Terratree

Linear *Phytophthora* Dieback Assessment of Toodyay Rd (Wheatbelt Section)

Prepared for Main Roads Western Australia

Ref: T15019

ecological assessment & management

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Executive Summary

Main Roads Western Australia engaged Terratree to undertake a linear *Phytophthora* Dieback (Dieback) assessment of native vegetation within the defined project corridor, encompassing 50km of Toodyay Rd (hereafter referred to as the 'study area'). This study area is divided into two sections, referred to as “Metro section” and “Wheatbelt section”. This report addresses the Wheatbelt portion of the assessment.

This linear assessment was conducted by DPaW Registered Dieback Interpreter Joseph Grehan. The linear Dieback assessment commenced on November 12th and 13th, 2015 by DPaW registered Dieback Interpreter Joseph Grehan and field assistant Kelby Jennings. The Dieback assessment was undertaken in accordance with Department of Parks and Wildlife, 2015: *FEM047* Phytophthora *Dieback Interpreter’s Manual for lands managed by the Department*, Forest and Ecosystems Management, Department of Parks and Wildlife, 5 March 2015. Revisits were undertaken on November 17 and December 10, after receiving initial sample results to further define, demarcate and map disease occurrence within the study area.

The linear Dieback assessment has resulted in six positive samples for *Phytophthora cinnamomi* and the identification of four discrete Dieback infestations within the study area including:

- A north-south drainage line and wetland area on the western side of Morangup Nature Reserve;
- Wetland area on the opposite side of the road to Morangup Nature Reserve;
- Culverts and the on the opposite side of the road to Morangup Nature Reserve; and
- Along Toodyay road (north of Fernie Road) which will need to be managed separately to ensure Protectable areas in Morangup Nature Reserve along Toodyay Road don’t become Infested.

The Dieback Interpreters Guidelines (DPaW 2015) were recently updated and now categorise land that has been cleared of native vegetation as 'Excluded' from assessment. Non-vegetated areas that are Excluded from assessment include pasture, pits, easements, development, large roads (sealed and unsealed), permanently flooded areas and parkland tree stands. Excluded areas are distinguished from 'Temporarily Uninterpretable' areas by the fact that they cannot regenerate naturally and eventually become Mappable.

Excluded areas comprise the majority of the study area (405.9 ha, 78.7%). The majority of these areas were agricultural land, but also included areas of native vegetation in Degraded or Completely Degraded condition. Due to a lack of susceptible species, poor vegetation condition and the presence of numerous disturbance impacts, a determination on disease status is not possible for these areas. Because Dieback is present in mapped sections along Toodyay Road, it is recommended that Excluded areas are managed as Infested as a precautionary measure.

Uninterpretable areas comprise 66.1 ha of the study area and contain no or very few disease indicator species. These areas generally consist of *Eucalyptus wandoo* woodland over *Acacia* and *Trymalium* spp. and other non-susceptible species, and contain no or very few Dieback susceptible species. Because the disease status of Uninterpretable areas cannot be determined they are managed as Infested and Uninfested concurrently. In practical terms this means that all vehicles and machinery must be ‘clean on entry’ into, and ‘clean on exit’ from Uninterpretable areas provided the area in question meets the requirements set out in the Protocol for being Protectable. Uninterpretable areas can be managed as Infested if they are Unprotectable.

A 7.3 ha area within Morangup Reserve has been mapped as Temporarily Uninterpretable due to a recent fire impacting vegetation. Because the disease status of this area is unknown at present, it will need to be managed as Protectable but separate from adjacent Uninfested Protectable areas within the reserve.

Seven discrete areas of native vegetation have been mapped as Uninfested, comprising 18.6 ha (3.6%) of the study area. Of these, four (11.5ha, 2.2%) were determined to be Unprotectable due to insufficient size (<4ha)

and/or area-to-edge-ratio (axis <100m). The table below presents the area (ha) and percentage of each Dieback occurrence category within the study area.

Dieback Occurrence Category	Area (ha)	% Area
Infested	17.7	3.5
Uninfested (Protectable)	7.1	1.4
Uninfested (Unprotectable)	11.5	2.2
Temporarily Uninterpretable	7.3	1.4
Uninterpretable	66.1	12.8
Excluded	405.9	78.7
Total	**515.6**	**100**

Terratree makes the following recommendations for managing *Phytophthora* Dieback during the Toodyay Road Project:

- A Dieback Management Plan should be prepared for the project by a suitably qualified and experienced person in accordance with best practice management techniques described in the following publications:
  - Management of *Phytophthora* Disease; Policy Statement 3. Department of Parks and Wildlife (2014).
  - "*Phytophthora cinnamomi* and Disease Caused by it" Volume 1 Management Guidelines, Department of Environment and Conservation (2004).
- The management plan should include:
  - A comprehensive risk assessment of potential disease vectors and proposed activities within project corridor.
  - Recommendations for hygiene management (wash-down) locations that consider the level of risk to biodiversity in the surrounding landscape.
  - A program to monitor and report on compliance with the hygiene protocols prescribed in the management plan.
  - A communication program to make personnel aware of the risk to biodiversity associated with spreading Dieback and the importance of adhering to hygiene protocols.

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1 Introduction

Main Roads Western Australia (MRWA) engaged Terratree Pty Ltd (Terratree) to undertake a linear *Phytophthora* Dieback (Dieback) assessment of native vegetation within a defined project corridor, encompassing 50km of Toodyay Rd (hereafter referred to as the 'study area'). This study area is divided into two sections, referred to as “Metro section” and “Wheatbelt section”. This report addresses the Wheatbelt portion of the assessment.

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1.1 Project Location

The Wheatbelt section is located along approximately 28 km of Toodyay Rd, between Bailup in the west and Toodyay in the east. The study area is composed predominately of agricultural land, with native vegetation remnants existing within road reserves and conservation estate.

1.2 Background

Phytophthora Dieback (‘Dieback’) is a soil borne pathogenic fungus with a range of hosts in the southwest of Western Australia. These predominantly come from the Proteaceae, Ericaceae, Myrtaceae, Xanthorrhoeaceae and Fabaceae plant families. While some plant species are resistant, others are susceptible to the disease caused by the pathogen resulting in chlorosis, dieback and usually death (Wills, R.T. and Keighery, G.J. 1994).

According to the most recent Western Australian (WA) State of the Environment Report (Environmental Protection Authority 2007) Dieback, which is listed as a Priority 1 threat, is the third greatest threat to biodiversity after salinity and climate change. It is a more serious threat than weeds, clearing of native vegetation, acid sulphate soils and soil erosion. It is significant in WA is because:

- Over 40% (2,300) of the native plant species and half of the endangered plant species in the south-west of WA are susceptible to the pathogen;
- The changes in plant community composition and structure that Dieback causes has impact throughout the whole ecosystem, including on the indigenous fauna; and
- Dieback can lead to significant soil erosion as a result of the loss of susceptible vegetation.

The Dieback pathogen is widespread in areas with greater than 800 mm of annual rainfall, less extensive in areas that receive between 600–800 mm, and mainly restricted to water-gaining sites in areas that receive 400–600 mm. The pathogen does not occur in areas that receive less than 400 mm of annual rainfall. In Western Australia Dieback is a significant environmental issue for projects between Geraldton in the Midwest and Esperance on the South Coast, and is widespread in the Southwest region.

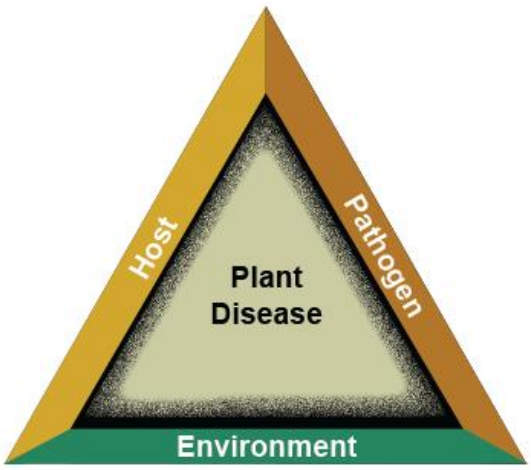
Dieback is spread through the movement of water and soil within the landscape. Major vectors of Dieback include wet soil adhering to vehicle tyres/tracks and earthmoving equipment, among others. Therefore, quarantine management procedures are an effective tool to reduce the spread of Dieback as a result of earthmoving activities.

Three variables are required to have disease expression caused by Dieback:

1. **Host** - plant species present that are susceptible to *Phytophthora* spp. (i.e. *Banksia*, *Hakea*, *Leucopogon*, *Xanthorrhoea* spp.).

2. **Pathogen** - The *Phytophthora* pathogen must be present in the landscape, residing either in susceptible or resistant plant species.

3. **Environment** - Soil temperatures between 15-30^{o} C and pH 5-6 (acidic) are required for *P. cinnamomi* survival and activity. Some species, including *P. multivora*, can survive in alkaline soils (pH 7+).



1.3 Regulatory Context

Phytophthora Dieback management is required under several regulatory mechanisms including:

- *Environmental Protection Act* (1986) Part V S.50A "Serious Environmental Harm" provisions;
- Projects being formally assessed under Part IV of *Environmental Protection Act* (1986) which require Department of Parks and Wildlife (DPaW) and/or Department of Mines and Petroleum (DMP) to comment on Dieback management and provide these agencies with the right to impose conditions to new approvals; and
- *Phytophthora* Dieback is listed as a Key Threatening Process with the Federal Government under the *Environmental Protection and Biodiversity Conservation Act* (1999).

2 Existing Environment

2.1 Biogeography

The study area is located within the Northern Jarrah Forest subregion, in accordance with the Interim Biogeographic Regionalisation for Australia (IBRA). The IBRA system identifies 89 bioregions and 419 subregions across Australia, based on climate, geology, landforms and characteristic vegetation and fauna.

Williams and Mitchell (2001) describe the Northern Jarrah Forest subregion (2,255,904 ha) as located upon a duricrusted plateau of the Yilgarn Craton, with Archaean granite and metamorphic rock capped by lateritic duricrust, forming drainage gullies along the eastern edge of the Darling Scarp. Average elevation is ~300m. Rainfall ranges from 1300mm on the scarp to approximately 700mm in the east and north.

Vegetation is characterised by Jarrah - Marri forest in the west (with Bullich and Blackbutt in valleys), grading to Wandoo and Marri woodlands in the east. Low *Banksia* woodlands can be found in sandy areas, with heath vegetation common in the understory and in association with granite outcropping.

Dominant land uses include agriculture, forestry (native forests and plantations), conservation, and mining, with limited rural residential development.

2.2 Regional Vegetation

Vegetation complexes within the Darling Scarp and Plateau were mapped by Mattiske and Havel (1998) as part of the Regional Forest Agreement process (RFA). The Wheatbelt study area contains nine vegetation complexes, listed in order of occurrence West-East (**Table 1**).Table 1: Regional Vegetation Complexes (Mattiske & Havel, 1998)

Table 2: Regional Vegetation Complexes (Mattiske & Havel, 1998)

Vegetation Complex	Geographic region	Landform Description	Soils	Soil Hydrology	Over Storey	Second Storey	Shrubs and Herbs
Dwellingup (D4)	Arid north, SE of Mundaring	Low rise forming a divide between shallow valleys within the Darling Plateau	Pale yellow brown gravelly sand	Mildly water shedding via subsoil, good infiltration and storage capacity	Woodland to open forest of *Eucalyptus marginata* subsp. *thalassica* with some *Corymbia calophylla*	Weakly developed second storey of *Allocasuarina fraseriana* and *Banksia grandis*	*Hakea cyclocarpa, Hakea ruscifolia, Isopogon dubius, Stirlingia latifolia, Styphelia tenuiflora, Daviesia incrassata* and *Patersonia rudis* subsp. *rudis*
Pindalup (Pn)	Perarid North, West of York	Slopes of a minor valley within the Darling Plateau	Pale brown sandy loam over clay	Mildly water shedding, with moderate infiltration but limited storage capacity	Woodland of *Eucalyptus wandoo*	No second storey	*Hakea incrassata, Hakea lissocarpha, Caustis dioica, Gastrolobium calycinum, Neurachne alopecuroidea, Centrolepis cephaloformis, Persoonia quinquenervis* and *Lechenaultia biloba*
Swamp (S)	Arid north, East of Mundaring	Broad shallow drainage lines in the Darling Plateau	Leached grey sands underlain by clay or iron/organic hardpan, or silty loams	Strongly water gaining, water logged for much of the year	Scattered emergents of *Melaleuca preissiana* and *Actinostrobus pyramidalis*	No second storey	Heath and Sedgeland of *Hakea varia, Hakea ceratophylla, Melaleuca incana, Melaleuca viminea, Verticordia acerosa, Meeboldina scariosa, Pericalymma ellipticum* and *Leptocarpus tenax*
Vegetation Complex	**Geographic region**	**Landform Description**	**Soils**	**Soil Hydrology**	**Over Storey**	**Second Storey**	**Shrubs and Herbs**
Yalanbee (Y5)	Perarid north, Between Toodyay and Bindoon	Mildly rising divide on the Darling Plateau	Yellow brown gravelly sand and sandy loam over kaolinitic clay at depth, some lateritic duricrust	Mildly water shedding via subsoil, very good infiltration and storage capacity	Woodland to Open Forest of *Eucalyptus marginata* subsp. *thalassica* and *Corymbia calophylla*	Few pockets of *Dryandra sessilis* var. *sessilis*	*Dryandra squarrosa* subsp. *squarrosa, Dryandra lindleyana, Hibbertia hypericoides, Hibbertia commutata, Phyllanthus calycinus, Acacia pulchella, Hakea lissocarpha , Daviesia decurrens* and *Olearia paucidentata*
Swamp (S)	Arid north, East of Mundaring	Broad shallow drainage lines in the Darling Plateau	Leached grey sands underlain by clay or iron/organic hardpan, or silty loams	Strongly water gaining, water logged for much of the year	Scattered emergents of *Melaleuca preissiana* and *Actinostrobus pyramidalis*	No second storey	Heath and Sedgeland of *Hakea varia, Hakea ceratophylla, Melaleuca incana, Melaleuca viminea, Verticordia acerosa, Meeboldina scariosa, Pericalymma ellipticum* and *Leptocarpus tenax*

