QUESTIONS ON NOTICE

Environment, Energy and Science Group – Department of Planning, Industry and Environment

KOALA POPULATIONS AND HABITAT IN NEW SOUTH WALES

1. *Please provide a table (or similar) with the structure of the new Department so we can understand the new arrangements*

   Response:

   Charts of the Department of Planning, Industry and Environment's (DPIE) Senior Executive Team and the structure of the Environment, Energy and Science Group are provided at **Attachment 1**.

2. *Please provide a list of the koala surveys you have undertaken. Including where they are being undertaken and when they will be completed.*

   Response:

   Since May 2018, surveys for koalas have been undertaken as part of the NSW Koala Strategy in:
   - Far North-east Hinterland
   - Moree Plains
   - Richmond Valley
   - Clarence Valley
   - Warrumbungles / Pilliga
   - Port Macquarie-Hastings
   - Dungog Shire
   - Myall Coast
   - Bathurst
   - Blue Mountains
   - Bungonia
   - Cooma
   - Jindabyne

   These surveys are complete, and data will be made available on Bionet.

   Other recent surveys have been undertaken for koalas at:
   - Bongil Bongil National Park
   - NSW Southern Highlands
   - Campbelltown
   - NSW South Coast

   DPIE is also running a community wildlife survey collecting information on 10 animals, including koalas. The results of the survey will be made available through the Sharing and Enabling Environmental Data (SEED Portal) at www.seed.nsw.gov.au. More information about the surveys is available at: www.environment.nsw.gov.au/wildlife-survey.

3. *How much of the three properties purchased under the koala strategy were identified as 'koala hubs' by former OEH? It has been suggested these lands are not koala hubs.*

Response:

Approximately 26 hectares of the 43-hectare Cudgera Creek Nature Reserve in Tweed is within a koala hub. There are several identified hubs within 20 kilometres of the two properties in the Southern Highlands.

4. *BCT. To date they have entered into 10 agreements protecting 254 hectares of koala habitat on their properties. How much has that cost?*

Response:

The Biodiversity Conservation Trust (BCT) has signed five conservation agreements in the Port Macquarie region and five conservation agreements in the Lismore-Ballina region, with a total investment of $7.9 million. This investment will provide for in-perpetuity annual conservation payments to landholders for undertaking agreed conservation actions.

5. *What level of input did you and your colleagues in the former OEH have into the new Coastal IFOA remake?*

Response:

Staff from the former Office of Environment and Heritage (OEH) were involved in discussions, workshops and expert panels regarding the preparation of the Costal IFOA.

OEH also advised on the preparation of specific settings for threatened plants and south coast koalas and were commissioned by the EPA to deliver accurate mapping of high priority threatened ecological communities. OEH contributed technical advice to updated modelling of koala habitat undertaken by Department of Primary Industries Forests and provided technical advice on new stream protections. OEH provided written feedback at various points in the process.

6. *In terms of funding for koala strategy within the department, could you give us an indication of what the funding has been annually and how it has changed over the past 10 years? And what resources have been put in and whether the trend is up or down.*

Response:

Expenditure on koalas is available from when the former Office of Environment and Heritage was formed (2010-11) to 2018-19:

- 2010-11 $0.04 million
- 2011-12 $0.35 million
- 2012-13 $0.79 million
- 2013-14 $0.73 million
- 2014-15 $0.85 million
- 2015-16 $1.16 million
- 2016-17 $2.37 million
- 2017-18 $7.0 million
- 2018-19 $13.51 million

7. *Provide a list of who is on the Biodiversity Advisory Panel*.

Response:

Panel appointments made on 30 August 2018 are:

- Professor Graciela Metternicht (Chairperson)
- Professor Jeffrey Bennett
- Mr Martin Fallding
- Professor Richard Kingsford
- Professor Angela Moles
- Professor Zada Lipman

8. *Provide a list of who is on the Native Vegetation Panel.*

Response:

This question should be redirected to Local Land Services.

9. *You are suggesting that four areas of outstanding biodiversity value have been established before the guidelines have been established*?

