the project area.

Previous Phytophthora Dieback Occurrence and vegetation community reports and maps pertaining to the study area were also studied prior to undertaking the field work.

4.2 Interpretation

Based on the considerations of Section 3 'Phytophthora Dieback', the personnel involved in the field work attempted to determine the presence of Phytophthora Dieback based on symptoms and disease signatures displayed in susceptible vegetation. These symptoms are supported (if necessary) through the strategic sampling and subsequent recovery of Phytophthora from soil and tissue samples taken during the assessment.

The detection of the plant pathogen Phytophthora Dieback involves the observation and interpretation of plant deaths (or reduction of biomass or perceived temporal change in vegetation structure) using a logical assessment of factors that imply pathogen presence above other possible causes of plant deaths or vegetation change. A combination of the following factors may indicate the presence of disease caused by *Phytophthora* Dieback or other *Phytophthora* species.

<u>Deaths of disease indicating species:</u>

An indicator species is a plant species, which is reliably susceptible to Phytophthora Dieback (i.e. will die). Common indicators include several species of *Banksia, Patersonia*, *Persoonia*, and *Xanthorrhoea*. The distribution and composition of indicator species will vary from place to place according to vegetation types.

Chronology of deaths:

As the pathogen spreads through an area, some or all susceptible plants become infected and die. Consequently there will be an age range from more recent deaths with yellowing or brown leaves through to older leafless stags to remnant stumps in the ground.

Pattern of deaths:

The topography, soil type, vegetation type and drainage characteristics of an area together with the influence of climatic patterns and disturbances will influence the shape or pattern of an infested area over time. A typical recent infestation may show a small cluster of dead indicator species which, in time, will spread to become a small circular shape 'the ulcer effect' and then begin lengthening towards natural drainage channels. A fringe of recent deaths is often seen around the edge of the infested area. Patterns may be further highlighted by a paucity of ground cover within the infested area.

Other causes of indicator species death:

Phytophthora cinnamomi is not the only agent to cause death of native vegetation. Other agents include, but are not limited to:

- other *Phytophthora* spp, *Armillaria luteobubalina*, various cankers, insects;
- drought, wind scorch, frost, salinity, water logging, fire and lightning;
- senescence, competition, physical damage;
- herbicides, chemical spills (for example fuel).

Based on the field assessment, the Project Area can be distributed to the following occurrence categories (Department of Parks and Wildlife, 2013).

Table 1 - Phytophthora Dieback occurrence categories

Vegetated area	Infested	Areas that have plant disease symptoms consistent with the presence of Phytophthora Dieback
	Uninfested	Areas free of plant disease symptoms that indicate the presence of Phytophthora Dieback.
	Uninterpretable	Areas where indicator plants are absent or too few to determine the presence or absence of Phytophthora Dieback.
	Temporarily	Areas that are sufficiently disturbed so that

	Uninterpretable	Phytophthora Dieback occurrence mapping is not possible at the time of inspection.
	Not yet resolved	Areas where the interpretation process has not confidently determined the status of the vegetation.
Non-vegetated area	Excluded	Areas devoid of vegetation are excluded from the assessment area.

4.3 Soil and tissue sampling

Suspicious sites have a representative soil and tissue sample taken to assist with the interpretation process. The laboratory result can confirm the presence of the *P. cinnamomi* pathogen. A negative result does not necessarily prove that the pathogen isn't present at the site, and should be supported by the field interpretation.

Sampling was conducted using the following procedure:

- All digging implements used were thoroughly sterilised prior to use with methylated spirits. The implements were then allowed to dry so that the integrity of the sample was not compromised.
- The area around the base of the plant/s to be sampled was cleared of vegetative matter to aid the digging process.
- The plant was dug to a satisfactory depth so that the tissue with the highest moisture content was obtained.
- Sections of the roots and stem base from all sides of the plant were taken and placed in a plastic bag. If any lesion was noticed on the tissue, it was also placed in the bag. A few handfuls of sand from various depths were also deposited in the plastic bag.
- The sample bags were irrigated with distilled water to try and simulate the optimum conditions for the *Phytophthora* to survive.
- All digging implements used were again sterilised after each sample was taken to ensure that infected soil was not transported to the next sample site.

4.4 Mapping

All field location data was collected using a hand-held non-differential GPS/PDA running ArcPad software. The expected accuracy of the unit is ± 5m. The recorded data was then transferred to a desktop computer and used to produce the relevant maps.

All location data was recorded and mapped in, and is reported in, GDA94 Zone 51.

4.5 Limitations of disease mapping

The assessment for the disease caused by Phytophthora Dieback is based on interpreting the vegetation for symptoms which can be ascribed to the disease presence. These observable factors must be present during the assessment period. Management recommendations may be included if it is considered that the disease may be cryptic, or the project area displays evidence of activities that are considered a high risk of introducing the disease.

5 Project area environmental data

As stated, the *P. cinnamomi* pathogen requires suitable environmental conditions to survive, and cause disease in susceptible vegetation communities. The environmental conditions across the project area suggest that large areas would be suitable for disease expression, if *P. cinnamomi* was present.

5.1 Rainfall

The project area is situated in the Winter rainfall zone (Figure 2, (Bureau of Meteorology, n.d.)), described as wet winters with low summer rainfall.

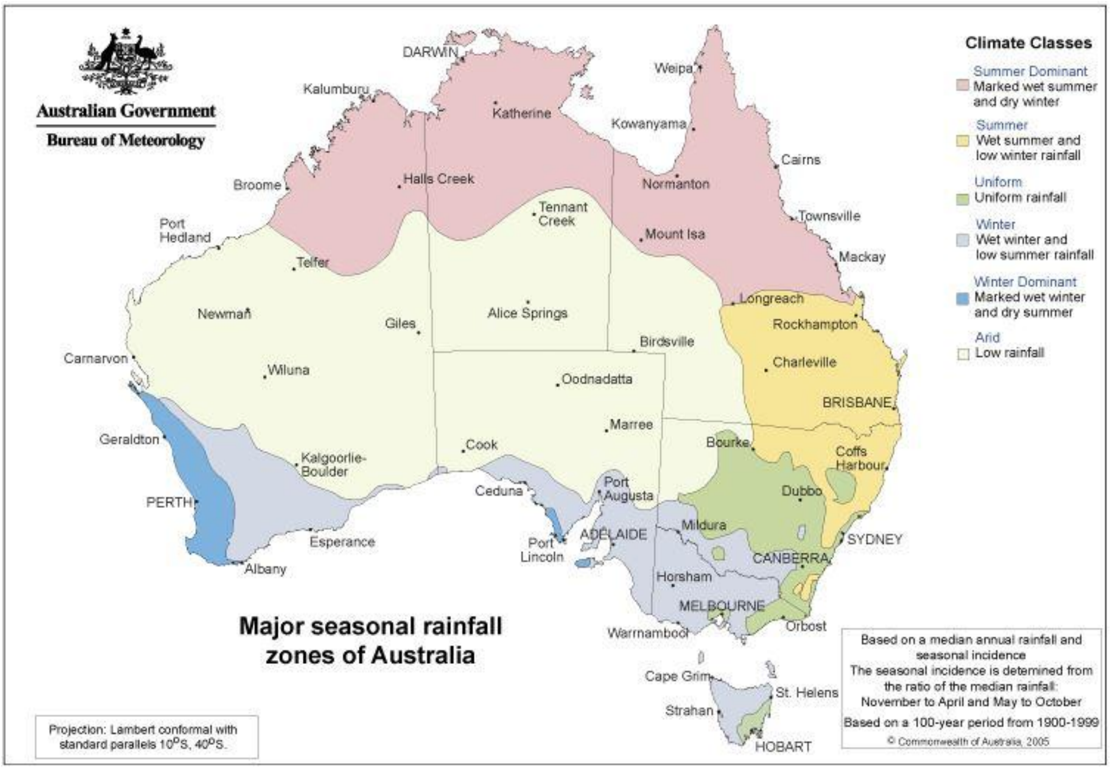

Figure 2 - Rainfall zones of project area

The annualised rainfall range across the project area (Bureau of Meteorology, n.d.), is summarised in the following Table 2, and shown spatially in Figure 12. The rainfall for the warmer months, January to April, is also shown. These months represent the conditions that (with sufficient rainfall) favour the survival of the pathogen, by providing warm and moist soils. By comparison, Dwellingup in the Darling Scarp with large areas of Phytophthora

Dieback infested forest, receives 1,242 mm of annual rainfall, and only 128.3 mm between January and April.

Table 2 - Summary of Weather Station data

Weather station	Map Ref	Annual rainfall	Rainfall (Jan-Apr)
Salmon Gums	B2	354 mm	103 mm
Oldfield	A4	494 mm	122.8 mm
Lort River	B3	356 mm	105.8 mm
Mt Ridley	C3	427 mm	135.9 mm
No Worries	E3	355 mm	122.2 mm
Sparkle Hill	E4	465 mm	140.7 mm

In the previous three years, each weather station has recorded summer rainfall events that have resulted in over 100 mm of rainfall occurring in a single month. In these events, it would be expected that overland water flow would occur allowing any pathogen present to spread with a non-contiguous pattern.

5.2 Soil types

The soil landscapes across the project area are defined by DAFWA as summarised in the following Table 3. Whilst some units contains soils which are alkaline or calcareous, many acidic soils present are suitable for Phytophthora Dieback.

Table 3 - Soil units across project area

UNIT	DESCRIPTION
Buraminya 1 Subsystem	Level to very gently undulating plain. Tertiary sediments and aeolian material (local or from interior). Grey non-cracking clays with alkaline grey shallow sandy duplex soils and calcareous loamy earths.
Buraminya 2 Subsystem	Gently sloping plain. Tertiary sediments over undulating basement rock of granite and gneiss. Calcareous loamy earths and associated alkaline grey shallow sandy duplex soils.
Buraminya 7 Subsystem	Level to gently undulating plain. Weathered Tertiary sediments & granite and gneiss. Alkaline grey shallow sandy duplex soils and Calcareous loamy earth with minor non-cracking grey clays.
Condingup 1 Subsystem	Gently undulating plain with subdued sandsheets and dunes. Aeolian sands / Pallinup formation. Pale deep sands and associated grey deep sandy

	duplex soils (some gravelly).
Esperance 2 Subsystem	Gravelly yellow mottled duplex soils, (30-80 cm sand over gravel).
Esperance 6 Subsystem	Red-brown to grey brown alluvial sands.
Halbert 1 Subsystem	Gently to undulating plain with many small playas. Lunettes and sand dunes are common on eastern side of lakes. Alkaline grey deep and shallow sandy duplex & associated salt lake soils, pale deep sands and calcareous loamy earths.
Halbert 2 Subsystem	Large level saline playas with associated lunettes on the eastern edges of lakes. Salt lake soils with associated calcareous loamy earths, pale deep sands and other soils.
Halbert 3 Subsystem	Gently undulating plain. Tertiary sediments with lacustrine sediments in many small lakes. Alkaline grey shallow and deep sandy duplex soils with associated calcareous loamy earths and pale deep sands.
Halbert 4 Subsystem	Gently undulating to undulating plain with few to common small playas. Alkaline grey shallow and deep sand duplex soils with associated calcareous loamy earths, salt lake soils and pale deep sands.
Halbert 5 Subsystem	Plain with many small playas. Lacustrine sediments / weathered Tertiary sediments. Calcareous loamy earths and alkaline grey shallow sandy duplex soils with associated salt lake soils.
Munglinup 2 Subsystem	Gently undulating plain and rises with occasional gravelly hillocks. Grey deep and shallow sandy duplex (gravelly) soils and duplex sandy gravels, associated pale deep sands some alkaline grey shallow sandy duplex soils.
Ney 1 Subsystem	Moderately inclined to steeply inclined crests and slopes of hills. Proterozoic granite and gneiss and associated colluvium. Bare rock and associated shallow sands.
Ney 2 Subsystem	Gently inclined to moderately inclined hillslopes. Proterozoic granite and gneiss and associated colluvium. Grey deep sandy duplex soils and pale deep sands with minor shallow gravel and grey non-cracking clays.
Ney 3 Subsystem	Gently inclined lower slopes of hills and associated rises. Tertiary sediments and colluvium of granite and gneiss over shallow bedrock. Grey deep sand duplex soils and pale deep sands with minor shallow gravel.
Oldfield 1 Subsystem	Undulating rises and plains in places increasing to rolling rises with incised ephemeral streams. Alkaline grey shallow sandy duplex, minor grey shallow sandy duplex, duplex sandy gravels, and reddish brown non-cracking clays.
Oldfield 4 Subsystem	Very gently undulating plain increasing to gently undulating rises near creeklines. Grey shallow sand duplex soils usually alkaline with minor grey shallow loamy duplex soils, reddish brown non-cracking clays and bare rock.