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Yalanbee (Y6)	Perarid north, York Rd E of Inkpen Rd	Undulating gravelly uplands	Yellow gravels and yellow gravelly sands with lateritic floaters	Mildly water shedding via subsoil, good infiltration and storage capacity	Woodland of *Eucalyptus wandoo* and *Eucalyptus accedens*	No second storey	*Allocasuarina campestris, Acacia pulchella, Acacia nervosa, Bossiaea eriocarpa, Leucopogon capitellatus, Leucopogon propinquus, Hakea lissocarpha, Hakea trifurcata, Hibbertia hemignosta, Petrophile serruriae, Lechenaultia biloba, Persoonia quinquenervis, Ptilotus manglesii, Daviesia incrassata* and *Lepidosperma gracile*

Vegetation Complex	Geographic region	Landform Description	Soils	Soil Hydrology	Over Storey	Second Storey	Shrubs and Herbs
Coolakin (Ck)	Perarid north, Between Toodyay and Bindoon	Moderately incised valley within the Darling Range Plateau	Red duplex soils with gravelly sandy loam topsoil and clay subsoil	Strongly water shedding and with good infiltration but only moderate storage capacity	Woodland of *Eucalyptus wandoo* with admixture of *Eucalyptus accedens* and *Corymbia calophylla* on upper slopes	No second storey	*Macrozamia riedlei, Xanthorrhoea preissii, Hakea lissocarpha, Lasiopetalum cardiophyllum* P2, *Bossiaea eriocarpa, Phyllanthus calycinus, Hibbertia hypericoides* and *Hibbertia commutata*
Michibin (Mi)	Perarid North, West of York	Gently undulating side slopes of a medium sized valley in the Darling Plateau	Yellow sandy loam	Mildly water shedding	Open Woodland of *Eucalyptus wandoo*	No second storey	*Xanthorrhoea preissii, Acacia pulchella, Lepidosperma tenue, Neurachne alopecuroidea, Dampiera alata, Haemodorum discolor, Chamaescilla corymbosa* and *Lechenaultia biloba*
Bindoon (Bi)	Perarid north, between Toodyay and Bindoon	Upper slopes of a major dissection of the Darling Plateau, below breakaway	Gravelly sandy loam over pink clay	Strongly water shedding, but with possible gain via subsoil, good infiltration but only moderate storage capacity	Open Forest of *Eucalyptus accedens* and *Eucalyptus wandoo*	A few large *Dryandra sessilis* var. *sessilis*	Largely without shrub or herb stratum, merely scattered clumps of *Acacia pulchella, Nemcia spathulata* and *Lasiopetalum cardiophyllum* P2
Williams (Wi)	Arid North, East and West of Wandering	Broad valley floor of a medium stream	Alluvial sandy loams and loam	Water gaining, periodically flooded and seasonally waterlogged, affected by salinity of the stream	Woodland of *Eucalyptus rudis, Eucalyptus loxophleba* subsp. *loxophleba* and *Eucalyptus wandoo*	*Melaleuca rhaphiophylla* on streamline ; *Acacia acuminata* away from stream	Shrub storey not recorded

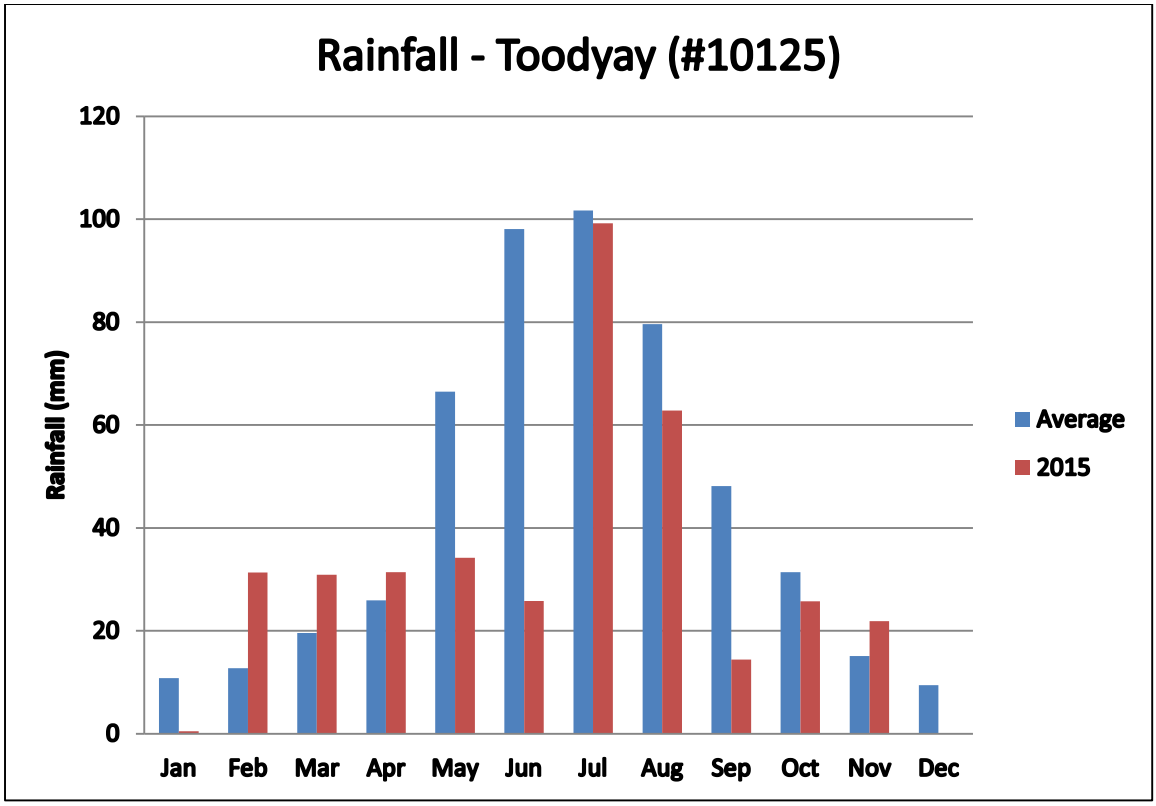
2.3 Climate

The study area experiences an Interior Mediterranean (Csa) climate under the Köppen climate classification system, characterised as mild, with dry, hot summers, where the warmest month averages >22^{0}C, and with a winter-dominant rainfall (Pidwirny, 2011). Weather Station Toodyay (#10125) receives an average annual rainfall of 520.3mm (**Graph 1**). *Phytophthora* Dieback is generally restricted to water-gaining sites in areas that receive 400-600mm rain per annum.

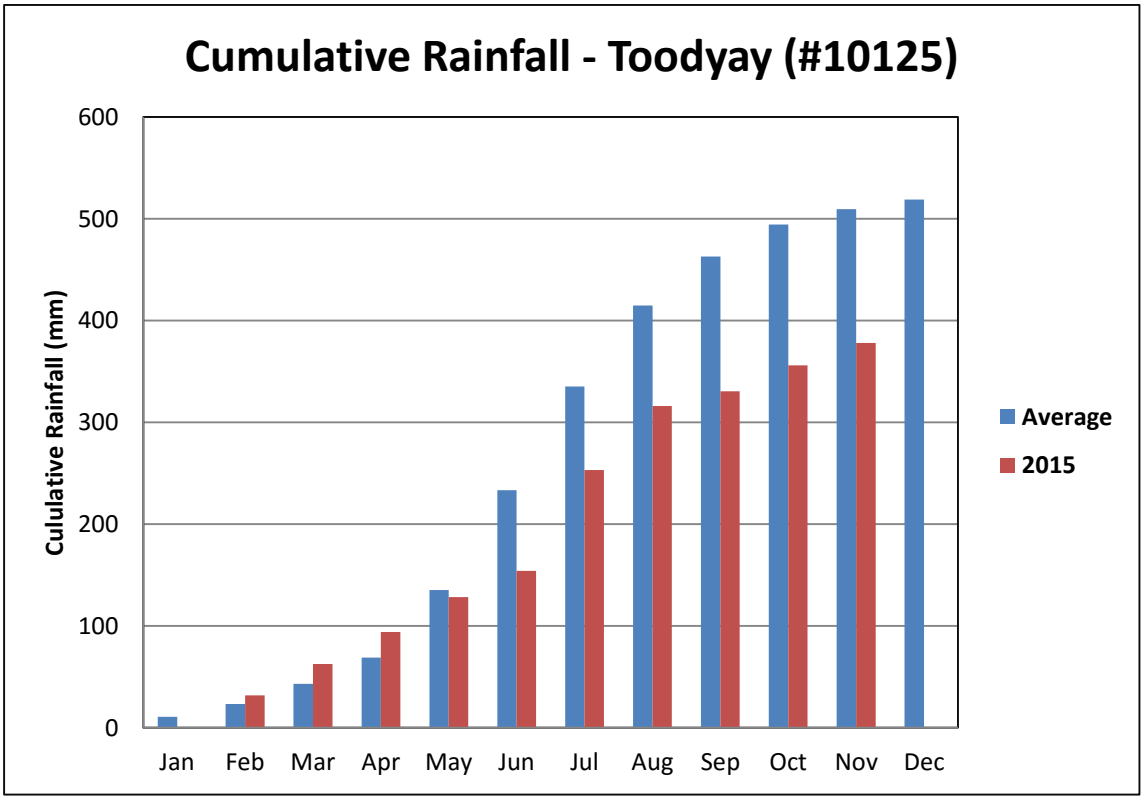
The south-west has being experiencing lower than average rainfall over the past decade. In 2015, Toodyay (#10125) recorded significantly reduced rainfall when compared against the long-term average (**Graph 2**). Rainfall has consistently been below average from May-October, with the exception of July, which recorded average levels. Cumulative rainfall to November is 378.1mm, representing 74.2% of the historical cumulative average.

Reduced rainfall is likely to negatively affect disease spread, as a less saturated soil profile and reduced surface water flows will inhibit pathogen mobility within the soil profile. Therefore, indicators of disease activity and expression, including disease indicator species deaths, are likely to be less evident.

Additionally, low rainfall can induce drought-stress mortality within susceptible vegetation during warmer months, which can imitate and/or mask Dieback disease expression.



Graph 1: Rainfall Data - Toodyay (BoM, 2015)



Graph 2: Cumulative Rainfall Data – Toodyay (BoM, 2015)

3 Desktop Review

A desktop assessment was undertaken prior to the field assessment in order to:

- Identify access to the study area and internal tracks;
- Examine topography and drainage of the study area and boarder landscape;
- Review sample history or Dieback occurrence mapping from within the study area and surrounding landscape;
- Identify possible disease vectors e.g. tracks, utility corridors and ground disturbance;
- Determine the location of high risk areas (e.g. areas of high disturbance and water-gaining sites); and
- Review disturbance and fire history (if available).

The number of previous samples taken in the area surrounding the study corridor was limited, with no samples or on–ground Dieback mapping undertaken previously within the study area. The Dieback Information Delivery and Management System (DIDMS) identified one positive sample for *P. cinnamomi*, approximately 1km north of the project area (3.5km SW of Toodyay). Hydrology mapping indicates that drainage for the area containing the positive sample does not intersect with the project area. Disease confidence mapping data does not display any areas in the vicinity of the project area as Infested.