Response:

Under clause 8 of the Biodiversity Conservation (Savings and Transitional) Regulation 2017, any area that was previously declared to be a critical habitat is taken to have been declared as an Area of Outstanding Biodiversity Value. The four existing critical habitats taken to be NSW's first Areas of Outstanding Biodiversity Values are:

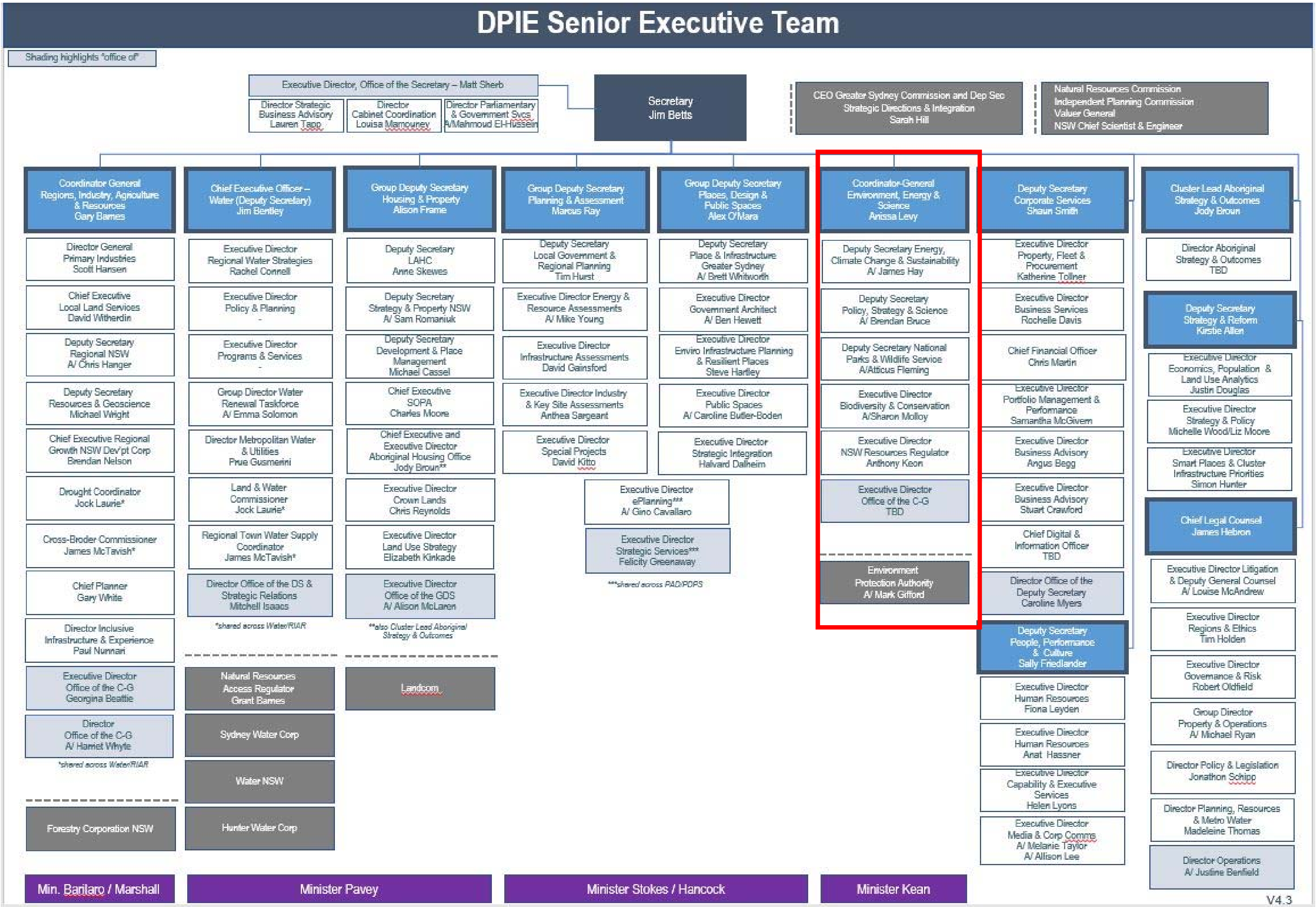
- Mitchell's Rainforest Snail critical habitat in Stotts Island Nature Reserve
- Little Penguin critical habitat in Sydney's North Harbour
- Gould's Petrel critical habitat in John Gould Nature Reserve
- Wollemi Pine critical habitat in Wollemi National Park.