Salmon Gums 1 Subsystem	Level plain or plateau of low relief and poor external drainage and extensive Gilgia microrelief. Alkaline grey shallow sandy duplex soils and calcareous loamy earths with minor noncracking clays.
Salmon Gums 2 Subsystem	Very gently inclined scarp with external drainage via a well developed network of incipient streams. Alkaline grey shallow sandy duplex soils and calcareous loamy earths with minor non-cracking clays and bare rock.
Salmon Gums 4 Subsystem	Gently inclined to moderately inclined slopes and crests of very low relief occurring in upper landscape positions. Alkaline grey shallow sandy duplex soils and duplex sandy gravels.
Scaddan 1 Subsystem	Alkaline solonetzic duplex soils.
Scaddan 2 Subsystem	Alkaline solodic duplex soils.
Scaddan 4 Subsystem	Red alkaline gradational soils.
Scaddan 6 Subsystem	Red-brown uniform siliceous sands.
Scaddan 7 Subsystem	Soil complex, S1 + S4.
Scaddan 8 Subsystem	Soil complex, S2 + S3.
Wittenoom 1 Subsystem	Moderately inclined to steeply inclined crests and slopes of hills. Proterozoic granite and gneiss and associated colluvium. Bare rock and associated stony soils.
Wittenoom 2 Subsystem	Hillslopes. Granite & gneiss & colluvium. Alkaline grey shallow sandy and loamy duplex soils with pale deep sands, minor non-cracking clays & shallow gravels.
Wittenoom 3 Subsystem	Gently inclined lower slopes and plains of hills. Sediments plus shallow colluvium of granite and gneiss. Alkaline grey shallow sandy and loamy duplex soils with pale deep sand, minor shallow gravels.
Young 1 Subsystem	Soil complex dominated by yellow to red solonetzic soils, on sloping valley sides.

5.3 Vegetation structure

The vegetation along the proposed fence alignment was assessed and mapped by Ecoscape Australia in 2013 and resulted in the mapping of 94 discreet vegetation types. Some vegetation units contain Phytophthora Dieback indicating species with varying levels of susceptibility.

6 Results

6.1 Phytophthora Dieback occurrence distribution

No Phytophthora Dieback infestations were identified during the assessment, however infestations of *P. rosacearum* (0.01% of total area) and *P. inundata* (0.1%) were observed within the study area. The majority (60.08%) of the study area was observed to be uninterpretable. An area comprising 5.86% of the study area was observed to be uninfested, while 33.96% of the study area was excluded from the field assessment (Table 4).

Table 4 - Area Summary

Category	Area (ha)	% of total area
Infested (with *P. cinnamomi*)	0 ha	0.00 %
Uninterpretable	3,808.58 ha	60.08 %
Uninfested	371.72 ha	5.85 %
P. rosacearum	0.73 ha	0.01 %
P. inundata	6.46 ha	0.10 %
Excluded	2,152.10 ha	33.96 %
TOTAL AREA	6,339.59 ha	

6.2 Disease expression and impact

Phytophthora cinnamomi

Phytophthora Dieback (disease caused by *P. cinnamomi*) was not observed in the vegetation within or immediately adjacent to the project area. The disease was observed at locations in proximity to the project area, including previously recorded infestations along South Coast Highway east of Ravensthorpe, and at sites in Cape Arid and Cape Le Grand National Parks. At each site, the disease was expressing in multiple deaths of *Xanthorrhoea platyphylla* and *Banksia speciosa* with a reasonable pattern of deaths at each site.

Phytophthora rosacearum

The infestation of *P. rosacearum* is located adjacent to Bandalup Road, near the intersection of Coujinup Road. The infestation appears restricted to a disused gravel extraction site (**Error! Reference source not found.**) with deaths noted in some individuals of *Banksia* *media*. The disease is not having a significant impact on the vegetation and the site was sampled (Sample 1, Table 5) due to the history of disturbance (Figure 4).

Phytophthora rosacearum has been recently split from the old *P. megasperma* complex (Hansen, Wilcox, Reeser, & Sutton, 2009). The pathogen has not been found widely in Western Australia but is an important pathogen of rosaceous fruit trees in North America, including apple, cherry, apricot and peach.

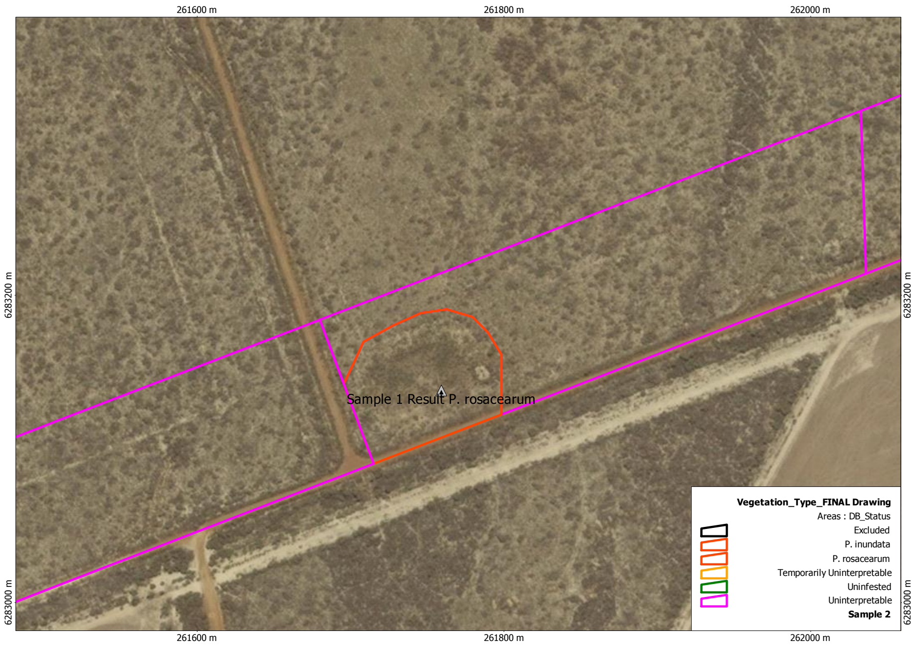

Figure 3 - *Phytophthora rosacearum* infestation

Figure 4 – View of *P. rosacearum* infestation

<u>*Phytophthora inundata*</u>

The infestation of *P. inundata* comprises an area of 6.46 ha, and is having a significant impact on the susceptible vegetation. The pathogen is normally associated with water-logged or flooded sites, and has been isolated frequently from waterways in the southwest of Western Australia (Huberli, Hardy, White, Williams, & Burgess, 2013). It has also been isolated from dead and dying native vegetation within Western Australia (Stukely, et al., 2007). Previous recoveries of *P. inundata* by Glevan Consulting have all been associated with dying remnant vegetation in water-gaining sites draining from farmland.

At the (hypothesised) originating site of this infestation (Sample 2, Table 5), the area has been disturbed with soil being moved and bunded (Figure 6) creating a ponding site. The adjacent vegetation, dominated by *Banksia speciosa* and *Xanthorrhoea platyphylla*, featured multiple deaths (Figure 7) and an obvious disease front, which was represented by the most recent deaths (Figure 8).

The infestation has spread to the firebreak, approximately 70 metres from the edge of the farmland. The vegetation on the northern side of the firebreak had been recently burnt possibly masking some disease symptoms on that side of the firebreak and making it difficult to determine the extent of the infestation. Deaths in *B. speciosa* and *X. platyphylla* were observed along the edge of the track, and it appears that the infestation has spread in a north-easterly direction along the firebreak, probably from water movement. Recent deaths in *X. platyphylla* were noted at numerous locations from the site of Sample 2 to the Sample 7 site (Figure 5). The extent of the infestation in this area has been extended arbitrarily beyond the observed symptoms, and is situated at the bounds of a low-lying area.

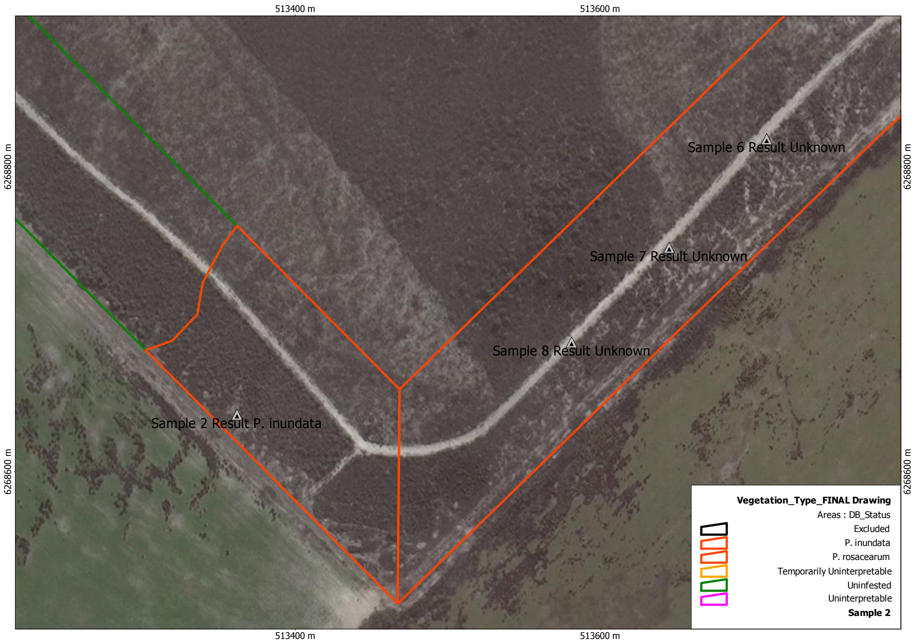

Figure 5 – Phytophthora inundata infestation

Figure 6 - Sample 2 site showing soil disturbance

Figure 7 - Sample 2 site showing age range of deaths

Figure 8 - Recent *B. speciosa* deaths on edge of infestation

6.3 Soil and tissue samples

Eight samples were taken during the field work component of the assessment (Figure 14). Five samples were taken during the initial assessment in June, while three samples were taken during the September assessment in an attempt to determine the extent of the *P. inundata* infestation.