4 Method

The linear Dieback assessment commenced on November 12th and 13th, 2015 by DPaW registered Dieback Interpreter Joseph Grehan and field assistant Kelby Jennings of Terratree. Revisits were undertaken on November 17and December 10, after receiving initial sample results to further define, demarcate and map disease occurrence within the study area. The study area was traversed by vehicle, with areas of native vegetation subject to intensive assessment on foot. Observations on vegetation health and disease expression were captured with hand held GPS units, including georeferenced photographs.

The objectives of the Dieback assessment were as follows:

- To identify and demarcate *Phytophthora* Dieback infestations (including appropriate buffer) within the study area;
- To accurately delineate and map Dieback occurrence categories within the study area;
- Comprehensively assess Protectable areas of vegetation for evidence of Dieback emergence or activity; and
- Collect soil and tissue samples from recently dead indicator species to test for pathogen presence.

4.1 Recent Changes to Dieback Occurrence Categories

The Dieback Interpreters Guidelines (DPaW 2015) were recently updated and now categorise land that has been cleared of native vegetation as 'Excluded' from assessment. Non-vegetated areas that are Excluded from assessment include pasture, pits, easements, development, large roads (sealed and unsealed), permanently flooded areas and parkland tree stands. Excluded areas are distinguished from 'Temporarily Uninterpretable' areas by the fact that they cannot regenerate naturally and eventually become Mappable. The Keighery vegetation disturbance scale presented in **Table 1** was used to determine the assessability of disturbed areas (DPaW 2015).

Table 2 presents the *Assessability of vegetated and non-vegetated areas*, which includes the Excluded category (DPaW, 2015). The Temporarily Uninterpretable category is allocated to areas of native vegetation which have been disturbed, but will recover over time and become Interpretable and therefore mappable. Examples of Temporarily Uninterpretable areas include vegetation that has been impacted by fire, grazing, timber harvesting, flooding or mining and rehabilitation. Recovery in Temporarily Uninterpretable areas may take longer than 3 years (DPaW, 2015).

The vegetation of Uninterpretable areas can range from Pristine to Very Good; however, whether the pathogen is present in resistant hosts or as Zoospores in permanent water bodies is indeterminable. Uninterpretable areas that meet the protocols for identifying Protectable Areas (DPaW, 2015) are managed as being both Infested and Uninfested so that the pathogen is neither imported into, nor exported from, these areas.

Table 1: Keighery Vegetation Disturbance Scale and Assessability (Keighery 1994, as referenced in DPaW, 2015)

Assessability	Scale		Condition
Assessable	1	Pristine	Pristine or nearly so, no obvious signs of disturbance.
	2	Excellent	Vegetation structure intact, disturbance affecting individual species and weeds are non-aggressive species.
	3	Very Good	Vegetation structure altered, obvious signs of disturbance. For example, disturbance to vegetation structure caused by repeated fires, the presence of some more aggressive weeds, dieback, logging and grazing.

Assessability	Scale		Condition
Possibly Assessable, discretion required	4	Good	Vegetation structure significantly altered by very obvious signs of multiple disturbances. Retains basic vegetation structure or ability to regenerate it. For example, disturbance to vegetation structure caused by very frequent fires, the presence of some very aggressive weeds at high density, partial clearing, dieback and grazing.
Not Assessable, Excluded from assessment	5	Degraded	Basic vegetation structure severely impacted by disturbance. Scope for regeneration but not to a state approaching good condition without intensive management. For example, disturbance to vegetation structure caused by very frequent fires, the presence of very aggressive weeds, partial clearing, dieback and grazing.
	6	Completely Degraded	The structure of the vegetation is no longer intact and the area is completely or almost completely without native species. These areas are often described as "parkland cleared" with the flora comprising weed or crop species with isolated native trees or shrubs.

Table 3: Assessability of vegetated and non-vegetated areas (DPaW, 2015)

Vegetation Condition	*Phytophthora* occurrence category	Typically present	May be present
Naturally vegetated areas. Keighery disturbance rating 3 or less. Phytophthora occurrence categorisation is or will be possible. Small un-vegetated areas can exist and may be included in the assessment area considering total environmental context	INFESTED	Dead and dying reliable indicator species	Healthy reliable indicator species. ISDs that have been killed by other agents
	UNINFESTED	Healthy reliable indicator species	ISDs that have been killed by other agents
	UNINTERPETABLE	Very few reliable indicator species	Occasional reliable indicators, but too few for Phytophthora dieback interpretation
	NOT YET RESOLVED	Usually reliable indicator species in an environment not favourable to disease development	Negative sample results for all Phytophthora species
Vegetation structure temporarily altered. Phytophthora occurrence assessment will be possible when vegetation structure recovers. Recovery times will be variable depending on severity and type of disturbance.	TEMPORARILY UNINTERPRETABLE	Indicator species masked by disturbance. Keighery disturbance rating of 4 or greater. Disturbance typically from; fire, harvesting, temporary flooding. Should recover (become interpretable) in 3 years or less.	Occasional reliable indicator species, but disturbance prevents accurate placement of Phytophthora occurrence boundaries. Recovery time may be longer than 3 years
Road disturbance area	DISEASE RISK ROAD	Unformed track with shoulders of interpretable vegetation	Shoulders and batters with regenerated vegetation. Incipient infestation
Vegetation structure severely altered. Keighery disturbance rating 5 or greater. Phytophthora occurrence assessment is not possible.	EXCLUDED	Pasture, pits, easements, infrastructure, large roads (sealed and unsealed) permanent flooding, plantations, parkland tree stands	Sporadic reliable indicator species

Vegetation Condition	*Phytophthora* occurrence category	Typically present	May be present
Can be determined by desktop assessment (aerial photo). Small vegetated areas can exist and may be Excluded from the assessment area considering total environmental context			

4.2 Protocols for Identifying Protectable Areas

According to Dieback Interpreters Guidelines (DPaW 2015), the following primary criteria are used to define 'Protectable Areas' as those that:

- Have been determined to be free of the pathogen *Phytophthora* spp. by a registered Dieback Interpreter (all susceptible indicator plant species are healthy and no plant disease symptoms normally attributed to *Phytophthora* Dieback are evident);
- Consists of areas where human vectors are controllable (e.g. not an open road, private property) (DPaW 2013, pp 101 - 102); and
- Are positioned in the landscape and are of sufficient size (e.g. > 4 ha with axis >100 m) such that a qualified Interpreter judges that the pathogen will not autonomously engulf them in the short term (a period of a few decades); or
- Includes areas of high conservation and/or socio-economic value (for example, a small Uninfested area with a known population of a susceptible species of Threatened flora).

4.3 Disease Indicator Species

Disease indicator species observed within the study area include representatives of the Proteaceae, Myrtaceae and Xanthorrhoeaceae families. *Banksia squarrosa* was the most reliable indicator of disease expression observed in the field, with evidence from *Xanthorrhoea, Hakea* and *Leucopogon* ssp. also used to provide supplementary evidence. Indicator species observed during the field survey are listed in **Table 4**.

Table 4: Disease Indicator Species

Family	Species
Casuarinaceae	*Allocasuarina fraseriana*
Ericaceae	*Leucopogon capitellatus*
Myrtaceae	*Eucalyptus marginata*
Proteaceae	*Banksia dallanneyi* var. *dallanneyi*
	Banksia grandis
	Banksia sessilis var. *sessilis*
	Banksia squarrosa
	Daviesia decurrens
	Persoonia elliptica
	Hakea lissocarpha
	Hakea ruscifolia
	Hakea trifurcata
Xanthorrhoeaceae	*Xanthorrhoea gracilis*
	Xanthorrhoea preissii
Zamiaceae	*Macrozamia riedlei*

4.4 Sampling

Soil and tissue samples were taken from recently dead or dying disease indicator species to confirm the presence or indicate the possible absence of Dieback and inform interpretation of the area. Negative sample results do not necessarily mean that the pathogen is absent because low levels of inoculum can lead to false negative results.

Sampling strategies for the assessment of Dieback include the following:

Initial standards sampling: Initial samples were taken to determine disease behaviour. The results inform the sampling strategy and enable the testing of early hypotheses (e.g. are other factors causing the deaths of susceptible species such as *Armillaria luteobubalina* or drought).

Sampling to support infested diagnosis: Recently dead and dying indicator species were sampled to support an infested diagnosis.

Sampling to supporting an uninfested diagnosis: Recently dead and dying indicator species were sampled to support an uninfested diagnosis. A cautious approach must be adopted when claiming that a negative result means that an area is Uninfested because false negative results can be recorded when inoculum levels are depleted due to prolonged unfavourable environmental conditions for the pathogen.

All sampling strictly adhered to the following procedures:

- All tools used in sampling were thoroughly sterilised with a 70:30 mixture of methylated spirits and water before samples were taken. Tools were dry prior to sampling so that the results were not compromised;
- The area around the base of the plant being sampled was cleared of leaf litter and debris so that this material was not included in the sample;
- The plant sampled was excavated to a suitable depth to ensure that adequate plant tissue material can be obtained from the roots and cambium layer around the collar of the plant being sampled;
- Material from all around the plant was taken in addition to any obvious lesions to avoid missing any infected material. All the plant tissue material and a few handfuls of soil from around the roots and other places in the soil profile were placed in a polythene bag;
- Distilled water to moisten the soil was poured into the bag to ensure the survival of any inoculum that may be present in the sample;
- All relevant information pertaining to the plant sampled and sample location was recorded on the Sample Information Sheet;
- Two aluminium tags which provide the date, project name, sample number, species sampled and the name of the interpreter were written. One tag was placed in the sample bag and the other was tied near the sample site which was also flagged with a day-glo orange flagging banner;
- The sample hole was backfilled to prevent fauna becoming trapped; and
- All tools were brushed off (to remove excess soil) and sterilised to prevent contamination of the next sample site and sample.

4.5 Buffers

The following buffers were applied during mapping of Infested areas in accordance with the Dieback Interpreter Guidelines (DPaW 2013):

- Minimum upslope buffers 15 m depending on complexity of disease expression; and
- Minimum downslope buffer of 25 m depending on degree of slope, drainage patterns, soil type and geology.

4.6 Limitations

The following limitations were encountered during the assessment:

- The Degraded / or Completely Degraded condition of the majority of native vegetation within the study area meant that most of the study area had to be Excluded from assessment;
- The widespread impact of drought made Dieback Interpretation more difficult; and
- Fuel reduction burns have significantly altered areas of vegetation in Morangup Reserve. As impacts to vegetation from fire removes and obscures evidence of Dieback, these areas have been mapped as Temporarily Uninterpretable.

5 Results

A total of nine soil and tissue samples were taken from recently dead disease indicator species within the Wheatbelt section (**Plate 6**). Six samples returned a positive result for *Phytophthora cinnamomi* (**Table 4**).

Table 5: Sample Results

Sample No.	Species	Easting (GDA 94, Zone 50)	Northing (GDA 94, Zone 50)	VHS Laboratory Results
TR-S02	*Xanthorrhoea preissii*	436275	6494639	Negative
TR-S03	*Banksia squarrosa*	436424	6494777	*P. cinnamomi*
TR-S04	*Banksia squarrosa*	436404	6494719	Negative
TR-S06	*Banksia squarrosa*	439405	6496279	*P. cinnamomi*
TR-S07	*Banksia squarrosa*	434628	6492157	*P. cinnamomi*
TR-S12	*Banksia squarrosa*	436780	6495010	*P. cinnamomi*
TR-S13	*Banksia squarrosa*	436349	6494760	*P. cinnamomi*
TR-S14	*Xanthorrhoea preissii*	436352	6494904	Negative
TR-S15	*Banksia squarrosa*	436505	8694824	*P. cinnamomi*

In total, 515.6 ha were assessed, with 109.7 ha being mappable and 405.9 ha being Excluded. **Table 5** provides an area statement of the size and proportion of each Dieback mapping category. **Figure 2** shows Dieback occurrence mapping and the sample locations within the study area.

Table 6: Dieback Mapping Area Statement

Dieback Occurrence Category	Area (ha)	% Area
Infested	17.7	3.5
Uninfested (Protectable)	7.1	1.4
Uninfested (Unprotectable)	11.5	2.2
Temporarily Uninterpretable	7.3	1.4
Uninterpretable	66.1	12.8
Excluded	405.9	78.7
Total	**515.6**	**100**

6 Discussion

6.1 Uninfested Areas

Seven discrete areas of native vegetation have been mapped as Uninfested, comprising 18.6 ha (3.6%) of the study area. Of these, four (11.5ha, 2.2%) were determined to be Unprotectable under DPaW's Protocol for identifying protectable areas (DPaW, 2015) due to insufficient size (<4ha) and/or area-to-edge-ratio (axis <100m).