10. *My understanding is that the best practice and the advice that has been provided previously is about overpasses and vegetative corridors. In relation to Appin Rd in Sydney's south-west, has anyone in your department provided advice that would confirm this rather than just the fencing that is being adopted?*

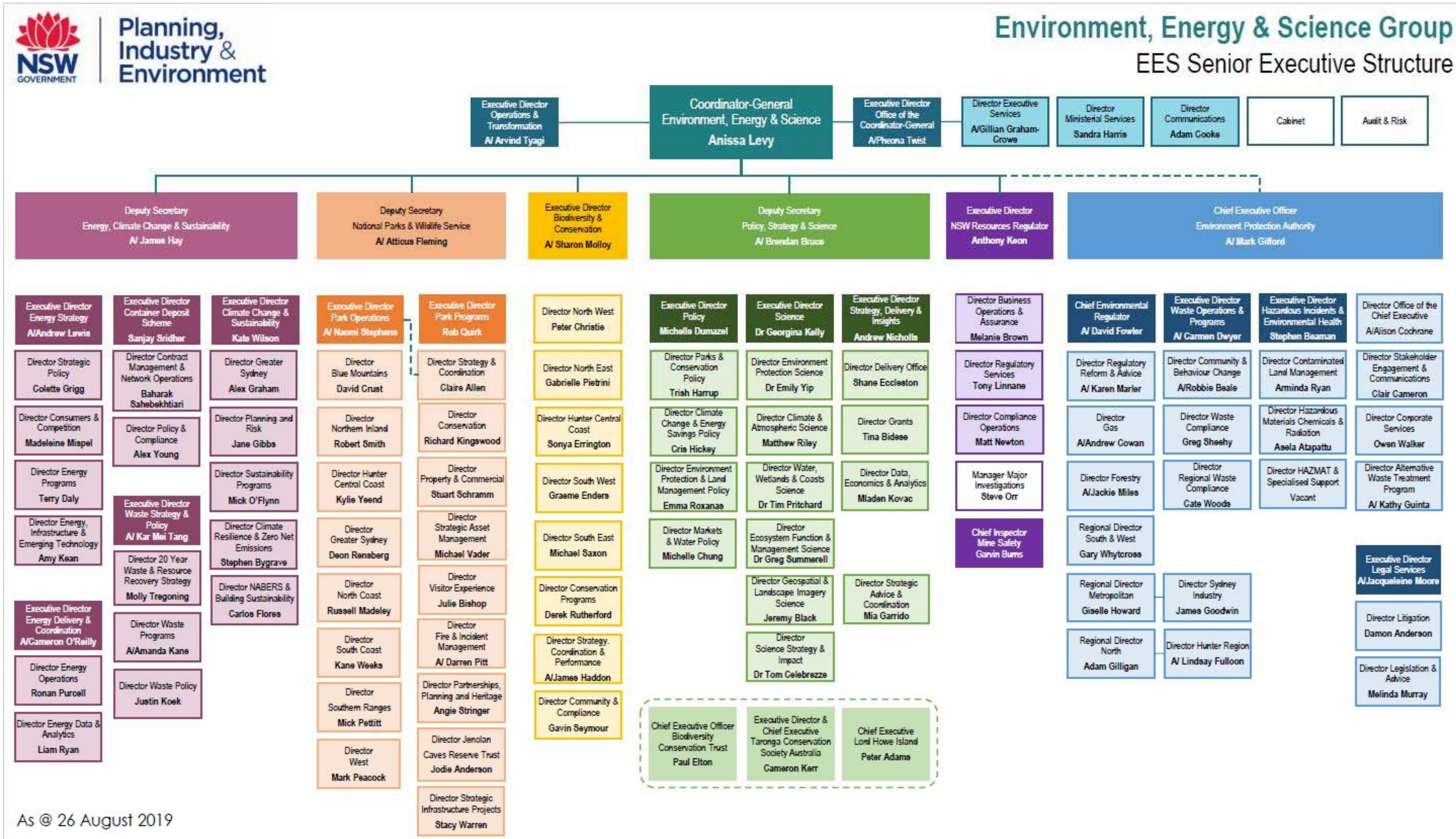
Response:

Environment, Energy and Science's advice is set out in the report *Conserving Koalas in Wollondilly and Campbelltown LGAs* at Attachment 2.

Attachment 1 – Organisation Structure (Department of Planning, Industry and Environment)



Attachment 2 – Organisation Structure (Environment, Energy and Science Group)



Conserving koalas in Wollondilly and Campbelltown LGAs

FINAL

January 2018

Table of Contents

Summary

This report identifies high quality koala habitat, core koala habitat, koala movement corridors and roadkill hotspots in the Wollondilly and Campbelltown Local Government Areas (LGAs). Existing data was used along with data collected specifically for this project. The report provides an estimate for koala densities in core koala habitat and extrapolated koala numbers potentially supported in movement corridors in the Wollondilly and Campbelltown LGAs, to categorise the relative importance of different corridors. These estimates provide a basis for OEH's management recommendations, in the Wollondilly and Campbelltown LGAs. Key koala conservation principles are coupled with the known areas of koala habitat to provide specific recommendations for the local conservation of the regional koala population extending from Campbelltown, through Wollondilly, to Wingecarribee.