Table 5 – Project Area Sample Summary

Sample	Plant sampled	Easting	Northing	Result
1	***B. media***	**261759**	**6283138**	***P. rosacearum***
2	***B. speciosa, X. platyphylla***	**513361**	**6268637**	***P. inundata***
3	*B. speciosa*	518235	6269501	Negative
4	*B. speciosa*	505708	6266279	Negative
5	*X. platyphylla*	506766	6266278	Negative
6	*B. petiolaris*	513709	6268818	*Phytophthora sp*
7	*X. platyphylla*	513645	6268747	*Phytophthora sp*
8	*X. platyphylla*	513581	6268685	*Phytophthora sp*

The results for Samples 6, 7 and 8 are not available at the time of drafting of the report. The results of the samples will not affect any mapping or recommendations in this report.

7 Discussion

The proposed Esperance extension to the State Barrier Fence project area covers approximately 6,340 hectares. The alignment has a survey width of 100 m (50m either side of the centre line) and the vegetation within and immediately adjacent was assessed both at a desktop level and through field interpretation.

7.1 Desktop assessment

A desktop assessment completed by Great Southern Bio logic in 2012 (Great Southern Bio Logic, 2012) assessed the likelihood of Phytophthora Dieback presence using the accepted risk factors of climate, vegetation type and currently known Phytophthora Dieback distribution. This survey was undertaken to assist in the refinement of the proposed route, and as such assessed a 10 kilometre wide corridor along the proposed route. The report determined the susceptible vegetation along the route based on all areas within the project area receiving greater than 400 mm of annual rainfall, and the Pre-European Vegetation dataset.

Vegetation associations that contained Proteaceae, Ericaceae and Xanthorrhoeaceae species would have been determined to be susceptible. This study concluded that two sections of the alignment were vulnerable to the risk of Phytophthora Dieback due to meeting the criteria that "All land with an annual average rainfall of more than 400 millimetres is considered vulnerable area. This is a large land mass stretching approximately from Perth, Bunbury and Augusta in the west to Narrogin, Ravensthorpe and Esperance in the east, and as far north as Kalbarri" (Department of Parks and Wildlife, 2013). These two sections are:

- Ravensthorpe End - from the existing fence to Neds Corner Road.
- Esperance End - Mt Ridley to Cape Arid.

This delineation of the project area resulted in the vulnerable section of the project area being 4,187.49 hectares, and 2,152.10 hectares that could be excluded from the assessment.

The same document suggests that in areas of lower rainfall, *Banksia* and *Xanthorrhoea* species should be preferred as sampled species.

The vegetation along the alignment was mapped by Ecoscape in 2013 as part of the overall project. The assessment resulted in 94 discreet vegetation communities, as well as a determination of cleared and degraded areas. An analysis of these communities was performed at a desktop level by Glevan Consulting to determine which communities contained Phytophthora Dieback indicating species that could be field interpreted. This analysis determined that the communities listed in Table 9 contained species that may display the presence of Phytophthora Dieback by an observation of patterns of deaths of the species.

The assessment area relating to these vegetation communities is summarised in the following Table 6. These vegetation communities equate to 42% of the area of the alignment in areas receiving greater than 400 mm annually (vulnerable), and 11% in the non-vulnerable section of the alignment.

Table 6 - Area of vegetation types with susceptible species

Vegetation community	Number of discreet areas (vulnerable)	Number of discreet areas (non-vulnerable)	Total Area (vulnerable)	Total Area (non-vulnerable)
AcLd	6	0	36.7 ha	0
BaMs	1	0	4.5 ha	0
BpBe	2	0	36.5 ha	0
BsBeAl	5	0	74.7 ha	0
CqAp	1	0	3.3 ha	0
EaCqLb	2	0	18.4 ha	0
EdMpLsp	1	1	17.5 ha	3.4 ha
EeAl	5	0	103.0 ha	
EeGbMs	4	0	152.7 ha	
EeMeLd	3	3	6.4 ha	10.7 ha
EeMsGa	46	21	972.8 ha	565.5 ha
EePmHh	10		106.5 ha	
EgAs	6	5	39.3 ha	37.5 ha
EiAiMe	0	6	0 ha	45.4 ha
EkBmPm	3		20.5 ha	

ElMsSm	15		401.8 ha	
ElPmGa	8		78.5 ha	
ElPmSm	3		61.6 ha	
EpAh	2		10.5 ha	
EpBmMs	14	1	130.2 ha	28.1 ha
EpMhGa	6		102.7 ha	
EsBpLt	1		4.1 ha	
EspMhLsp	2		9.2 ha	
EspPmCl	1		2.7 ha	
EtMuGsp	4		50.9 ha	
EuMtDl	5		68.0 ha	
HcBe	5		159.4 ha	
Total interpretable area			2672.2 ha	690.6 ha

7.1.1 Determination of Vulnerable areas

Whilst the accepted zone vulnerable to Phytophthora Dieback is areas receiving greater than 400mm of annual rainfall, a document produced by South Coast NRM to develop a priority system for areas protectable from Phytophthora Dieback suggested that “regions within the 300mm and 400mm rainfall isohyets receiving high summer rainfall (above 50mm)” would be included in the analysis (South Coast NRM, 2014). This assumption is made based on the warm, moist conditions favoured by the pathogen and that significant summer rainfall events could provide the environmental conditions necessary in areas of generally lower rainfall.

A research of Bureau of Meteorology data (Bureau of Meteorology, n.d.) shows that in the previous ten years, Salmon Gums (annual rainfall 354 mm) has experienced a total of four summer months (January – April) of greater than 100mm of rainfall. Similar events have been recorded from the Mt Ridley (427 mm annual rainfall, 5 summer rainfall events), Lort River (356 mm, 3) and No Worries (355, 2) meteorological stations. To cover this scenario, Glevan Consulting additionally assessed ‘susceptible’ vegetation in the non-vulnerable area to ensure Phytophthora Dieback symptoms were not present in these areas. These areas are still mapped as being Excluded to simplify the mapping and management.

7.2 Field Assessment

7.2.1 Determination of interpretable areas

The interpretability of an area is dependent on which susceptible species are present at the site, the density of those species, and any disturbance present that may mask disease symptoms, e.g. burnt or scrub-rolled. The presence of multiple species provides greater assurance that Phytophthora Dieback symptoms may be observed, due to the variance of susceptibility in species.

During the June field visit, the alignment from the Ravensthorpe end to Fields Road, and from Dempster Road to Fisheries Road, were assessed to observe Phytophthora Dieback symptoms (if present), and correlate the interpretability of the vegetation communities with the indicator species present.

Whilst it is a general statement that Banksias can be used as a reliable indicator of the presence of Phytophthora Dieback, its reliability is a continuum of from species that are very reliable to those that are almost resistant. An analysis of the Banksia and Dryandra families was undertaken (Shearer, Crane, & Cochrane, 2013) which showed that some Banksia species present along the alignment appear to be not very susceptible to *P. cinnamomi* in glasshouse trials.

Banksia media occurs along many sections of the alignment, and in the glasshouse study showed only a 4% mortality rate. For this reason, sections of vegetation with occasional *Banksia media* would not be considered interpretable. Alternatively, *Banksia speciosa* showed a mortality rate of 53% and also showed a defined disease expression in the *P. inundata* infestation.

Research of the susceptibility continuum of *Hibbertia* species has been published, but data on other families present on the alignment is not yet available. A search of the VHS database on sample recoveries for each species does show the efficacy of some species as Phytophthora Dieback indicators. This data does not support any inference of mortality of the species, but recoveries of *P. cinnamomi* from the samples does show that the species will display the presence of Phytophthora Dieback. The species present in the alignment, and in the sample database include *Adenanthos cuneatus* (8 positive recoveries from 23 samples), *Banksia armata* (1,2), *B. media* (21,185), *B. nutans* (7,68), *B. pulchella* (2,4), *B. speciosa* (91,245), *Isopogon trilobus* (3,17) and *Xanthorrhoea platyphylla* (42,152).

This assessment determined that, of the vegetation communities that contained susceptible species, only the BaMs, BpBe, BsBeAl, EeAl and HcBe types contained reliable Phytophthora Dieback indicating species in a richness and density that would allow the disease to be confidently observed, if present. The following Table 7 gives reason for the interpretability of these vegetation types. None of these vegetation communities appear in the non-vulnerable section of the alignment.

Table 7 - Interpretable Communities

Vegetation type	Species present (with Banksia mortality rate)	Reasons for interpretability
BaMs	*Banksia armata* var. *armata (17%), Xanthorrhoea platyphylla*	Multiple species present, including *X. platyphylla* which has been a reliable disease indicator in other nearby surveys by Glevan Consulting.
BpBe	*Banksia pilostylis (4%), Adenanthos cuneatus, Banksia petiolaris (13%), Leucopogon crassifolius*	Multiple species present.
BsBeAl	*Banksia speciosa (53%), Leucopogon crassifolius, Banksia petiolaris (13%), Stirlingia anethifolia, Banksia pilostylis (4%)*	Multiple species present.
EeAl	*Banksia repens (0%), Xanthorrhoea platyphylla*	Presence of *X. platyphylla*.
HcBe	*Leucopogon crassifolius, Adenanthos cuneatus, A. dobsonii, Andersonia parvifolia, Banksia nutans* var. *nutans (62%), B. obovata (18%), B. obtusa (unknown), B. petiolaris (13%), B. pulchella (88%), B. repens (0%), B. tenuis* var. *tenuis (38%), Isopogon* sp. Fitzgerald River (D.B. Foreman 813), *I. trilobus, Patersonia lanata* forma *lanata, Petrophile teretifolia, Stirlingia anethifolia*	Multiple species present.

7.2.2 Assessment of interpretable areas

The alignment (except for approximately 70 kilometres each side of Salmon Gums, the non-vulnerable section) was assessed for the presence of Phytophthora Dieback by Evan Brown of Glevan Consulting. This field assessment largely supported the findings of the desktop evaluation regarding the extent of interpretable areas. The area considered interpretable based on the presence of indicators was 378.1 hectares and was bound by Henkes Road in the west, to the finish point on Fisheries Road (Figure 11).

Within the interpretable areas, the possible presence of Phytophthora Dieback was determined by the observation of fresh deaths of indicator species associated with a pattern of deaths, and / or an avenue of introduction of the disease, e.g. tracks, water courses or disturbance activities.

No infestations of *P. cinnamomi* were observed on the alignment. This result was not unexpected due to the remoteness of the project area and the distance to existing infestations.