The remaining three Uninfested areas (7.1ha, 1.4%) are characterised by the following:

- No positive sample results for *P. cinnamomi*
- Notwithstanding the impacts of drought, there is an acceptable diversity of healthy disease indicator species including *Banksia squarrosa*, *B. sessilis, Xanthorrhoea preissii*, *Daviesia* spp. and *Leucopogon* spp.
- Vegetation in Very Good to Excellent condition;
- Area ≥4ha, axis ≥100m; and
- No evidence of disease pattern or chronology.

Plate 1 shows Uninfested vegetation within the study area.

6.2 Infested Areas

Six positive samples for *P. cinnamomi* resulted in the identification of four discrete Dieback infestations within the study area (**Figure 2**). These results were extrapolated along drainage lines and slope gradients to ensure all potentially Infested areas are identified and managed accordingly. In total 17.7 ha (3.5 % of the study area) is Infested with *P. cinnamomi.* The north-south drainage line and wetland area on the western side of Morangup Nature Reserve are Infested (Figures 2a and 2b) with disease spreading upland. Toodyay road is also infested in this area, with culverts on the south side of the road opposite Morangup Reserve returning positive results for *P. cinnamomi*.

Plate 2 shows an example of dead *Xanthorrhoea preissii* individuals within Infested vegetation.

6.3 Uninterpretable Areas

Uninterpretable areas comprise 66.1 ha (12.8%) of the study area. These areas generally consist of *Eucalyptus wandoo* woodland over *Acacia* and *Trymalium* spp., (**Plate 3**) and contain no or very few disease Indicator species. Because the disease status of Uninterpretable areas cannot be determined they are managed as Infested and Uninfested concurrently. In practical terms this means that all vehicles and machinery must be 'clean on entry' into and 'clean on exit' from Uninterpretable areas provided the area in question meets the requirements set out in the Protocol for being Protectable (refer to Section 4.2).

6.4 Temporarily Uninterpretable Area

One area of 7.3 ha (1.4% of the study area) has been mapped as Temporarily Uninterpretable, in accordance with the Dieback Interpreter's Guidelines (DPaW, 2015). This area is located in Morangup Reserve, and is classified as Temporarily Uninterpretable due to a recent fire impacting vegetation and destroying or masking evidence of disease caused by Dieback (**Plate 4**). This area is expected to recover and become Interpretable in 1-3 years.

6.5 Excluded Areas

Excluded areas, as defined in Table 1, comprise the majority of the study area (405.9 ha, 78.7%). The majority of these areas were agricultural land, but also included areas of native vegetation in Degraded or Completely Degraded condition (Plate 5). Due to a lack of susceptible species, poor vegetation condition and the presence of numerous disturbance impacts, a determination on disease status is not possible for these areas.

6.6 Other Impacts

6.6.1 Drought

Impacts to vegetation as a result of prolonged drought are differentiated from impacts caused by *P. cinnamomi* by the following characteristics:

- No disease pattern or chronology in the surrounding vegetation
- The plant had senesced gradually rather than succumbing quickly as is usually the case with deaths attributed to *P. cinnamomi*
- No visible lesions or mycelium on the roots of the dead or dying plant
- Re-shooting or epicormic growth visible on dying plants (Plate 5)
- The presence of single or multiple dead branches with the remainder of the plant appearing to be healthy may be attributed to drought or pathogenic fungi.

Drought impacts were observed throughout the project area, especially in areas with a shallow soil profile. However due to the high rate of *P. cinnamomi* recovery from samples taken, the dry conditions did not affect recovery of the pathogen or lead to false negative results.

6.6.2 *Armillaria luteobubalina*

Armillaria luteobubalina (*Armillaria*) or Australian Honey Fungus is a species of mushroom which causes *Armillaria* root-rot in affected plants. The fungus is widespread in Jarrah (*Eucalyptus marginata*) and Karri (*E. diversicolor*) forests of the southwest of Western Australia, and has also been recorded on the south coast region in Fitzgerald River National Park (Shearer *et al.* 1994a, 1997). *Armillaria* is dispersed by spores produced by the mushroom and also reproduces vegetatively through the roots of affected plants. It affects many of the same plant genera as *Phytophthora,* in particular members of the Myrtaceae and Proteaceae plant families such as *Eucalyptus* and *Banksia* species. *Armillaria* forms quite visible white or yellow leathery mycelial sheath which can be seen beneath the bark in the roots or lower stem. Other observable factors that can be applied in the diagnosis of *Armillaria* infection include:

- Clusters of fruiting bodies around or near the base of the plant
- A pungent mushroom smell
- An inverted V shaped scar at the base of the plant
- Yellow-white stringy rot under the bark in the roots and base of affected plants (DPaW 2013)

No evidence of *Armillaria* was observed within the study area.

6.6.3 Other Pathogenic fungi

In addition to the impact of drought the possibility also exists that cankers caused by aerial fungi are having an impact on *Banksia* species, in particular. The impact of cankers caused by pathogenic fungus on Proteaceous species was examined by Crane and Burgess (2012) in coastal vegetation between Esperance and Cervantes. The study demonstrated pathogenicity in seven *Banksia* spp. over a wide geographic range. The pathogenic fungus was identified as a new genus and species within the *Cryphonectriaceae* (*Diaporthales*) and is described as *Luteocirrhus shearii* gen. sp. *nov*. The fungus causes the death of single branches. However, it can lead to multiple branch deaths or cause complete crown dieback as occurred with some of the *Banksia baxteri* and *B. verticillata* sampled (Crane and Burgess 2012).

No evidence of canker of other pathogenic fungi were observed within the study area.

7 Conclusion and Recommendations

In conclusion, the linear Dieback assessment along the Wheatbelt section of Toodyay Road has resulted in six positive samples for *P. cinnamomi* and the identification of four discrete Dieback infestations within the study area. A north-south drainage line and wetland area on the western side of Morangup Nature Reserve is Infested, with culverts and the wetland area on the opposite side of the road also returning positive results for *P. cinnamomi*. Another infestation along Toodyay road north of Fernie Road will need to be managed separately to ensure Protectable areas in Morangup Nature Reserve along Toodyay Road don't become Infested.

Excluded areas comprise the majority of the study area (405.9 ha, 78.7%). Because Dieback is present in mappable sections along Toodyay Road, as a precautionary measure all Excluded area within the study area should be managed as Infested.

Uninterpretable areas comprise 66.1 ha of the study area and contain no or very few disease indicator species. Uninterpretable areas are managed under the assumption that they are Infested, and Uninfested provided the area satisfies the Protocol for being protectable Uninterpretable areas can be managed as Infested if they are unprotectable.

A 7.3 ha within Morangup Reserve has been mapped as Temporarily Uninterpretable due to a recent fire impacting vegetation. Because the disease status of this area is unknown at present it will need to be managed as Protectable but separate from adjacent Uninfested Protectable areas within the reserve.

Seven discrete areas of native vegetation have been mapped as Uninfested, comprising 18.6 ha (3.6%) of the study area. Of these, four (11.5ha, 2.2%) were determined to be Unprotectable due to insufficient size (<4ha) and/or area-to-edge-ratio (axis <100m).

Terratree makes the following recommendations for managing *Phytophthora* Dieback during the Toodyay Road Project:

- A Dieback Management Plan should be prepared for the project by a suitably qualified and experienced person in accordance with best practice management techniques described in the following publications:
  - Management of *Phytophthora* Disease; Policy Statement 3. Department of Parks and Wildlife (2014).
  - "*Phytophthora cinnamomi* and Disease Caused by it" Volume 1 Management Guidelines, Department of Environment and Conservation (2004).
- The management plan should include:
  - A comprehensive risk assessment of potential disease vectors and proposed activities within project corridor.
  - Recommendations for hygiene management (wash-down) locations that consider the level of risk to biodiversity in the surrounding landscape.
  - A program to monitor and report on compliance with the hygiene protocols prescribed in the management plan.
  - A communication program to make personnel aware of the risk to biodiversity associated with spreading Dieback and the importance of adhering to hygiene protocols.

8 References

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9 Glossary of Terms

Disease - the combination of a pathogen, host and correct environmental conditions, which results in disease symptoms or death of a host.

Environment - the sum of all external factors which act on an individual organism during its lifetime.

Host - means the plant which is invaded by a pathogen and from which the pathogen derives its energy.

Infested Areas - areas that accredited person have determined have plant disease symptoms consistent with the presence of the pathogen *Phytophthora*

Inoculum - cells, tissue, or viruses that are used to inoculate a new culture

Pathogen - any organism or factor causing disease within a host

***Phytophthora* Dieback** - a term referring to the disease symptoms caused by *Phytophthora* species in susceptible vegetation.

Susceptible - influenced or able to be harmed by *Phytophthora* Dieback

Sporulation - a type of reproduction that occurs in fungi, algae, and protozoa and involves the formation of spores by the spontaneous division of a cell into four or more daughter cells, each of which contains a part of the original nucleus.

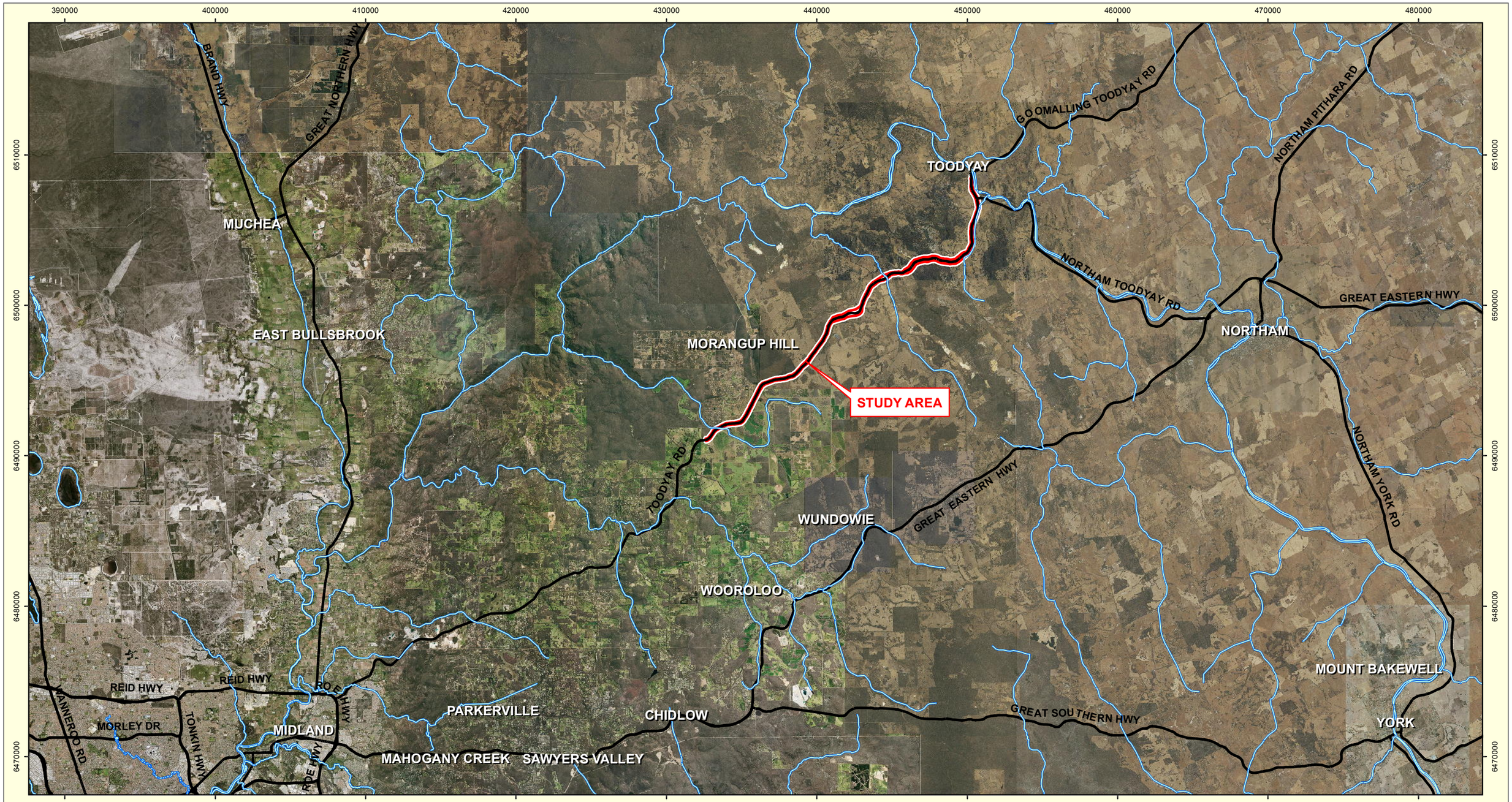
Not Yet Resolved - areas that are interpretable for Dieback but where a determination regarding the disease status cannot be made due to a lack of evidence in the form of positive sample results.