Information and recommendations outlined in this report are communicated in the context of residential and urban development in the Wilton and Greater Macarthur Growth Areas (GAs). Information on core koala habitat and koala movement corridors is essential knowledge during planning for development in south-west Sydney. While data collection for koalas in the Wollondilly and Campbelltown areas is ongoing, data used in this report represent the best-available information to inform management decisions related to future development. Previously developed information for koala habitat and movement corridors (see DECC 2007) was completed at a regional scale and is not appropriate for use at the scale needed for the Wilton and Macarthur GAs.

1 Introduction

The NSW Government recently commenced funding koala research and on-ground management actions under the *Saving our Species* (SoS) conservation program. As part of the SoS program, OEH initiated the Wollondilly Koala Conservation Project. This project is collecting new information on koala distribution, abundance, movement, and habitat usage within the Wollondilly LGA. Work commenced in March 2016. Data collection and analysis are ongoing.

Given large parts of the Wollondilly and adjacent Campbelltown areas are earmarked for development as part of the Wilton and Greater Macarthur growth areas (GA), OEH has prepared this document to inform government and non-government stakeholders of priority areas for koala conservation and key actions required to avoid or minimise impacts and threats from new developments. Information of this nature is essential to ensure that future urban growth does not compromise the viability of the koalas in the area, and the wider regional koala population extending from Campbelltown, through Wollondilly, to Wingecarribee. This area is projected to support thousands of new dwellings, town centres, and associated infrastructure.

For this document, OEH has combined existing data from a range of sources, including the NSW BioNet database, and new data from the Wollondilly Koala Conservation Project. Core koala habitat and koala movement corridors in the Wollondilly and Campbelltown LGAs, specifically southern Campbelltown, Appin and Wilton, are identified at a local scale (approximately 1:10,000). Both core koala habitat and koala movement corridors are critical to the long-term persistence of the regional koala population. This information has been used to inform management recommendations, including identification of koala roadkill hotspots and mitigation measures to reduce the incidence of koala roadkill.

The focus area is the Wilton and Greater Macarthur GAs. However, koala habitat and corridors in the GAs are linked to important koala habitat and metapopulations to both the north and south. Therefore, mapping was undertaken for a larger area from the Georges River north of Holsworthy to Colo Vale in the Wingecarribee Shire.

While the Wollondilly Koala Conservation Project is ongoing, the information collected to date has improved our understanding of the regional koala population. The data collected updates existing koala habitat and corridor mapping done at a regional scale (DECC 2007) from south Campbelltown to Appin and across to the Wilton area. The new mapping will allow prioritisation of management actions within these areas.

The scientific methods, the areas recommended for protection and the mitigation measures identified have been peer reviewed by two renowned koala scientists, Associate Professor Mathew Crowther and Dr Stephen Phillips. Their reviews in Attachments 1 and 2 indicate that the conservation areas and measures recommended in this report represent the minimum requirements for koala conservation in the area.

The use of best-available information is crucial in understanding what is required to maintain the regional koala population, and specifically the metapopulations in the Wollondilly and Campbelltown areas. As more information becomes available it will be used to refine outcomes, particularly in relation to filling identified data gaps.

2.1. Methods

A number of data input layers were used to identify koala habitat and movement corridors. These are listed below and are referred to throughout this methods section:

- Koala Linkage (DECC 2007)
- Koala habitat model (DECC 2007)
- Presence-absence spotlighting data (downloaded from BioNet November 2017; OEH 2017)
- Koala habitat assessment 20 x 20 m vegetation plots (downloaded from VIS November 2017; OEH 2017)
- Preferred koala use trees for Wollondilly (OEH unpub. data)
- Native vegetation of the Sydney Metropolitan Area (OEH 2013)
- Native vegetation of the Woronora, O'Hares and Metropolitan Special Areas (NPWS 2003)
- Cumberland Plain Native Vegetation Mapping (Tozer 2003)
- Native Vegetation of the Nattai and Bargo reserves (DEC 2004).

Other layers referred to (but not formally used to derive koala habitat and movement corridors) include:

- Cumberland Plain Priority Conservation Lands (DECCW 2011)
- Cumberland Subregion Biodiversity Investment Opportunities Map (BIO Map) (OEH 2015)
- Campbelltown Council Biodiversity Corridors (Campbelltown Council 2017)
- ELA wildlife corridors for Mt Gilead and surrounds (ELA 2017).