The infestation of *P. rosacearum* is confined to a disused gravel extraction site. It is possible that the pathogen was introduced into the area as a result of rubbish dumping. Whilst the impact of this pathogen on Western Australian vegetation is not well understood, it is known to be a significant pathogen of rosaceous fruit trees. This location will require a level of hygiene procedures to mitigate any spread of the pathogen. This infestation has not been demarcated however signage on Bandalup Road should be used to inform the road users of the hygiene procedures.

The infestation of *P. inundata* is having a significant impact on the remnant vegetation at the site, particularly the *B. speciosa* and *X. platyphylla*. The disease has probably entered the vegetation from the adjacent farmland and has been exacerbated by the drainage and the soil movement at the site.

The infestation appears to be spreading via overland water flow along the firebreak, with many fresh dead *X. platyphylla* observed along the bund of the track and immediately adjacent to the track. This infestation, being on both sides of the firebreak, will also be spread by uncontrolled use of the track in moist-soil conditions or by the unhygienic maintenance of the track.

The vegetation on the north-eastern side of the track had been recently burnt making it difficult to determine the extent of the disease in this vegetation. This infestation has not been demarcated due to the difficultly in determining the disease boundary in the burnt vegetation. Signage should be placed on the track to inform the track users of the hygiene procedures.

8 Recommendations

A detailed management plan designed to mitigate the possible introduction of Phytophthora cinnamomi into the project area should be developed prior to construction activities commence. This plan will take into account the direction of construction, construction stages and timing, and the disturbance footprint.

Prior to construction, and for general access on the alignment, the following hygiene procedures should be considered.

P. rosacearum site	Erect signage at the site to discourage the movement of vehicles or extraction of material from the pit. Bandalup Road is well-formed at the site and the use of the track can be unrestricted.
P. inundata site	Install signage on the firebreak, and the pathway between the farmland and vegetation to provide information on the hygienic vehicle movement through the site. The signs should be placed at:

Western end	513341mE 6268729mN, and 513287mE 6268696mN.
Eastern end	513812mE 6268904mN, and 513821mE 6268860mN.

The following Clean on Entry (COE) points are suggested for the hygienic access of the route by vehicles. The Table 8, and shown spatially in Figure 13 below shows the COE number and the direction of travel that will require a clean down. The COE points have been suggested at locations where the fence alignment interacts with public thoroughfares where hygiene cannot be controlled. At these points, vehicles and machinery should be clean upon entry. In addition;

- Soil and plant material of infested or unknown dieback status should not be introduced to uninfested or temporarily uninterpretable sections of the study area.
- Soil and plant material should not be transported from the infested or temporarily uninterpretable sections of the study area for use at any other protectable area site.
- If possible, restrict access to dry soil conditions only. Where vehicles or machinery are required to access the study area during, or shortly after rainfall, they must carry

clean down equipment, and remove any soil or plant material at designated hygiene points.

Table 8 - COE Point Locations

COE	Direction of travel	Map reference	Description
1	N	E4	Entering alignment from Fisheries Road
2	NE	E4	Exiting P. inundata site
3	NW	E4	Exiting P. inundata site
4	SE	E4	Entering alignment from Balladonia Road
5	N	E4	Entering alignment from Fisheries Road
6	NE	E3	Entering alignment from Bebenorin Road
7	SE	E3	Entering alignment from Henkes Road
8	SE	E3	Entering alignment from Muntz Road
9	SE	E2	Entering alignment from Parmango Road
10	NW	E2	Entering alignment from Parmango Road
11	NE	D3	Entering alignment from intersection of Mount Ney Road and Howick Road
12	W	D3	Entering alignment from Mount Ney Road
13	SE	C2	Entering alignment from Dempster Road
14	NE	C2	Entering alignment from Ridley Road
15	NW	B2	Entering alignment from Rollond Road
16	NE	B2	Entering alignment from Rollond Road
17	NW	B2	Entering alignment from Rollond Road
18	NW	A3	Entering alignment from Rollond Road
19	NW	A3	Entering alignment from West Point Road Road
20	NW	A3	Entering alignment from West Point Road Road
21	N	A3	Entering alignment from Coujinup Road
22	W	A3	Entering alignment from West Point Road Road