Uninfested Areas - areas that an accredited person has determined to be free of plant disease symptoms that indicate the presence of the pathogen *Phytophthora* Dieback

Uninterpretable Areas - areas situated in areas receiving > 600+ mm per annum rainfall or are water gaining sites (e.g. granite outcrops, impeded drainage or engineering works which aggregate rainfall) in the 400-600mm per annum rainfall zone where indicator plants are absent or too few to determine the presence or absence of disease caused by *Phytophthora* Dieback

Excluded Area- areas that have been disturbed to an extent that they are not assessable and therefore excluded from dieback interpretation

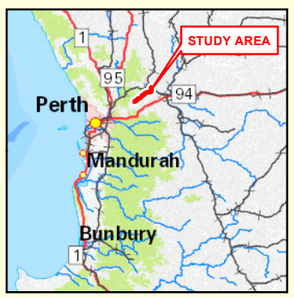
Figures



LEGEND

- Study Area
- Major Road
- Watercourse

Source: Imagery - Landgate



PROJECT LOCATION

Toodyay Road Dieback Assessment (Wheatbelt Section)

N

0 3 6 12 18 24 30

Kilometers
Coordinate System
GDA 1994 MGA Zone 50

Scale: 1:250,000 @ A3	Prepared: ENVIRONMAPS	Project No: T15019	Figure 1
Date: 21/12/2015	Checked: K. Jennings		
Revision: Rev A	Reviewed: J. Grehan		

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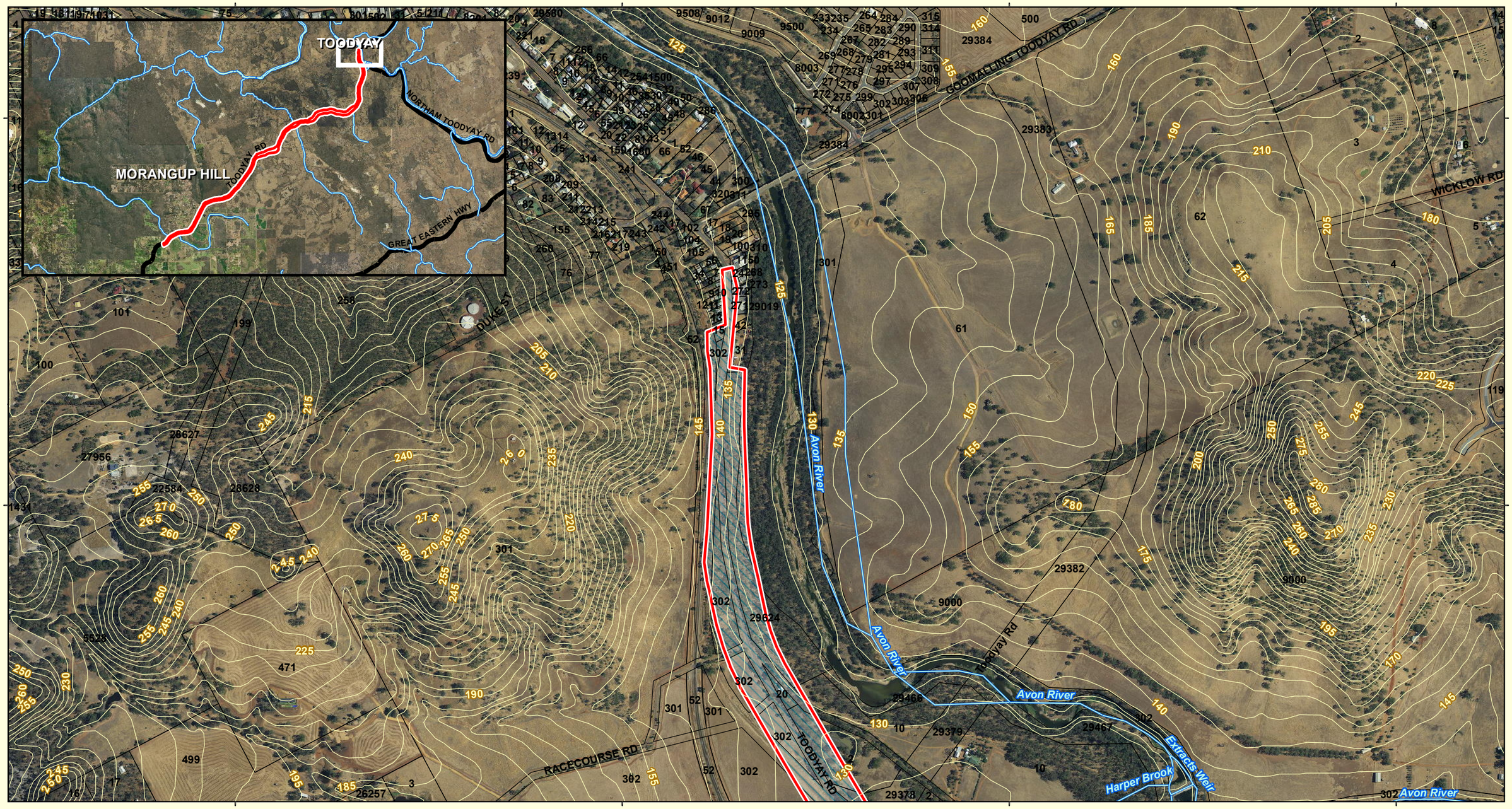


LEGEND

- Study Area
- Cadastre
- Contour (mAHD)
- Watercourse

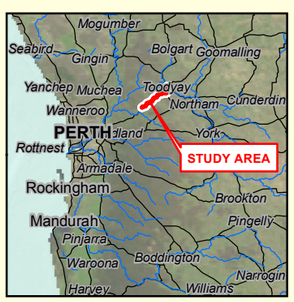
Dieback Occurrence Categories

- Infested
- Uninfested (Protectable)
- Uninfested (Unprotectable)
- Excluded
- Uninterpretable
- Temporarily Uninterpretable

Dieback Sample Results

- *P. cinnamomi*
- Negative
- Results Pending

Source: Watercourse, Contours, Imagery - Landgate



DIEBACK OCCURRENCE

Toodyay Road Dieback Assessment (Wheatbelt Section)

N

0 0.125 0.25 0.5 0.75 1 1.25

Kilometers
Coordinate System
GDA 1994 MGA Zone 50

Scale: 1:10,000 @ A3	Prepared: ENVIRONMAPS	Project No: T15019	Figure 2j
Date: 04/01/2016	Checked: K. Jennings		
Revision: Rev A	Reviewed: J. Grehan		

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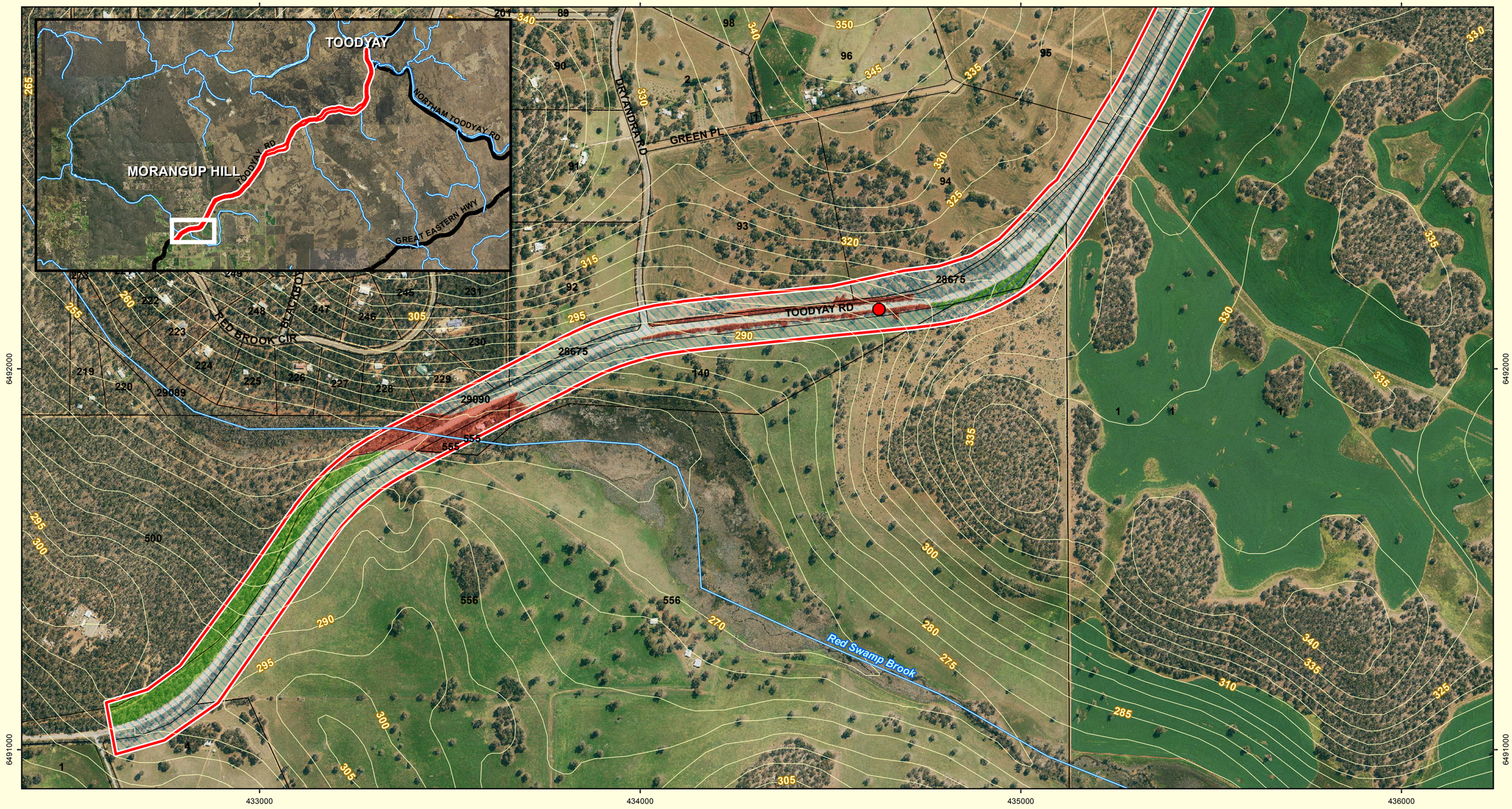

LEGEND

- Study Area
- Cadastre
- Contour (mAHD)
- Watercourse

Dieback Occurrence Categories

- Infested
- Uninfested (Protectable)
- Uninfested (Unprotectable)
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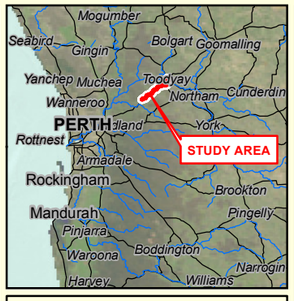
- Uninterpretable
- Temporarily Uninterpretable

Dieback Sample Results

- *P. cinnamomi*
- Negative
- Results Pending

Source: Watercourse, Contours, Imagery - Landgate



DIEBACK OCCURRENCE

Toodyay Road Dieback Assessment (Wheatbelt Section)

N

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Kilometers
Coordinate System
GDA 1994 MGA Zone 50

Scale: 1:10,000 @ A3	Prepared: ENVIRONMAPS	Project No: T15019	Figure 2a
Date: 04/01/2016	Checked: K. Jennings		
Revision: Rev A	Reviewed: J. Grehan		

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LEGEND

- Study Area
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Dieback Occurrence Categories

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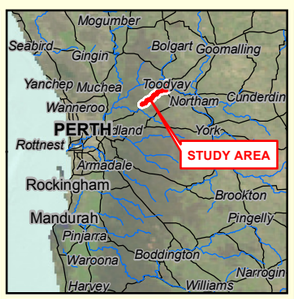
Source: Watercourse, Contours, Imagery - Landgate



DIEBACK OCCURRENCE

Toodyay Road Dieback Assessment (Wheatbelt Section)