2.1.1 Using fine-scale vegetation mapping to produce maps for core koala habitat and koala movement corridors

The vegetation in the Wollondilly and Campbelltown areas has been mapped to a fine to very fine scale, and plant communities are known with a high degree of confidence. As such, core koala habitat and koala movement corridor mapping were based on the finest scale vegetation mapping available for the region. Vegetation communities reflect the geology of the region, with shale and shale-transition soils and sandstone derived soils influencing the proportion of koala feed trees in each vegetation type. The mapping available for this area is between 1:8,000 and 1:25,000.

North from Wedderburn the vegetation map used was the *Native Vegetation of the Sydney Metropolitan Area* (OEH 2013). This is a recent, validated vegetation map of NSW Plant Community Types (PCTs) developed in line with the NSW Native Vegetation Interim Type Standards (DECCW 2010). It was produced at a scale of 1:8,000 and has a high degree of accuracy in line-work and attribution of vegetation communities.

The remainder of the study area is covered by a mosaic of vegetation mapping, including the *Cumberland Plain Native Vegetation Map* (Tozer 2003), *Native Vegetation of the Nattai and Bargo reserves* (DEC 2004) and the *Native Vegetation of the Woronora, O'Hares and Metropolitan Catchments* (NPWS 2003) (all at a scale of 1:25,000). These maps are limited by the accuracy of the aerial photography available at the time of production. Wherever possible, line-work was updated (using high resolution ASD40 2014 aerial photography), improving line-work accuracy and excising any new areas of clearing. Areas that had been under-scrubbed or semi-cleared since the mapping was undertaken were re-attributed. Although still fine-scale compared to most vegetation maps, the difference in the accuracy of the underlying mapping between the south and the north is one of the limitations of the final products.

2.1.2 Why not use SEPP44 definitions?

SEPP 44 definitions of ‘core koala habitat’ were not used due to the high number of known local feed trees used by koalas, particularly for the Wollondilly LGA, that are not listed in SEPP 44. Core koala habitat for the purpose of this document is defined in the Glossary.

2.1.3 Defining koala habitat

In the Campbelltown and Wollondilly LGAs, there is a long-established relationship between the presence of koalas and vegetation that grows on higher fertility soils such as shale or shale-transition soils (e.g. Prevett *et al.* 2001, Phillips and Callaghan 2002; Ward 2002; Lunney *et al.* 2010). Koalas favour vegetation growing on fertile soils due to the increased nutrient availability in eucalypt leaves (Moore et al. 2010). Therefore, all shale and shale-enriched vegetation types with a dominant eucalypt canopy were initially classified as being high quality habitat (HQH). HQH patches greater than 100 ha were identified as ‘core’ koala habitat. Low-fertility sandstone vegetation communities including heaths, heathy woodlands, swamps and rocky woodlands were classified as low-quality habitat (LQH). Eucalypt-dominated riparian sandstone communities, rainforest communities on shale with some eucalypts present and regenerating acacia scrubs on shale were classified as medium-quality habitat (MQH). Table 1 shows mapped vegetation communities and their soil classification and their assigned habitat quality based on the vegetation community descriptions listed in the relevant vegetation map (*Cumberland Plain Native Vegetation Map* (Tozer 2003), *Native Vegetation of the Nattai and Bargo reserves* (DEC 2004), *Native Vegetation of the Sydney Metropolitan Area* (OEH 2013) and the *Native Vegetation of the Woronora, O’Hares and Metropolitan Catchments* (NPWS 2003))

Table 1: Vegetation communities within the study area, soil classification and koala habitat quality.