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10 Appendix – Maps

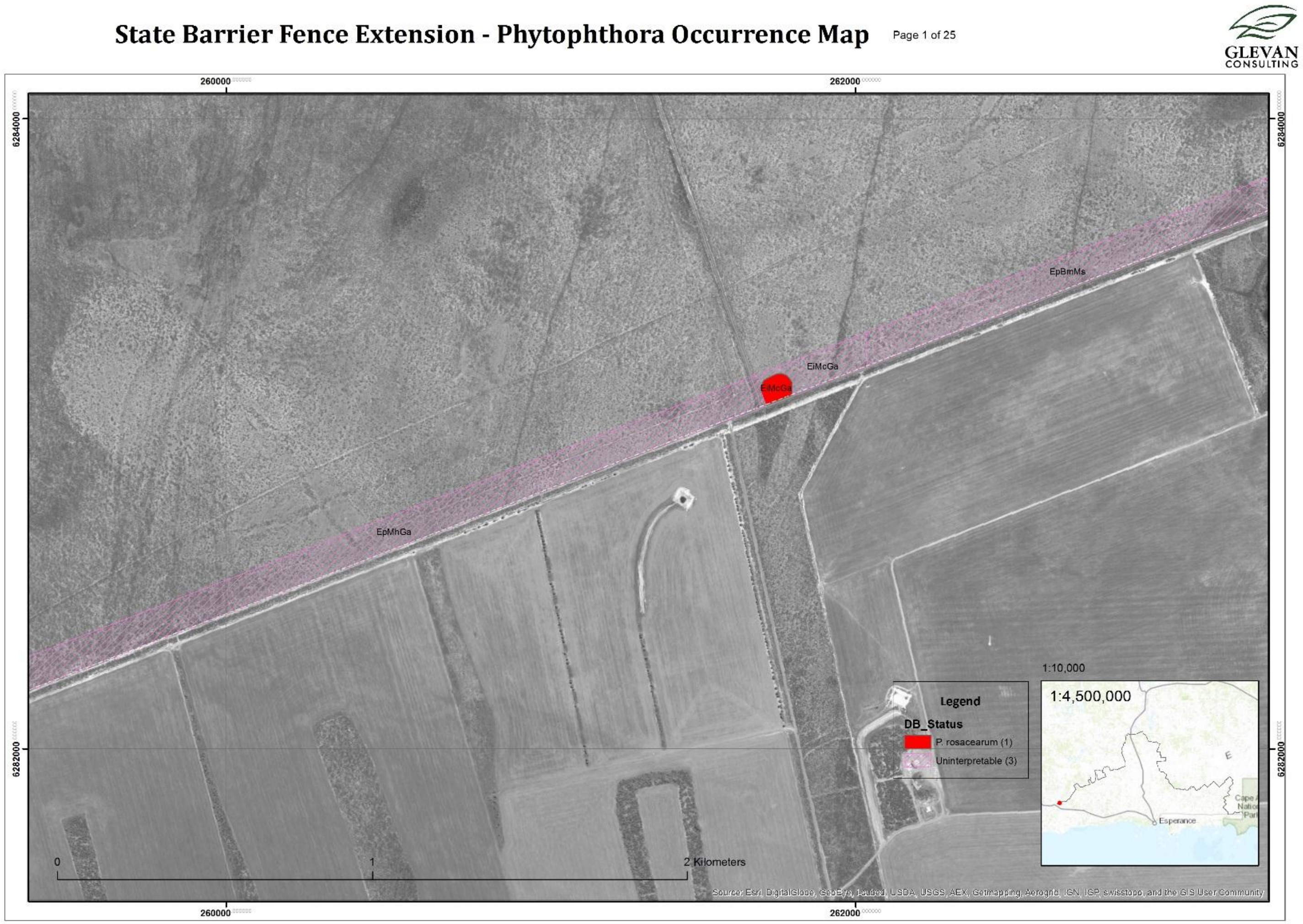

Figure 9 – *P. rosacearum* Infestation

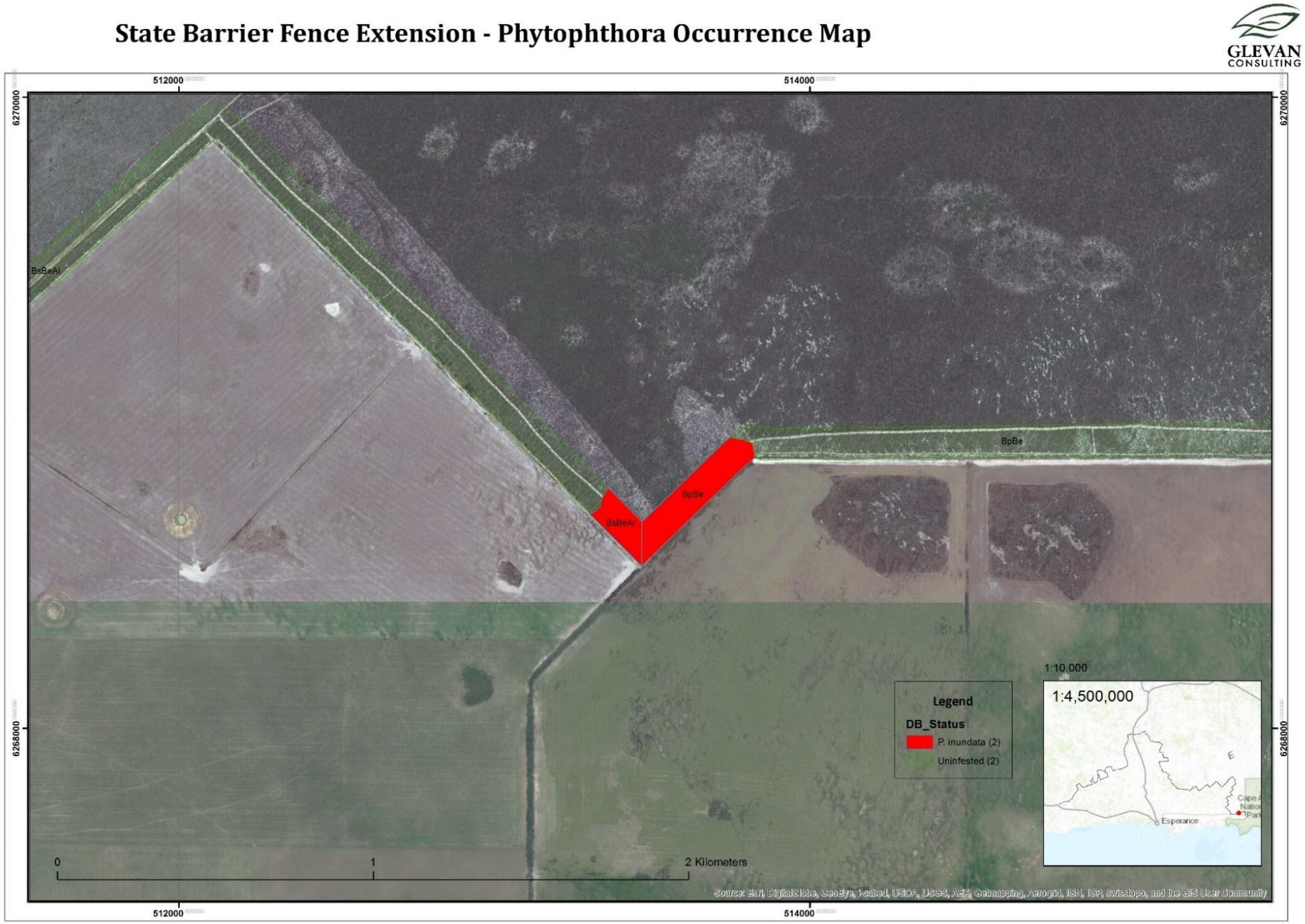

Figure 10 - *P. inundata* infestation

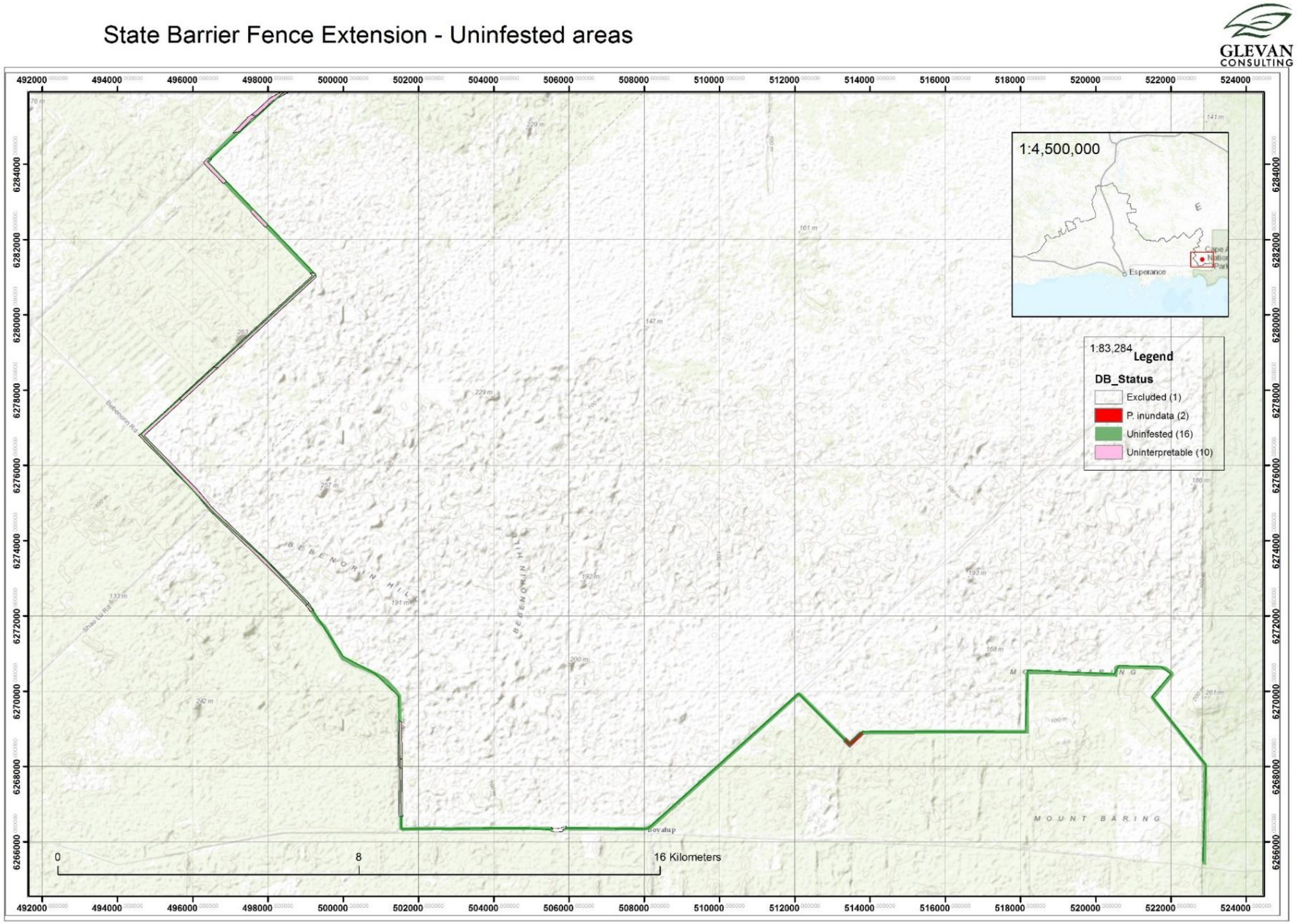

Figure 11 - Uninfested areas of project area

State Barrier Fence Extension - Rainfall data

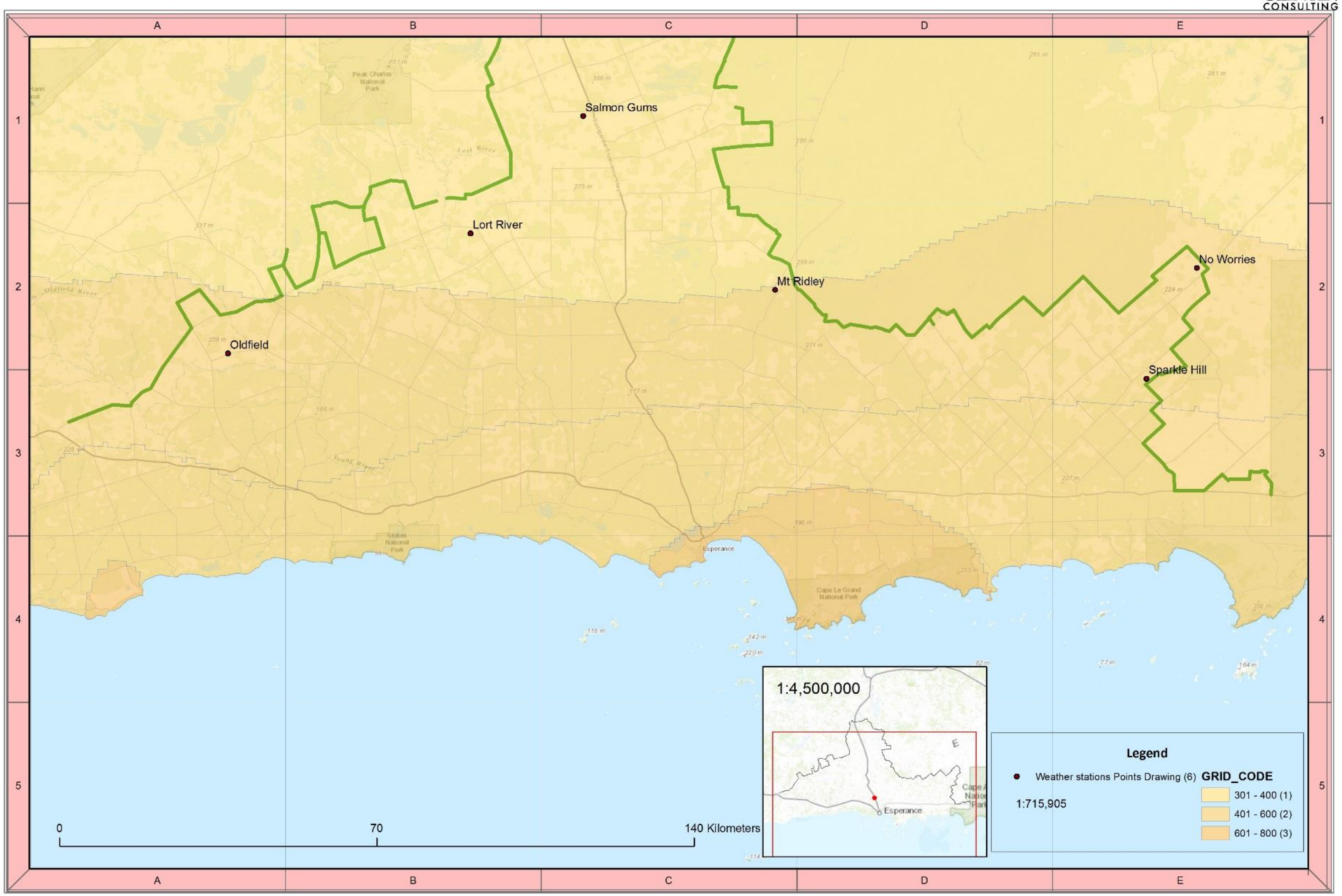

Figure 12 - BOM Weather Stations

State Barrier Fence Extension - Suggested COE Points

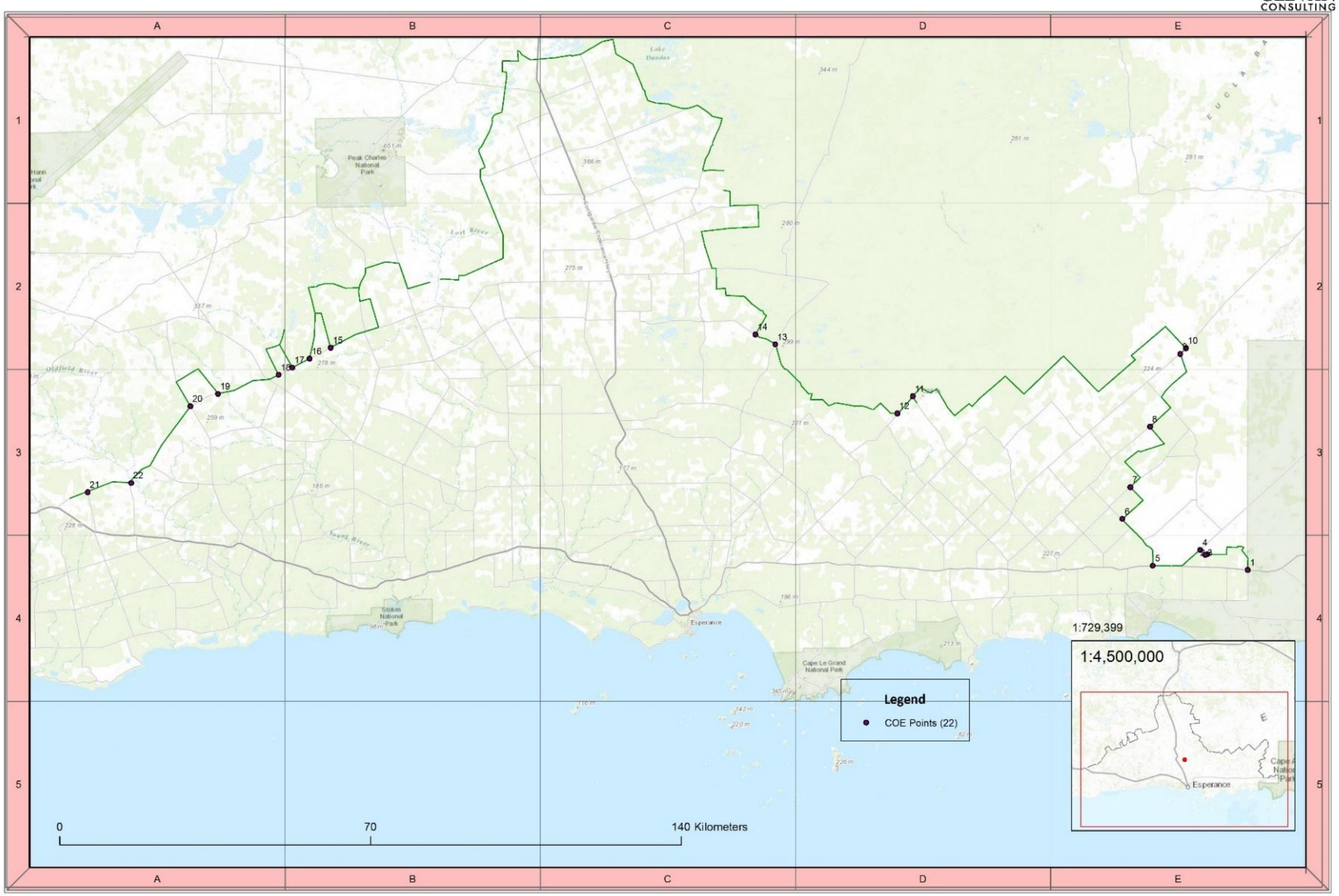

Figure 13 - COE Locations

State Barrier Fence Extension - Sample locations

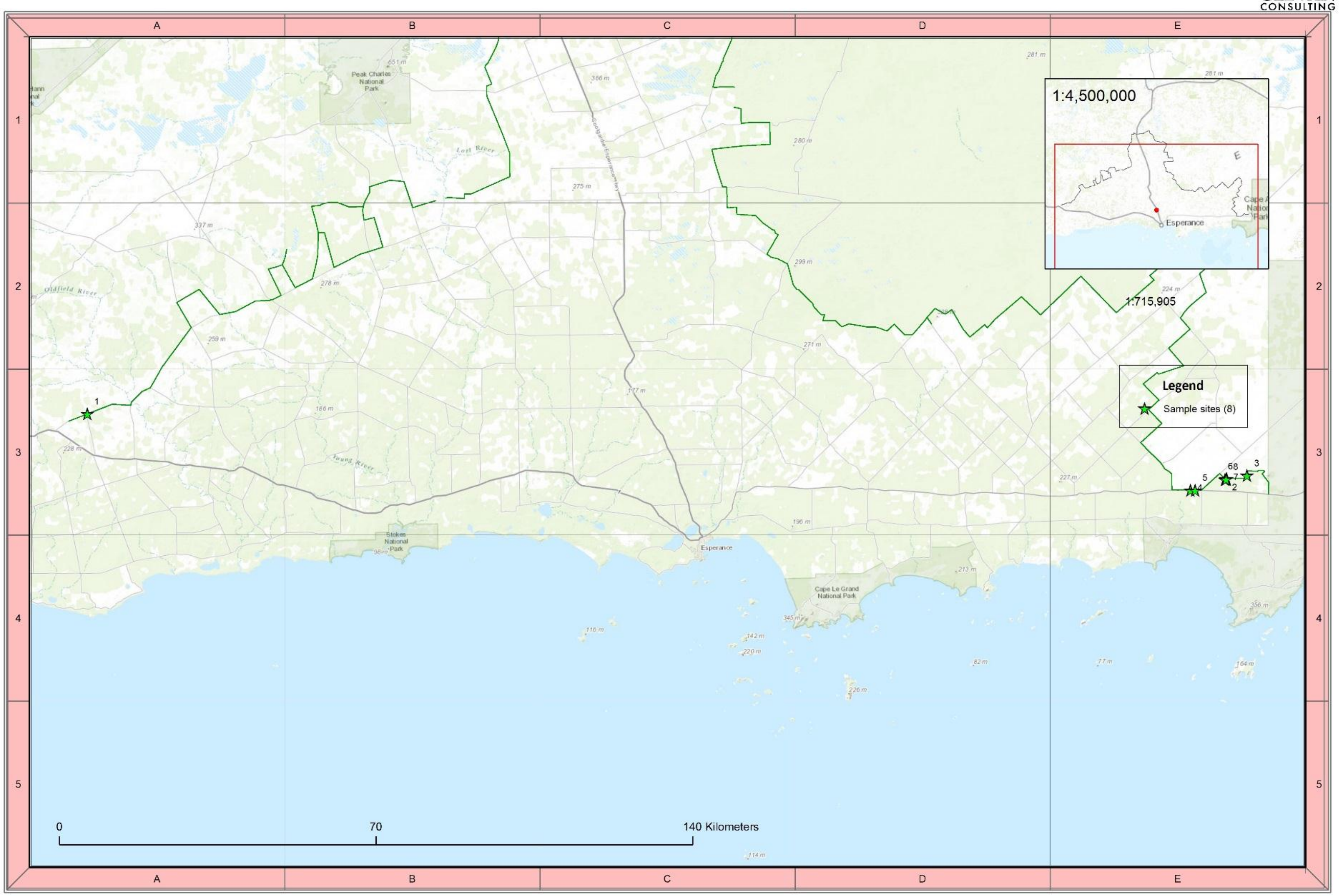

Figure 14 - Sample location

11 Appendix – Vegetation communities with susceptible species.

All species in bold in Table 9 are from the Proteaceae, Ericaceae or Xanthorrhoeaceae families.

Table 9 - Vegetation communities containing susceptible species

Vegetation code	Description	Other common species
AcLd	*Allocasuarina campestris, Melaleuca uncinata* and *Acacia mimica* var. *angusta* mid shrubland over *Lepidosperma drummondii, Platysace effusa* and *Hibbertia gracilipes* low open sedgeland/ shrubland	*Astus tetragonus, Callitris preissii, Calothamnus quadrifidus subsp. quadrifidus, Calytrix breviseta subsp. stipulosa, Cryptandra myriantha, Dampiera sacculata, Darwinia* sp. Mt Ney Virgate (A.S. George 15837), *Eucalyptus grossa, E.* sp. Fraser Range (D. Nicolle 2157), *Gastrolobium discolor, Gompholobium confertum, Laxmannia paleacea, Lepidosperma ?resinosum, Leptospermum incanum,* ***Leucopogon cuneifolius****, Levenhookia pusilla, Melaleuca glaberrima, Neurachne alopecuroidea, Philotheca gardneri subsp. gardneri, Platysace effusa, Poranthera microphylla, Schoenus breviculmis, Spartochloa scirpoidea, Stylidium breviscapum, Thryptomene australis subsp. brachyandra, Verticordia eriocephala*
BaMs	***Banksia armata* var. *armata***, *Melaleuca striata* and *Grevillea baxteri* mid open shrubland over *Melaleuca scabra,* ***Xanthorrhoea platyphylla*** and *Lepidosperma* sp. low shrubland	*Beaufortia empetrifolia, Conothamnus aureus, Eucalyptus extrica, Hakea prostrata,* ***Leucopogon crassifolius****, Mesomelaena stygia* subsp. *stygia, Taxandria spathulata*
BpBe	***Banksia pilostylis*** and ***Adenanthos cuneatus*** mid open shrubland over *Beaufortia empetrifolia, Hypolaena humilis* and *Melaleuca scabra* low shrubland/ rushland	***Banksia petiolaris****, Eucalyptus extrica, Gahnia trifida,* ***Leucopogon crassifolius****, Melaleuca pulchella, M. striata*
BsBeAl	***Banksia speciosa*** and *Hakea obliqua* subsp. *obliqua* tall shrubland over *Beaufortia empetrifolia,* ***Leucopogon crassifolius*** and *Melaleuca striata* mid open shrubland over *Anarthria laevis,* ***Banksia petiolaris*** and ***Stirlingia anethifolia*** low open rushland/ shrubland	*Acacia cochlearis, A. nigricans,* ***Banksia pilostylis****, Grevillea baxteri*