N

0 0.125 0.25 0.5 0.75 1 1.25

Kilometers
Coordinate System
GDA 1994 MGA Zone 50

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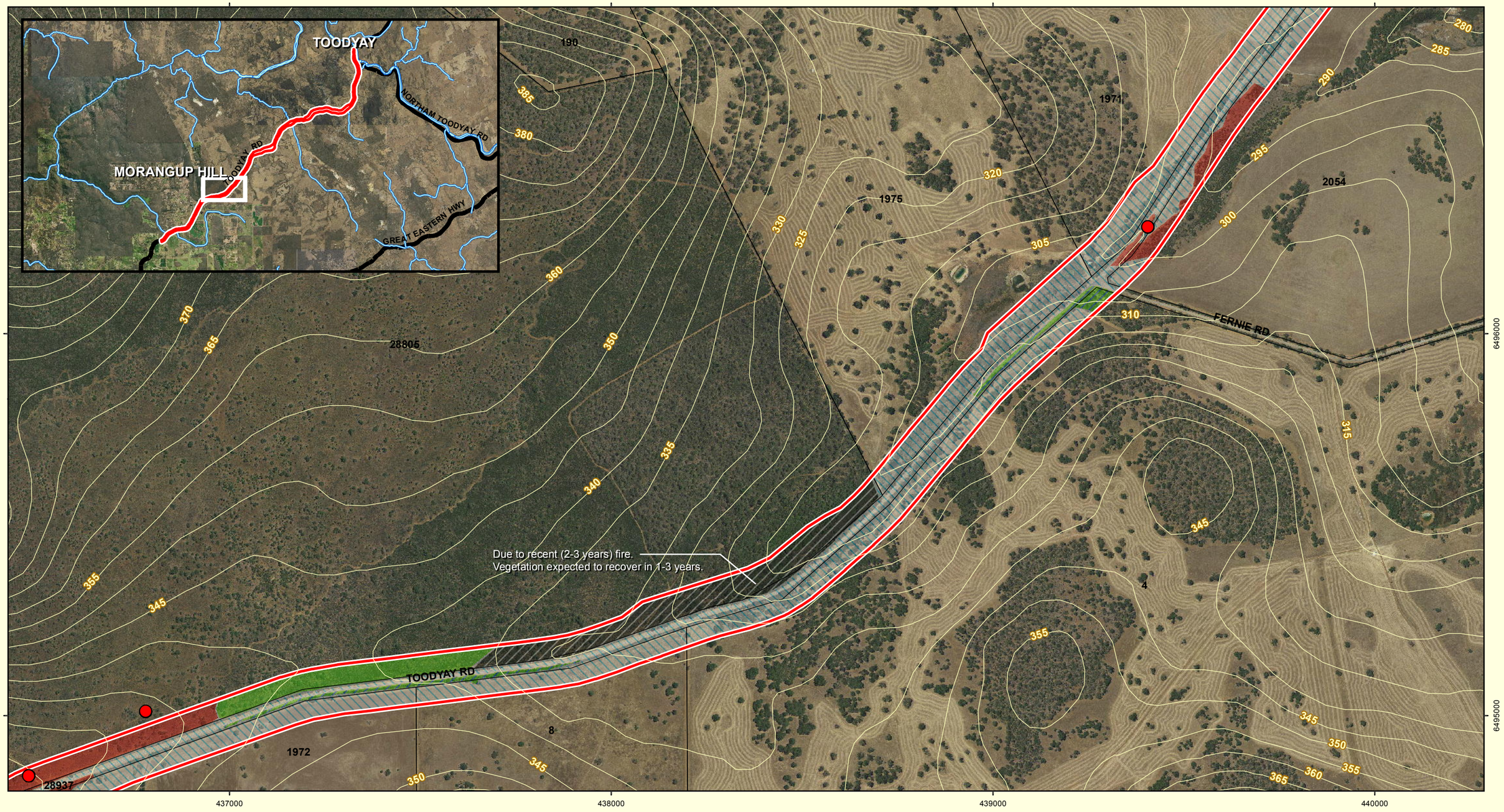

LEGEND

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- Negative
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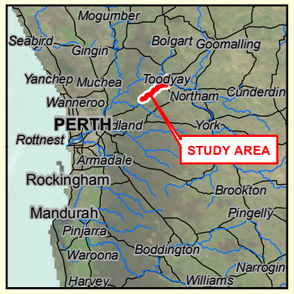
Source: Watercourse, Contours, Imagery - Landgate



DIEBACK OCCURRENCE

Toodyay Road Dieback Assessment (Wheatbelt Section)

N

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Kilometers
Coordinate System
GDA 1994 MGA Zone 50

Scale: 1:10,000 @ A3	Prepared: ENVIRONMAPS	Project No: T15019	Figure 2c
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Revision: Rev A	Reviewed: J. Grehan		

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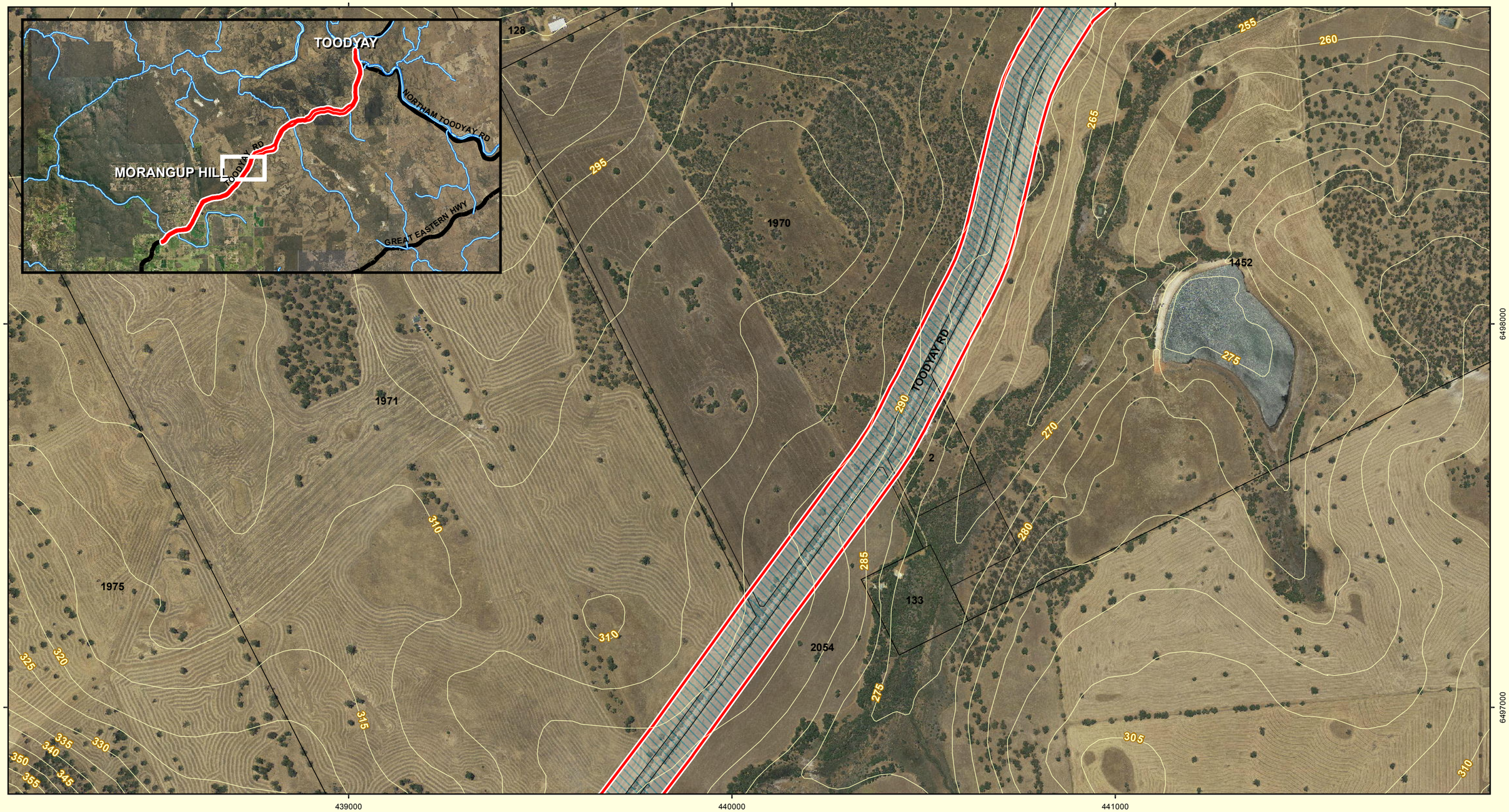

LEGEND

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Dieback Occurrence Categories

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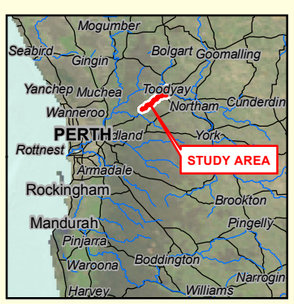

DIEBACK OCCURRENCE

Toodyay Road Dieback Assessment (Wheatbelt Section)

N

0 0.125 0.25 0.5 0.75 1 1.25

Kilometers
Coordinate System
GDA 1994 MGA Zone 50

Scale: 1:10,000 @ A3	Prepared: ENVIRONMAPS	Project No: T15019	Figure 2d
Date: 04/01/2016	Checked: K. Jennings		
Revision: Rev A	Reviewed: J. Grehan		

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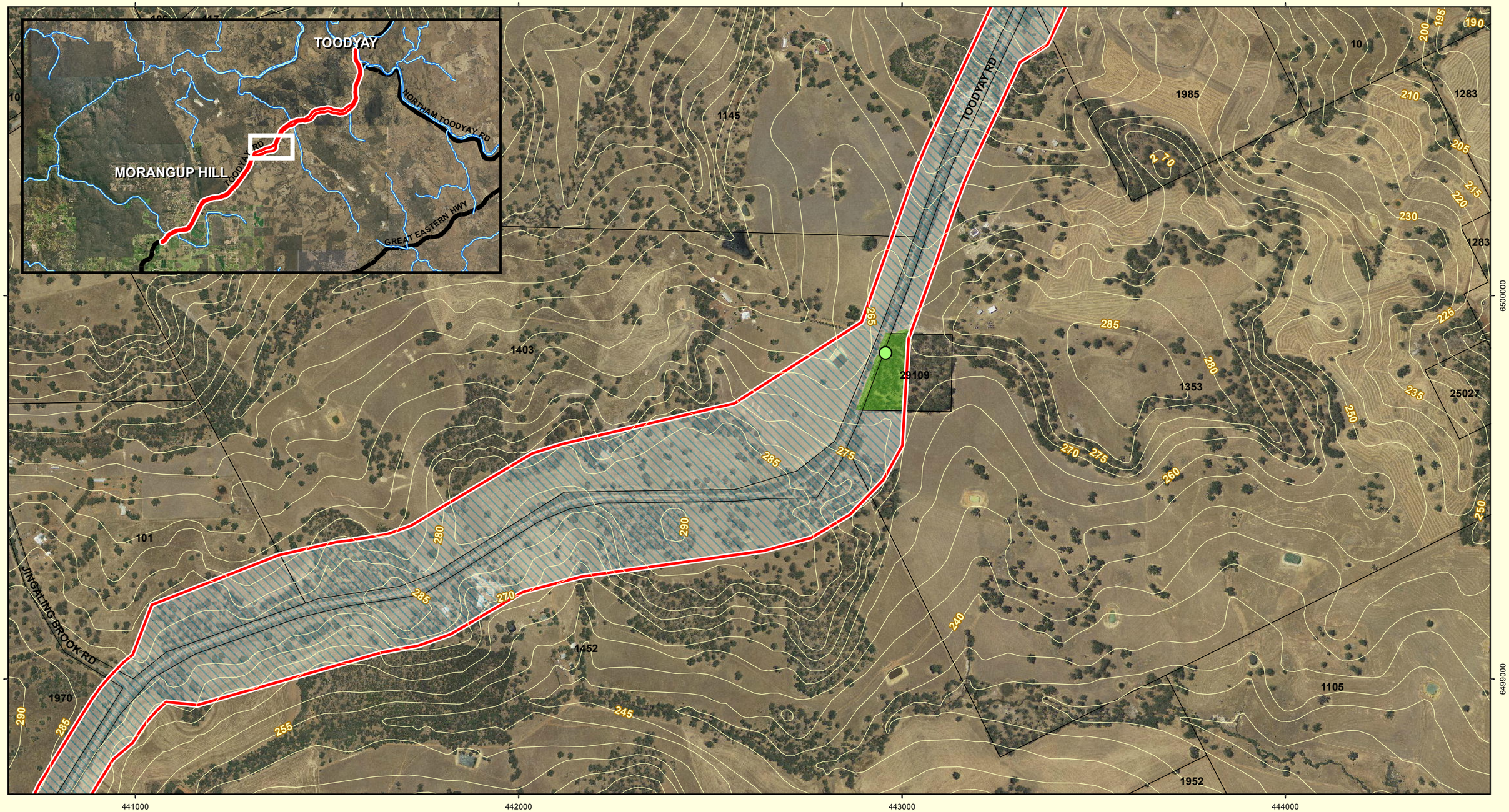