Vegetation Community	Soil Classification	Koala Habitat Quality
Cumberland Plain Alluvial Woodland	Shale	HQH
Cumberland Plain Shale Hills Woodland	Shale	HQH
Cumberland Plain Shale Plains Woodland	Shale	HQH
Cumberland Plain Shale Sandstone Transition Forest (HSI)	Shale transition	HQH
Cumberland Plain Shale Sandstone Transition Forest (LSI)	Shale transition	HQH
Eastern Gully Forest	Sandstone	MQH
Exposed Sandstone Scribbly Gum Woodland	Sandstone	MQH
Highlands Shale Tall Open Forest: Form C Tall Open Variant	Shale	HQH
Moist Shale Woodland	Shale	HQH
Nattai Sandstone River Peppermint Forest	Sandstone	MQH
Nepean Enriched Sandstone Woodland	Shale enriched	HQH
Nepean Gorge Moist Forest	Sandstone	MQH
O'Hares Creek Shale Forest	Shale transition	HQH
Riparian Forest	Shale transition	HQH
Riparian Scrub	Sandstone	LQH
Rock Pavement Heath	Sandstone	LQH
Rock Plate Heath-Mallee	Sandstone	LQH
Sandstone Gully Apple-Peppermint Forest	Sandstone	MQH
Sandstone Gully Peppermint Forest	Sandstone	MQH
Sandstone Heath-Woodland	Sandstone	LQH
Sandstone Ridgetop Woodland	Sandstone	LQH
Sandstone Riparian Scrub	Sandstone	LQH
Sheltered Sandstone Blue-leaved Stringybark Forest	Sandstone	MQH
Transitional Shale Dry Ironbark Forest	Shale transition	HQH
Transitional Shale Open Blue Gum Forest	Shale transition	HQH
Transitional Shale Stringybark Forest	Shale transition	HQH
Upland Swamps: Banksia Thicket	Sandstone	LQH
Upland Swamps: Fringing Eucalypt Woodland	Sandstone	LQH
Upland Swamps: Sedgeland-Heath Complex	Sandstone	LQH
Upland Swamps: Tea-Tree Thicket	Sandstone	LQH
Upper Georges River Sandstone Woodland	Shale enriched	HQH
Western Sandstone Gully Forest	Shale enriched	HQH
Western Sydney Dry Rainforest	Shale	MQH
Woronora Tall Mallee-Heath	Sandstone	LQH
Regenerating Vegetation		LQH/MQH
Weeds and Exotics		LQH
Exposed Rock		LQH

2.1.4 Validation of high quality habitat

High quality koala habitat was subject to a series of validation steps using four independent datasets.

Floristic validation

The draft high quality habitat map was validated using floristic plot data collected as part of the Wollondilly Koala Conservation Project (OEH 2017). 143 20 x 20 m, full floristic validation plots were completed within the study area and used to validate high quality habitat. Tree species recorded in vegetation plots were used to confirm the presence and association of koala use trees with mapped high-quality habitat. These plots have been entered into the OEH Vegetation Information System (VIS) (OEH 2017). The plots were not used in the development of the vegetation mapping used to assign koala habitat quality and are therefore a suitable validation dataset.

Systematic presence/absence spotlighting data

The correlation between presence of koalas and shale, shale-transition and shale-enriched vegetation types (e.g. Prevett *et al.* 2001, Phillips and Callaghan 2002; Ward 2002; Lunney *et al.* 2010). was checked using systematic presence-absence spotlighting data (BioNet; OEH 2017), Over 800 systematic, two-hectare spotlighting surveys have been undertaken as part of the Wollondilly and Southern Highlands Koala Conservation Projects. For this report, all spotlighting sites within the eastern part of the Wollondilly LGA were used (**Figure 2**). Those sites within 500m of another site were excluded to promote independence, leaving 173 sites in total.

Spotlighting sites where koalas were observed and not observed were overlayed on the map of high quality habitat. The number of spotlighting sites and koalas recorded in and out of high quality habitat was determined using GIS.

An estimate of densities of koalas in each habitat category (core v non-core) was calculated by dividing the number of koalas observed by the effective area surveyed. A Pearson's Chi-squared test was used to determine if there was a significant difference in koala density in core and non-core habitat using R.3.3.0 (R Core Team 2013).

Spotlighting is likely to under-estimate koala numbers and densities as spotlighting is imperfect at detecting koalas and it is possible that some koalas within the survey areas were not detected.

Incidental koala sightings

The correlation between shale and shale-transition vegetation types and koalas was also assessed using all koala sightings from the NSW Atlas of Wildlife for the Wollondilly Study Area (BioNet; OEH 2017). Records with accuracy over 1 km were discarded, leaving 582 valid records. Of these, 500 records (86%) had an accuracy of 100m or less.

Koala records were clipped to the map of core and non-core koala habitat with a 100m buffer. The buffer was included so that koala records on roads that intersect with core habitat were classified as core habitat rather than non-core habitat. The percentage of records on identified core and non-core habitat was calculated.

Association with preferred koala use trees

A list of preferred koala use trees in Wollondilly LGA has been determined through radio tracking of eight collared koalas (OEH unpublished data). Diurnal and nocturnal observations of radio-collared koalas were undertaken over a period of up to 6 months at least weekly in which the trees species, diameter at breast height and tree height were recorded for each direct koala observation. Koalas were observed between 30-53 times in the field. Data for two females with lower numbers of observations and overlapping home ranges (Daenerys and Ellaria) was combined. Preferred koala use trees were determined as those which were used at least 15% of the time by at least one koala.