CqAp	*Calothamnus quadrifidus, Acacia assimilis* subsp. *atroviridis* and *Grevillea teretifolia* mid open shrubland over *Acacia pinguiculosa* subsp. *teretifolia, Cryptandra graniticola,*	*Acacia acanthoclada* subsp. *acanthoclada, Allocasuarina campestris, Amphipogon turbinatus, Astroloma serratifolium, Brachyloma geissoloma, Calytrix leschenaultii, Cassytha glabella, Chorizema aciculare* subsp. *aciculare, Conostylis argentea, Dampiera lavandulacea, D. sacculata, Daviesia*

	Lepidosperma rigidulum low shrubland/ sedgeland	*pachyphylla, Dodonaea caespitosa, Goodenia scapigera subsp. scapigera, Grevillea disjuncta, G. nudiflora, Hibbertia pungens, Kunzea affinis, Lepidosperma drummondii, Leptospermum maxwellii*, ***Leucopogon brevicuspis*, *L. concinnus*, *L. cuneifolius*, *L. fimbriatus*, *L. tamminensis* var. *australis*,** *Lysinema pentapetalum, Melaleuca eurystoma, M. glaberrima, M. hamata, M. sapientes, M. societatis, Neurachne alopecuroidea, Opercularia vaginata*, ***Petrophile fastigiata***, *Pimelea imbricata* var. *piligera, Platysace effusa, Santalum acuminatum, Schoenus breviculmis, Spartochloa scirpoidea, Stylidium dichotomum, Thryptomene australis subsp. brachyandra, Thysanotus ?patersonii, Verticordia acerosa* var. *preissii, V. chrysantha*
EaCqLb	*Eucalyptus angulosa* mid open woodland over *Calothamnus quadrifidus* and ***Banksia media*** mid open shrubland over ***Leucopogon breviflorus***, *Cyathostemon* aff. *tenuifolius* and *Schoenus subfascicularis* low open shrubland/ sedgeland	
EdMpLsp	*Eucalyptus dissimulata* subsp. *dissimulata* and *E. scyphocalyx* mid mallee woodland over *Melaleuca plumea, M. hamata* and *M. sapientes* mid shrubland over *Lepidosperma* sp. Bandalup Scabrid (N. Evelegh 10798), ***Leucopogon* sp. Coujinup (M.A. Burgman 1085)** and *Hibbertia* sp. low open sedgeland/ shrubland	
EeAl	*Eucalyptus extrica, Grevillea baxteri* and *Hakea obliqua* subsp. *obliqua* low open mallee shrubland/ shrubland over *Anarthria laevis, Mesomelaena stygia* subsp. *stygia* and ***Banksia repens*** low sedgeland/ shrubland	*Beaufortia empetrifolia, Calothamnus gracilis, Caustis dioica, Conothamnus aureus, Daviesia apiculata, Melaleuca pulchella, M. striata, Mesomelaena stygia* subsp. *stygia, M. tetragona*, ***Xanthorrhoea platyphylla***
EeGbMs	*Eucalyptus extrica* low sparse mallee shrubland over *Grevillea baxteri, Daviesia apiculata* and ***Adenanthos cuneatus*** mid open shrubland over *Mesomelaena stygia* subsp. *stygia, Beaufortia empetrifolia* and *Calothamnus gracilis* low sedgeland/ shrubland	*Anarthria laevis*, ***Banksia repens***, *Calytrix decandra, Conothamnus aureus, Eucalyptus angulosa, Hakea cinerea, H. obliqua* subsp. *obliqua, H. prostrata*, ***Isopogon* sp. *Fitzgerald River (D.B. Foreman 813)***, *Leptospermum spinescens, L. crassifolius, Melaleuca scabra, M. striata, M. tuberculata* var. *macrophylla*, ***Petrophile teretifolia*, *Stirlingia anethifolia***, *Taxandria spathulata*
EeMeLd	*Eucalyptus eremophila* mid open woodland over *Melaleuca exuvia, M. thyoides* and *Cyathostemon* cf. ambiguus tall open shrubland over *Lepidosperma drummondii, Darwinia* sp. Karonie (K. Newbey 8503) and *Microcybe multiflora* subsp. *baccharoides* low open sedgeland/ shrubland	*Aotus* sp. Dundas (M.A. Burgman 2835), ***Leucopogon hamulosus*, *Lomandra effusa***, *Melaleuca subalaris*