LEGEND

- Study Area
- Cadastre
- Contour (mAHD)
- Watercourse

Dieback Occurrence Categories

- Infested
- Uninfested (Protectable)
- Uninfested (Unprotectable)
- Excluded
- Uninterpretable
- Temporarily Uninterpretable

Dieback Sample Results

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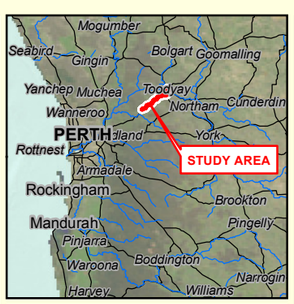
- Negative
- Results Pending

Source: Watercourse, Contours, Imagery - Landgate



DIEBACK OCCURRENCE

Toodyay Road Dieback Assessment (Wheatbelt Section)

N

0 0.125 0.25 0.5 0.75 1 1.25

Kilometers
Coordinate System
GDA 1994 MGA Zone 50

Scale: 1:10,000 @ A3	Prepared: ENVIRONMAPS	Project No: T15019	Figure 2e
Date: 04/01/2016	Checked: K. Jennings		
Revision: Rev A	Reviewed: J. Grehan		

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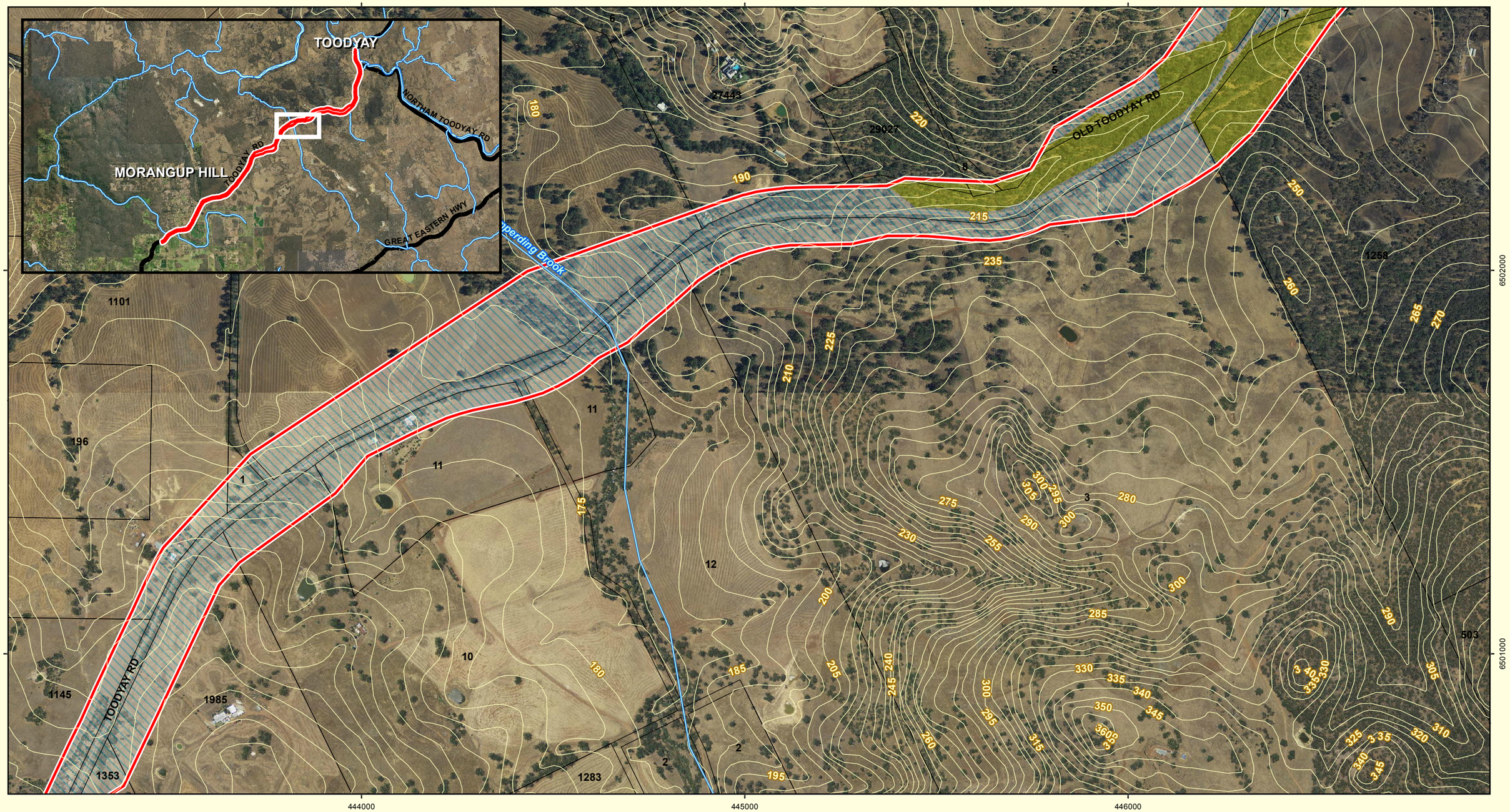


LEGEND

- Study Area
- Cadastre
- Contour (mAHD)
- Watercourse

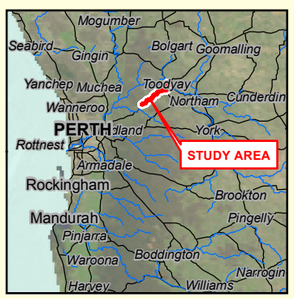
Dieback Occurrence Categories

- Infested
- Uninfested (Protectable)
- Uninfested (Unprotectable)
- Excluded
- Uninterpretable
- Temporarily Uninterpretable

Dieback Sample Results

- *P. cinnamomi*
- Negative
- Results Pending

Source: Watercourse, Contours, Imagery - Landgate



DIEBACK OCCURRENCE

Toodyay Road Dieback Assessment (Wheatbelt Section)

N

0 0.125 0.25 0.5 0.75 1 1.25

Kilometers
Coordinate System
GDA 1994 MGA Zone 50

Scale: 1:10,000 @ A3	Prepared: ENVIRONMAPS	Project No: T15019	Figure 2f
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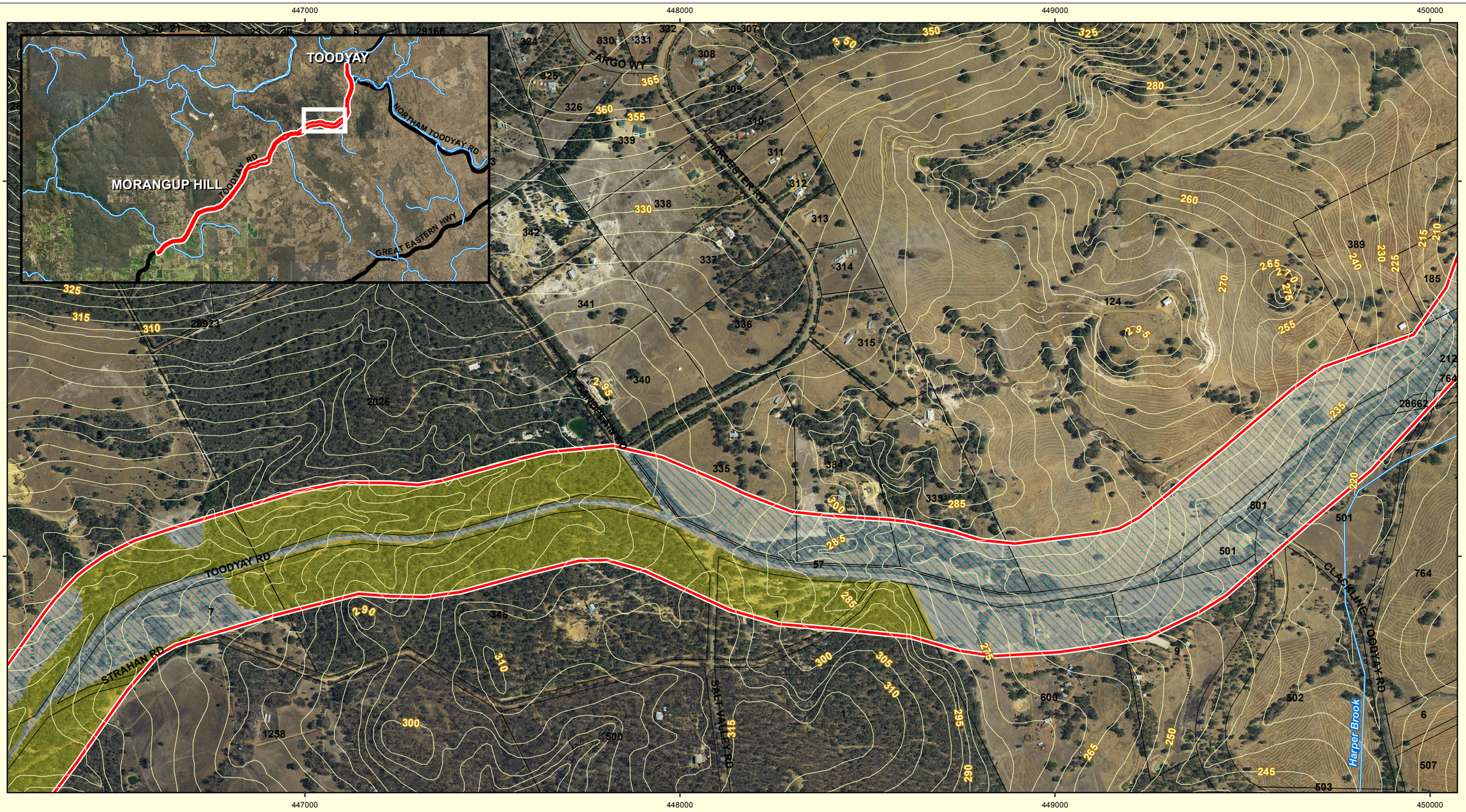


LEGEND

- Study Area
- Cadastre
- Contour (mAHD)
- Watercourse

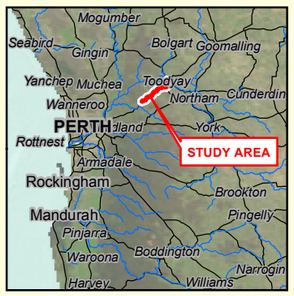
Dieback Occurrence Categories

- Infested
- Uninfested (Protectable)
- Uninfested (Unprotectable)
- Excluded
- Uninterpretable
- Temporarily Uninterpretable

Dieback Sample Results

- *P. cinnamomi*
- Negative
- Results Pending

Source: Watercourse, Contours, Imagery - Landgate



DIEBACK OCCURRENCE

Toodyay Road Dieback Assessment (Wheatbelt Section)