The canopy species for each vegetation community within the study area were listed, as described in the associated Technical Report for each relevant vegetation map (References). Identified preferred koala use trees for Wollondilly LGA were highlighted for each vegetation type, and the number of preferred tree species per vegetation type counted. The number of vegetation communities with preferred koala trees and the average number of preferred koala trees was then calculated for sandstone vegetation communities and shale/shale-enriched vegetation communities.

2.1.5 Delineating koala movement corridors

To identify the most important connections of koala habitat in the region, and define these as primary, secondary and tertiary movement corridors, the following steps were taken:

- HQH patches greater than 100 ha were identified as 'core'. Tracking of koalas in the region has shown that 100 ha is sufficient to support the home range of at least one male koala and multiple females. In this region, the average home range size of tracked koalas is 94 hectares, with males averaging 114 ha (n=8) and females averaging 38 ha (n=3) (unpublished OEH data from the Wollondilly and Southern Highlands Koala Conservation Projects).
- Patches of 'core' separated by more than 1 km by cleared land were excluded from movement corridors. This 1 km threshold was sourced from the maximum distances of open land crossed by tracked koalas during the Wollondilly and Southern Highlands Koala Conservation Project (OEH unpublished data).
- Smaller patches of HQH within 100 m of patches of 'core' in corridors were included as part of the corridors.
- Patches of non-core koala habitat (MQH or LQH) that connect patches of 'core' within corridors, or were entirely within 'core' habitat in corridors, were also included as part of corridors.
- Lower quality habitat (MQH or LQH) that was peripheral to the corridors was not included in corridors.
- Scattered trees were included in corridors when they were completely or largely contained within the corridors.
- Scattered trees peripheral to corridors will be used by koalas, but these were identified as 'supporting' habitat and excluded from corridors.
- Strips of high quality habitat less than 200 m wide and less than 2 km long that led into the low-quality sandstone habitat of the Woronora Plateau surrounds were truncated.

Identified corridors were then categorised into primary, secondary, and tertiary corridors.

- Primary corridors were those that contained patches of 'core' koala habitat which were contiguous (gaps between trees are less than 100 m) and together contained over 380 ha of core habitat.
- Secondary corridors were those that contained patches of 'core' koala habitat and scattered trees separated by more than 100 m, were narrow or had pinch points of less than 50 m wide, and together contained between 100 ha and 380 ha of core habitat. Otherwise, if containing greater than 380 ha of habitat or were not narrow, secondary corridors were those that did not connect to primary corridors on both ends.
- Tertiary corridors were those that contained patches of 'core' koala habitat that were poorly linked to primary corridors, together contained between 30 ha and 100 ha of core habitat, and did not connect to primary corridors on both ends. Otherwise, if containing greater than 100 ha of habitat, tertiary corridors were those did not connect to other corridors.
- The corridor network was broken down into sub-catchments and named accordingly – e.g. Georges, Nepean, Cataract, Allen's Creek corridors.
- Each of these corridors was attributed in the digital layer as to its name, classification as a primary, secondary or tertiary corridor, the width of the connection to a primary corridor, the width at the narrowest point, and the source layer.

Note that cleared land was excluded from mapped movement corridors. This is despite cleared land forming a part of movement corridors. Rehabilitation of cleared land would be a priority for improved functionality of the corridor.

2.1.6 Koala movement corridor validation

The koala movement corridor map developed for this report was validated by comparing it with a Generalised Linear Model (GLM) of koala habitat and associated corridor map (DECC 2007). The 2007 habitat model of corridors was laid over the newly-defined corridors from this study and the level of correlation between the pathways identified. The DECC (2007) layer is a computer-based spatial interpolation (S-PLUS and ArcGIS Spatial Analyst) of koala corridors made from known sightings of koalas modelled with environmental variables (DECC 2007). The layer products cover Greater Southern Sydney region, including all the current study area and were derived at a scale of 1:25,000. These maps and the modelling process were extensively reviewed and the habitat model appears in a peer reviewed publication (Lunney et al. 2010). The dataset used to derive the 2007 model was independent from the dataset used to create the current layers; therefore, it is suitable as a validation tool for the current corridor layer.

2.2 Results

2.2.1 Core koala habitat

Core koala habitat is shown in Figure 1. Koalas in the area are living in an increasingly fragmented landscape. The strongholds for the koala metapopulations of the Campbelltown and Wollondilly LGAs are the large patches of core habitat along the eastern edge of the Cumberland Plain. The remaining areas of shale-sandstone transition forest along the Nepean River and its major tributaries provide the only other core habitat for koalas in the Campbelltown and Wollondilly areas. This habitat is more limited in extent and linear in configuration; however, it still supports significant numbers of resident koalas and is vital to the persistence of the regional koala population.