EeMsGa	*Eucalyptus eremophila, E. flocktoniae* and *E. scyphocalyx* low woodland/ mallee woodland over *Melaleuca societatis, M. sapientes* and *M. teuthidoides* mid shrubland over *Gahnia ancistrophylla, Spyridium minutum* and *Comesperma spinosum* low open sedgeland/ shrubland	*Acacia binata, A. crassuloides, A. hadrophylla, A. mutabilis* subsp. *mutabilis, A. octonervia, A. patagiata, A. sorophylla, Alyogyne hakeifolia, Aotus* sp. Southern Wheatbelt (C.A. Gardner & W.E. Blackall 1412), *Baeckea latens,* ***Banksia media****, Boronia baeckeacea* subsp. *baeckeacea, B. inornata* subsp. *leptophylla, Bossiaea leptacantha, Coopernookia polygalacea, C. strophiolata, Cyathostemon* sp., *Daviesia benthamii* subsp. *acanthoclona, Daviesia campephylla, D. lancifolia, Dillwynia divaricata, Dodonaea bursariifolia, Eucalyptus conglobata, E. cylindriflora, E. extensa, E. leptocalyx, E. luculenta, E.s pileata, E. platypus, E. stoatei, E. suggrandis* subsp. *suggrandis, E. uncinata, E. urna, Eutaxia lutea, Gahnia aristata, Grevillea huegelii, G. oligantha, G. pectinata, G. plurijuga* subsp. *plurijuga, Hakea commutata, Halgania andromedifolia, Hibbertia exasperata, H. psilocarpa, Leptomeria pachyclada, Logania stenophylla, Melaleuca bromelioides, M. cucullata, M. glaberrima, M. hamata, M. lateriflora, M. marginata, M. pauperiflora* subsp. *pauperiflora, M. podiocarpa, M. rigidifolia, M. undulata, Microcorys glabra* var. *glabra, Micromyrtus elobata* subsp. *scopula, Phebalium obovatum, Prostanthera serpyllifolia* subsp. *microphylla, Pultenaea ?arida, P. spinulosa, Spyridium mucronatum* subsp. *mucronatum, Westringia cephalantha* var. *caterva, W. dampieri, W. rigida*
EePmHh	*Eucalyptus extrica, E. angulosa* and *E. leptocalyx* mid open mallee shrubland over *Phymatocarpus maxwellii, Beaufortia empetrifolia* and *Melaleuca pulchella* mid shrubland over *Hypolaena humilis, Acacia crispula* and *Anarthria laevis* low open rushland/ shrubland	***Banksia media, B. repens****, Beaufortia schaueri, Calothamnus gracilis, Conothamnus aureus, Cyathostemon* aff. *tenuifolius, Dampiera lavandulacea, Daviesia apiculata, Eucalyptus uncinata, Gahnia ancistrophylla, Grevillea oligantha, G. pectinata, Hakea cinerea,* ***Isopogon* sp. Fitzgerald River (D.B. Foreman 813)**, *Melaleuca lateriflora, M. scabra, M. societatis, Mesomelaena stygia* subsp. *stygia, Micromyrtus elobata* subsp. *scopula, Neurachne alopecuroidea*
EgAs	*Eucalyptus grossa, Melaleuca uncinata* and *Calothamnus quadrifidus* subsp. *quadrifidus* mid shrubland over *Acacia sulcata* var. *platyphylla, Lepidosperma drummondii* and *Cryptandra minutifolia* subsp. *brevistyla* low open shrubland/ sedgeland	*Acacia evenulosa, Allocasuarina campestris, Aluta appressa, Baeckea latens,* ***Banksia elderiana****, Boronia inconspicua, Callitris roei, Calytrix breviseta* subsp. *stipulosa, Coopernookia strophiolata, Dampiera* sp., *Daviesia benthamii* subsp. *acanthoclona, Dillwynia divaricata, Dodonaea caespitosa, Drummondita hassellii, Eucalyptus conglobata, E. perangusta, Eutaxia lutea, Grevillea aneura, G. oncogyne, Hakea bicornata, H. commutata, H. laurina, H. lissocarpha, Hibbertia gracilipes, Lepidosperma ?resinosum, L.* aff. *brunonianum, L.* sp. Bandalup Scabrid (N. Evelegh 10798), *Leptospermum* sp., ***Leucopogon cuneifolius, L. obtusatus, L.* sp. Coujinup (M.A. Burgman 1085), *L.* sp. Kau Rock (M.A. Burgman 1126)**, *Lysinema pentapetalum, Melaleuca rigidifolia, M. undulata, Mirbelia granitica, Neurachne alopecuroidea, Olax benthamiana,* ***Petrophile fastigiata****, Platysace effusa, Pultenaea indira* subsp. *indira, Rytidosperma setaceum, Schoenus breviculmis, Spyridium minutum, Trymalium myrtillus* subsp. *myrtillus, Verticordia chrysantha, V. eriocephala*
EiAiMe	*Eucalyptus incrassata* and *E. uncinata* tall mallee woodland over ***Adenanthos ileticos****,* ***Banksia media*** and *Phymatocarpus*	*Acacia triptycha, Baeckea crassifolia, Beaufortia empetrifolia, Calytrix duplistipulata, Darwinia luehmannii, Hakea cinerea, H. multilineata, Melaleuca plumea*

	maxwellii mid open shrubland over *Micromyrtus elobata* subsp. *scopula* and *Darwinia polycephala* low sparse shrubland	
EkBmPm	*Eucalyptus kessellii, E. pleurocarpa* and *E. pileata* mid open mallee shrubland over ***Banksia media*** mid sparse shrubland over *Phymatocarpus maxwellii, Melaleuca pulchella* and *Daviesia lancifolia* low shrubland	***Banksia blechnifolia***, *Darwinia* sp. Lake Cobham (K. Newbey 3262), *Eucalyptus flocktoniae, E. incrassata, Gahnia aristata, Melaleuca ?plumea*, Restionaceae sp.
ElMsSm	*Eucalyptus leptocalyx, E. uncinata* and *E. varia* subsp. *varia* mid open mallee shrubland over *Melaleuca societatis* and *M. glaberrima* mid shrubland over *Spyridium mucronatum* subsp. *mucronatum, Boronia inornata* subsp. *leptophylla* and *Gahnia ancistrophylla* low open shrubland/ sedgeland	*Aotus* sp. Southern Wheatbelt (C.A. Gardner & W.E. Blackall 1412), ***Banksia media***, *Comesperma spinosum, Coopernookia strophiolata, Cyathostemon* aff. *tenuifolius, Daviesia benthamii* subsp. *acanthoclona, Eucalyptus ?pileata, E. luculenta, Eutaxia lutea, Grevillea oligantha, G. pectinata, G. plurijuga, Melaleuca hamata, M. lateriflora, M. podiocarpa, M. thyoides, Micromyrtus elobata* subsp. *scopula, Nematolepis phebalioides, Pultenaea elachista*
ElPmGa	*Eucalyptus leptocalyx, E. pleurocarpa* and *E. micranthera* mid open mallee shrubland over *Phymatocarpus maxwellii, Melaleuca pulchella* and *M. plumea* mid shrubland over *Gahnia ancistrophylla* and *Boronia crassifolia* low open sedgeland/ shrubland	***Banksia media***, *Hakea cinerea, Cyathostemon* aff. *tenuifolius*
ElPmSm	*Eucalyptus leptocalyx, E. uncinata* and *E. angulosa* mid open mallee shrubland over *Phymatocarpus maxwellii, Melaleuca societatis* and ***Banksia media*** mid shrubland over *Spyridium mucronatum* subsp. *mucronatum, Microcybe pauciflora* subsp. *pauciflora* and *Conostephium drummondii* low open shrubland	*Cyathostemon* aff. *tenuifolius, Leptomeria pachyclada, Lissanthe rubicunda, Melaleuca plumea, M. undulata, Micromyrtus elobata* subsp. *scopula*, ***Persoonia teretifolia***
EpAh	*Eucalyptus pleurocarpa* and *E. tumida* mid sparse mallee shrubland over *Allocasuarina humilis, Melaleuca hamata* and ***Banksia armata* var. *armata*** low open shrubland	*Acacia gonophylla, Amphipogon turbinatus, Boronia crassifolia, Calytrix breviseta subsp. stipulosa, Chorizema aciculare subsp. aciculare, Daviesia lancifolia, Desmocladus myriocladus, Eutaxia lutea, Gompholobium baxteri, G. marginatum, Goodenia pterigosperma, Grevillea oncogyne, Hakea corymbosa, H. lissocarpha, Hypolaena humilis, Lasiopetalum rosmarinifolium, Lepidosperma* aff. *brunonianum*, ***Leucopogon cuneifolius***, ***Lomandra mucronata***, *Lysinema pentapetalum, Melaleuca glaberrima, M. rigidifolia, Mesomelaena stygia* subsp. *stygia, Monotaxis paxii, Neurachne alopecuroidea, Opercularia vaginata, Pimelea erecta, Platysace effusa, Schoenus pleiostemoneus, Schoenus racemosus, Schoenus subflavus* subsp. hispid culms (K.R. Newbey 8278), *Spyridium minutum, Stenanthemum ?emarginatum, Stylidium piliferum, Verticordia eriocephala*
EpBmMs	*Eucalyptus pleurocarpa, E. phaenophylla* and *E. incrassata* mid open mallee shrubland over *Beaufortia micrantha* var.	*Acacia assimilis* subsp. *atroviridis, A. curvata, A. gonophylla, A. lasiocarpa* var. *bracteolata, A. pinguiculosa* subsp. *teretifolia, A. singula*, ***Adenanthos cuneatus***, *Allocasuarina humilis, A. spinosissima,*