N

0 0.125 0.25 0.5 0.75 1 1.25

Kilometers
Coordinate System
GDA 1994 MGA Zone 50

Scale: 1:10,000 @ A3	Prepared: ENVIRONMAPS	Project No: T15019	Figure 2g
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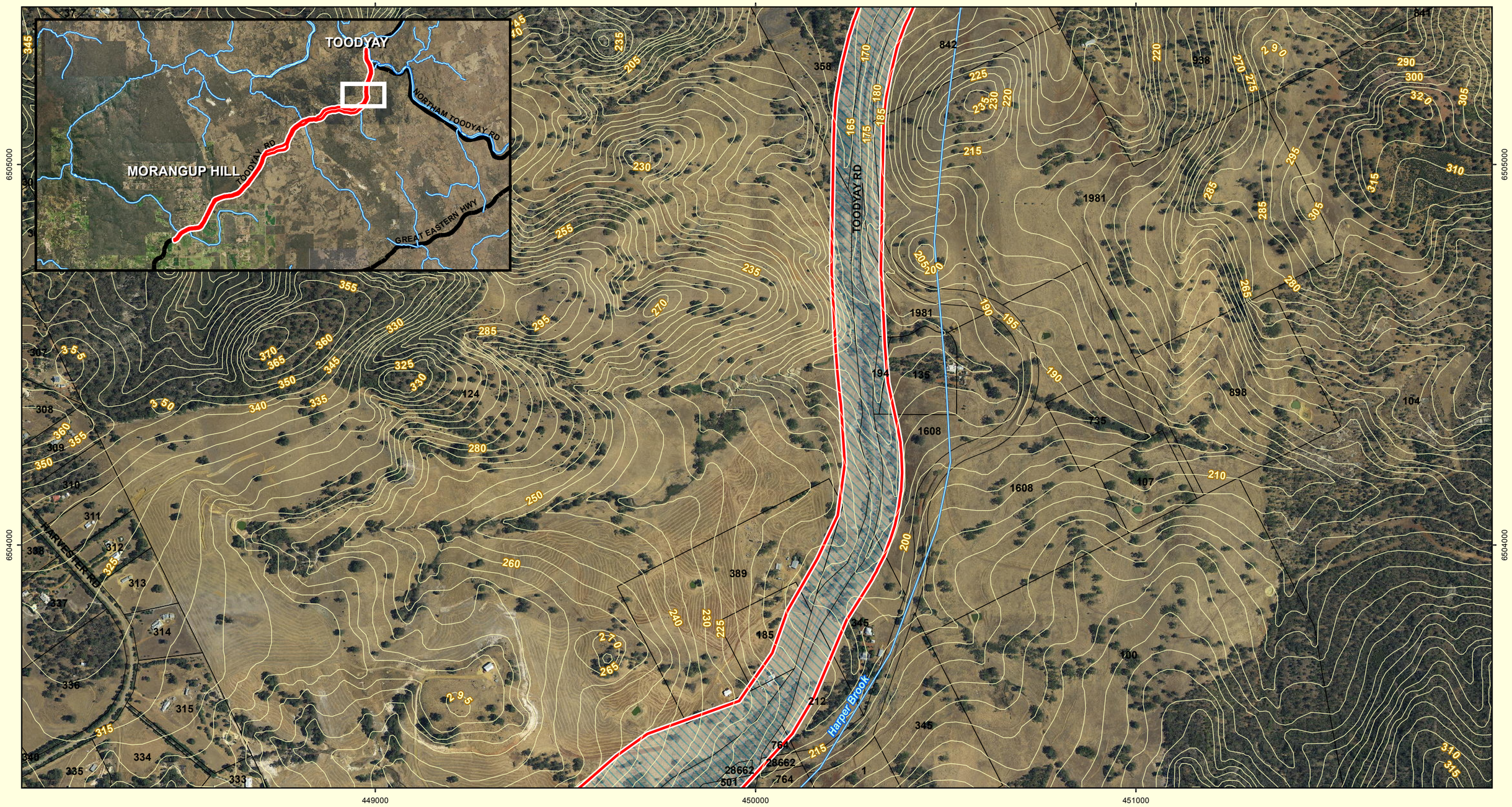

LEGEND

- Study Area
- Cadastre
- Contour (mAHD)
- Watercourse

Dieback Occurrence Categories

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- Uninfested (Unprotectable)
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Dieback Sample Results

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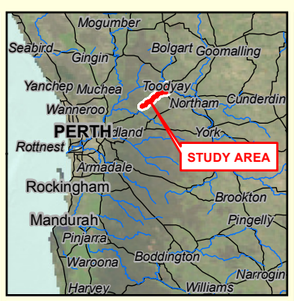
Source: Watercourse, Contours, Imagery - Landgate



DIEBACK OCCURRENCE

Toodyay Road Dieback Assessment (Wheatbelt Section)

N

0 0.125 0.25 0.5 0.75 1 1.25

Kilometers
Coordinate System
GDA 1994 MGA Zone 50

Scale: 1:10,000 @ A3	Prepared: ENVIRONMAPS	Project No: T15019	Figure 2h
Date: 04/01/2016	Checked: K. Jennings		
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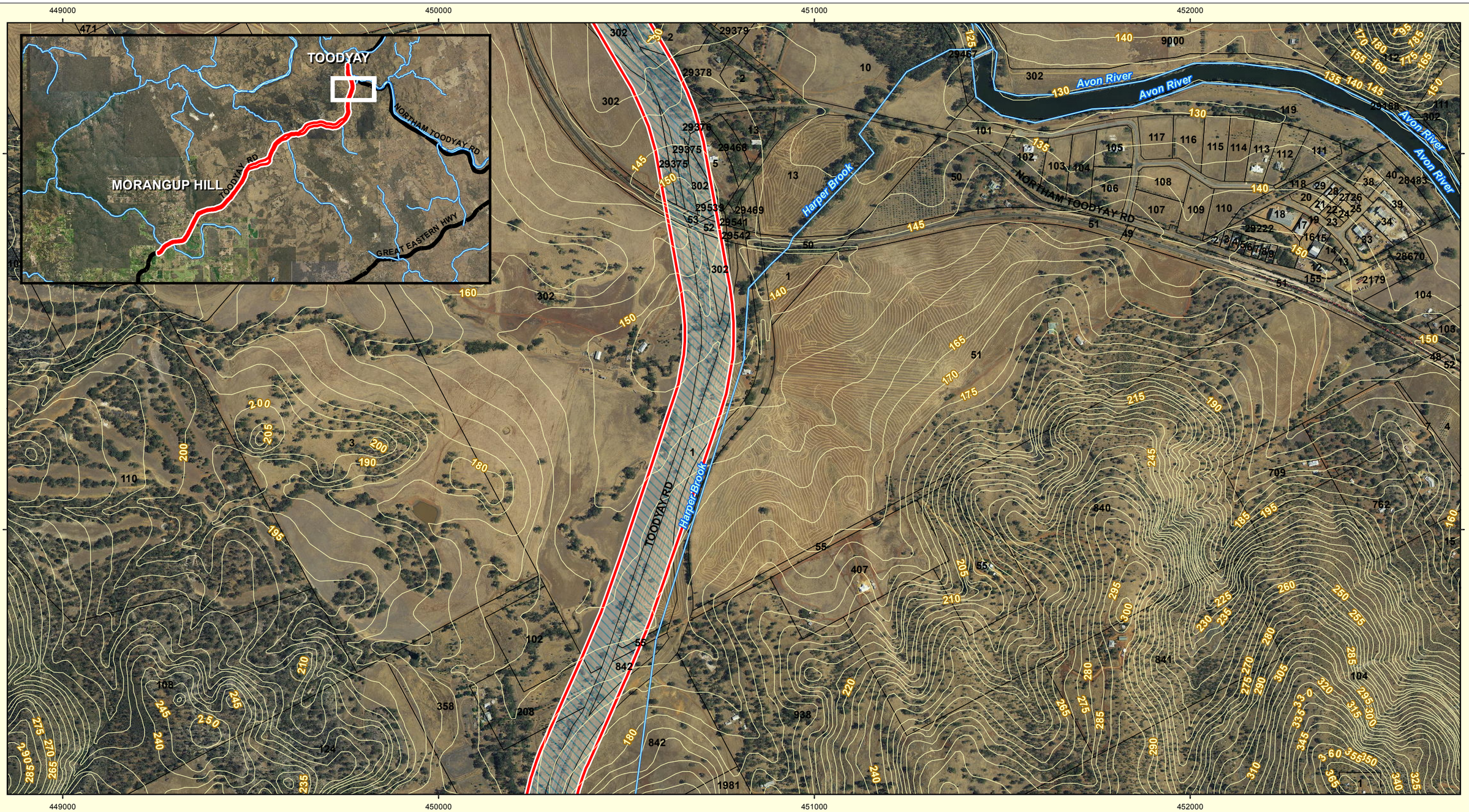

LEGEND

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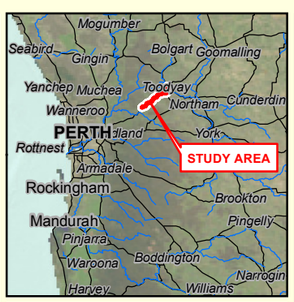

DIEBACK OCCURRENCE

Toodyay Road Dieback Assessment (Wheatbelt Section)

N

0 0.125 0.25 0.5 0.75 1 1.25

Kilometers
Coordinate System
GDA 1994 MGA Zone 50

Scale: 1:10,000 @ A3	Prepared: ENVIRONMAPS	Project No: T15019	Figure 2i
Date: 04/01/2016	Checked: K. Jennings		
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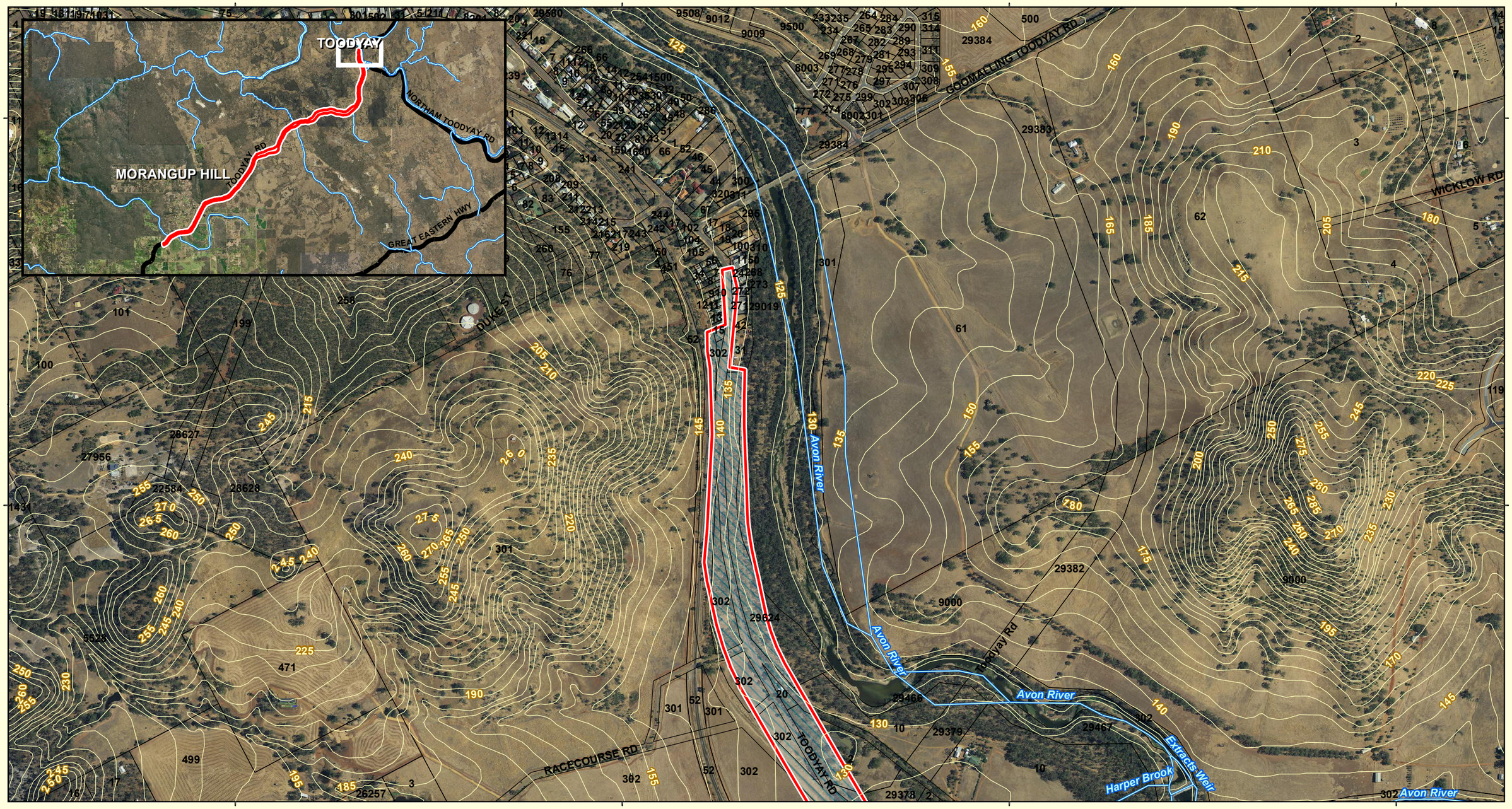

LEGEND

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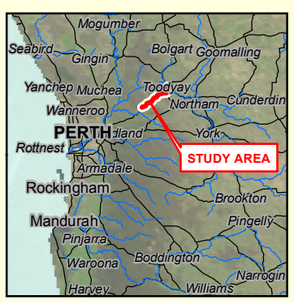

DIEBACK OCCURRENCE

Toodyay Road Dieback Assessment (Wheatbelt Section)

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Kilometers
Coordinate System
GDA 1994 MGA Zone 50

Scale: 1:10,000 @ A3	Prepared: ENVIRONMAPS	Project No: T15019	Figure 2j
Date: 04/01/2016	Checked: K. Jennings		
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Plates

Plate 1: Example of Uninfested vegetation within the study area

Plate 2: Dead *Xanthorrhoea preissii* (TR-S03) within Infested vegetation

Plate 3: Temporarily Uninterpretable vegetation, due to recent fire

Plate 4: Uninterpretable vegetation, due to a lack of Disease Indicator Species

Plate 5: Excluded area, due to a vegetation condition

Plate 6: Sample site TR-S15, with *Banksia squarrosa* infected *with P. cinnamomi*