	micrantha, M. rigidifolia and *M. hamata* mid open shrubland over *Mesomelaena stygia* subsp. *stygia, Lysinema pentapetalum* and *Lepidosperma* spp. low open sedgeland/ shrubland	*Amphipogon avenaceus, A. turbinatus, Anthotium humile, Argentipallium niveum, Baeckea pachyphylla,* ***Banksia blechnifolia, B. cirsioides, B. media****, Beaufortia schaueri, Beyeria sulcata* var. *gracilis, Callitris roei, Calothamnus gibbosus, C. gracilis, C. quadrifidus* subsp. *quadrifidus, Calytrix duplistipulata, C. leschenaultii, Cassytha glabella, Cheiranthera filifolia, Chordifex sphacelatus, Conostylis argentea, Dampiera angulata* subsp. *angulata, D. lavandulacea, Daviesia lancifolia, D. pachyphylla, D. teretifolia, Desmocladus myriocladus, Eucalyptus falcata, E. falcata* subsp. *falcata, E. kessellii, E.* sp. Fraser Range (D. Nicolle 2157), *E. uncinata, Exocarpos sparteus, Gahnia ancistrophylla, Gastrolobium nutans, Gompholobium baxteri, G. confertum, Gompholobium marginatum, Goodenia concinna, G. trichophylla, Grevillea disjuncta, G. nudiflora, G. oligantha, Hakea cinerea, H. corymbosa, H. marginata, H. nitida, H. strumosa, Hemigenia teretiuscula, Hibbertia gracilipes, H. pungens,* ***Isopogon trilobus****, Isotropis drummondii, Kunzea jucunda, Lasiopetalum rosmarinifolium, Laxmannia paleacea, Leptospermum erubescens, L. nitens,* ***Leucopogon concinnus, L. fimbriatus, L.* sp. Newdegate (M. Hislop 3585), *L. tamminensis* var. *australis*, *Lomandra micrantha* subsp. *teretifolia*, *L. mucronata****, Melaleuca glaberrima, M. pulchella, M. societatis, M. subfalcata, M. tuberculata* var. *macrophylla, M. tuberculata* var. *tuberculata, Microcorys glabra* var. *glabra, Neurachne alopecuroidea, Olearia ciliata,* ***Persoonia helix****,* ***Petrophile fastigiata, P. teretifolia****, Pimelea imbricata* var. *piligera, Platysace effusa, Pultenaea indira* subsp. *indira, Schoenus obtusifolius, S. pleiostemoneus, S. racemosus, S. sesquispiculus, S. subflavus* subsp. long leaves (K.L. Wilson 2865), *Spyridium cordatum, Stylidium involucratum, S. piliferum, Templetonia rossii, Tetrapora verrucosa, Thomasia microphylla, Tricostularia compressa, Verticordia acerosa* var. *preissii, V. chrysantha, V. inclusa*
EpMhGa	*Eucalyptus phaenophylla, E. leptocalyx* and *E. uncinata* mid mallee woodland over *Melaleuca hamata, M. subfalcata* and *Exocarpos sparteus* mid sparse shrubland over *Gahnia ancistrophylla, Spyridium cordatum* and *Acacia ingrata* low sparse sedgeland/ shrubland	*Acacia octonervia, A. sulcata,* ***Banksia media****, Calothamnus gibbosus, Cyathostemon* sp., *Daviesia benthamii* subsp. *acanthoclona, Eucalyptus eremophila* subsp. *eremophila, E. incrassata, Gahnia aristata, Grevillea pectinata, Melaleuca glaberrima, M. lateriflora,* ***Styphelia intertexta***
EsBpLt	*Eucalyptus sporadica* and *E. clivicola* mid mallee woodland/ woodland over *Baeckea pachyphylla, Melaleuca eurystoma* and *M. hamata* mid open shrubland over *Lepidosperma tuberculatum* and *Tetraria* sp. Mt Madden (C.D. Turley 40 BP/897) mid open sedgeland	*Acacia acanthoclada* subsp. *acanthoclada, A. pinguiculosa* subsp. *teretifolia, Astroloma serratifolium, Austrostipa hemipogon, Beaufortia schaueri, Boronia inconspicua, Callitris roei, Calothamnus quadrifidus* subsp. *quadrifidus, Calytrix leschenaultii, Cheiranthera filifolia, Dampiera angulata* subsp. *angulata, D. lavandulacea, Dianella brevicaulis, Dodonaea caespitosa, Exocarpos sparteus, Gahnia ancistrophylla, Gastrolobium nutans, Grevillea nudiflora, Hakea laurina, H. nitida,* ***Isopogon* sp. Fitzgerald River (D.B. Foreman 813)**, *Kunzea jucunda, Lasiopetalum compactum, L. rosmarinifolium, Lepidosperma* aff. brunonianum, *L.* sp. Bandalup Scabrid (N. Evelegh 10798), ***Leucopogon concinnus, L. fimbriatus, L.* sp.**

		Newdegate (M. Hislop 3585), *Melaleuca acuminata* subsp. *acuminata, M. glaberrima, M. societatis, M. subfalcata, Neurachne alopecuroidea, Opercularia vaginata,* ***Petrophile fastigiata****,* Rinzia communis
EspMhLsp	*Eucalyptus* sp. Fraser Range (D. Nicolle 2157) and *Allocasuarina huegeliana* mid low open mallee shrubland/ woodland over *Melaleuca hamata, Acacia patagiata* and *A. mutabilis* subsp. *angustifolia* mid open shrubland over *Lepidosperma* aff. *brunonianum* and ***Lomandra micrantha* subsp. *teretifolia*** low sparse sedgeland	*Exocarpos sparteus*
EspPmCl	*Eucalyptus* sp. Fraser Range (D. Nicolle 2157) mid sparse mallee shrubland over *Phymatocarpus maxwellii,* ***Adenanthos cuneatus*** and *Acacia assimilis* subsp. *atroviridis* mid shrubland over *Calytrix leschenaultii, Lepidosperma carphoides* and *Chordifex sphacelatus* low sparse shrubland/ sedgeland/ rushland	
EtMuGsp	*Eucalyptus tumida, E. uncinata* and *E. flocktoniae* mid sparse mallee shrubland over *Melaleuca undulata, M. societatis* and *Grevillea plurijuga* low open shrubland over *Gahnia* sp. Ravensthorpe (G.F. Craig 5005), *Acacia gonophylla* and *A. crassuloides* low sparse sedgeland/ shrubland	*Acacia evenulosa, A. glaucissima, Acrotriche cordata, Baeckea latens, Boronia inconspicua, B. inornata* subsp. *inornata, Cassytha sp., Comesperma spinosum, Cyathostemon* aff. *tenuifolius, Dampiera lavandulacea, Daviesia benthamii* subsp. *acanthoclona, D. lancifolia, Dianella revoluta, Eucalyptus leptocalyx, Eutaxia lutea, Exocarpos aphyllus, Gahnia ancistrophylla, G.* sp. L (K.R. Newbey 7888), *G.* sp. South West (K.L. Wilson & K. Frank KLW 9266), *Gompholobium baxteri, G. confertum, Goodenia laevis* subsp. *laevis, Grevillea oncogyne, Hakea commutata, H. laurina, Hibbertia* aff *gracilipes, H. exasperata, H. psilocarpa, Hypolaena humilis, Lasiopetalum rosmarinifolium, Lepidosperma* aff. *brunonianum, L. gahnioides,* ***Leucopogon cuneifolius, L. obtusatus, L.* sp. Kau Rock (M.A. Burgman 1126)**, *Melaleuca glaberrima, M. hamata, M. rigidifolia, Microcorys glabra* var. *glabra, Neurachne alopecuroidea, Pimelea cracens, Pultenaea indira* subsp. *indira, Rytidosperma setaceum, Spyridium minutum, Stylidium turleyae, Tetraria* sp. Mt Madden (C.D. Turley 40 BP/897), *Thysanotus manglesianus, Wilsonia humilis*
EuMtDl	*Eucalyptus uncinata* and *E. tumida* mid sparse mallee shrubland over *Melaleuca teuthidoides, M. rigidifolia* and *M. hamata* mid shrubland over *Daviesia lancifolia, Pultenaea elachista* and *Microcybe albiflora* low open shrubland	*Acacia glaucissima, Baeckea latens, Boronia inornata* subsp. *leptophylla, Cassytha melantha, Comesperma spinosum, Daviesia incrassata* subsp. *incrassata, D. lancifolia, Eucalyptus tetraptera, Eutaxia lutea, Exocarpos aphyllus, Gahnia* sp. Ravensthorpe (G.F. Craig 5005), *Gahnia* sp. South West (K.L. Wilson & K. Frank KLW 9266), *Gastrolobium musaceum, Gompholobium baxteri, Grevillea oncogyne, G. plurijuga* subsp. *plurijuga, Hakea laurina, Hibbertia exasperata, H. gracilipes, H. psilocarpa, Lepidosperma* sp. Bandalup Scabrid (N. Evelegh 10798), *Leptomeria pachyclada,* ***Leucopogon* sp. Kau Rock (M.A. Burgman 1126),** *Melaleuca bromelioides, M. cucullata, M. glaberrima, M. thyoides,*

		Microcybe albiflora, Neurachne alopecuroidea, ***Persoonia teretifolia****, Pultenaea elachista, Santalum acuminatum, Spyridium minutum*
HcBe	*Hakea cinerea, H. pandanicarpa* subsp. *pandanicarpa* and *Eucalyptus extrica* mid open shrubland/ mallee shrubland over *Beaufortia empetrifolia,* ***Leucopogon crassifolius*** and *Melaleuca pulchella* low shrubland	*Acacia cyclops, A. pachyphylla,* ***Adenanthos cuneatus, A. dobsonii****, Anarthria laevis,* ***Andersonia parvifolia****, Anigozanthos rufus, *Arctotheca calendula,* ***Banksia nutans*** **var.** ***nutans, B. obovata, B. obtusa, B. petiolaris, B. pulchella, B. repens, B. tenuis*** **var.** ***tenuis****, Boronia crassifolia, B. spathulata, Bossiaea preissii, Calectasia grandiflora, Calothamnus gracilis, Calytrix decandra, C. leschenaultii, Cassytha glabella, Chordifex sphacelatus, Conospermum distichum, Conostylis seorsiflora subsp. seorsiflora, C. setigera subsp. setigera, Conothamnus aureus, Dampiera parvifolia, Daviesia apiculata, *Disa bracteata, Diuris concinna, Drosera menziesii subsp. menziesii, D. paleacea* subsp. *trichocaulis, Gompholobium baxteri, Goodenia pterigosperma, Grevillea baxteri, Hakea corymbosa, H. denticulata, H. obliqua subsp. obliqua, H. varia, Hibbertia* aff. *recurvifolia, H. gracilipes, *Hypochaeris glabra, Hypolaena exsulca,* ***Isopogon*** **sp. Fitzgerald River (D.B. Foreman 813),** ***I. trilobus****, Jacksonia capitata, Lechenaultia formosa, Lepidosperma squamatum, Lepyrodia macra, Levenhookia stipitata, Lyginia imberbis, Lysinema ciliatum, L. pentapetalum, Melaleuca calcicola, M. scabra, M. striata, M. tuberculata* var. *macrophylla, Mesomelaena stygia* subsp. *stygia, Oligarrhena micrantha, Oxymyrrhine gracilis,* ***Patersonia lanata*** **forma** ***lanata****,* ***Petrophile teretifolia****, Phymatocarpus maxwellii, Schoenus pleiostemoneus, S. subfascicularis, S. subflavus* subsp. long leaves (K.L. Wilson 2865), *Stachystemon brachyphyllus,* ***Stirlingia anethifolia****, Stylidium macranthum, S. preissii, Taxandria spathulata, Tricostularia aphylla, T. compressa, Verticordia vicinella*