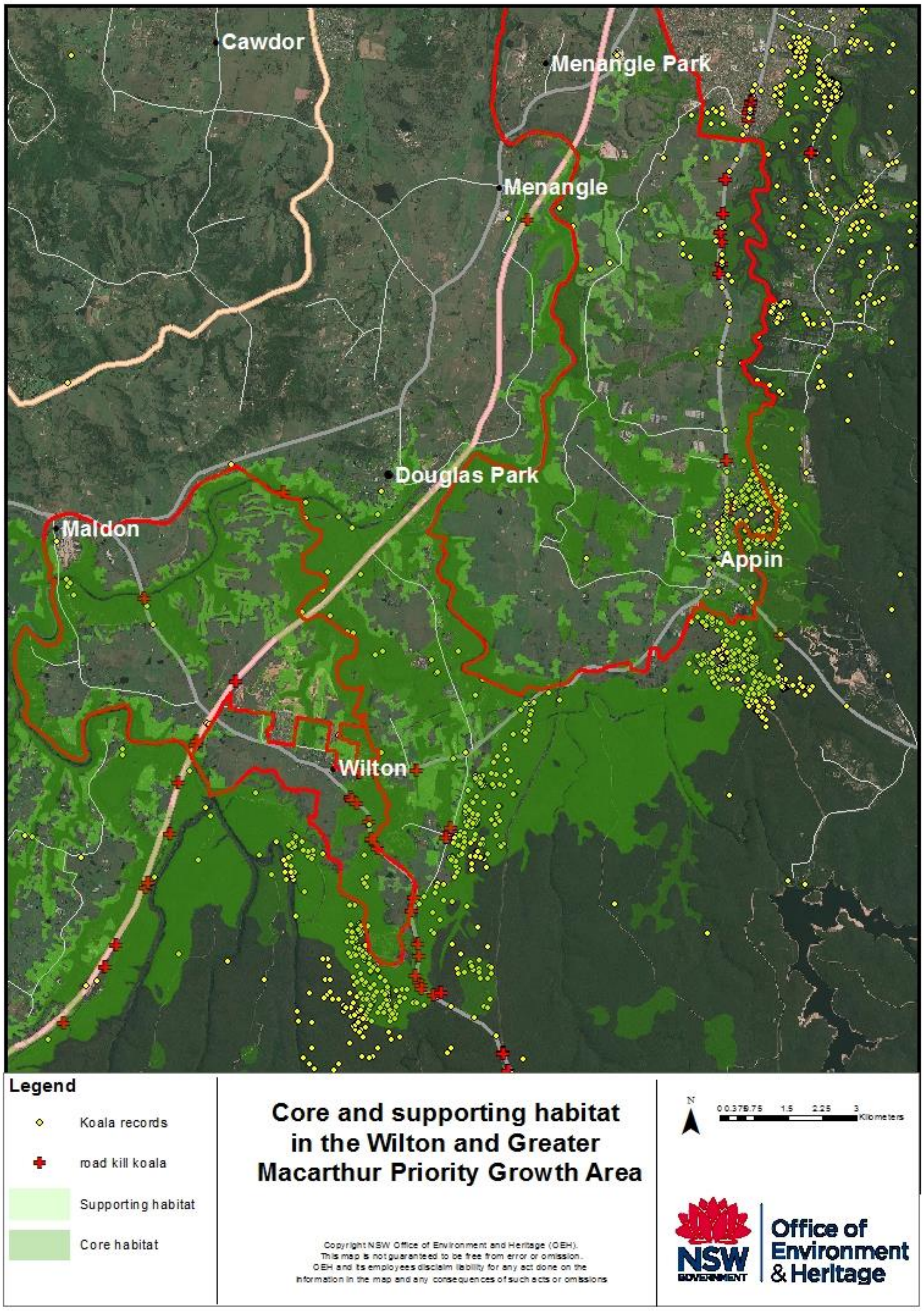


Figure 1 Core and supporting koala habitat in the Wilton and Greater Macarthur Priority Growth Areas. Note that koala records are sightings and do not indicate koala densities

2.2.2 Validation of high quality koala habitat

Floristic validation

High quality koala habitat validated well against the 143 new floristic plots. There was good agreement between the mapped high quality habitat and the koala feed trees identified in the floristic plots.

Systematic presence/absence spotlighting data

There is a strong correlation between koalas recorded on spotlighting surveys and areas classified as high quality koala habitat (Table 2 and Figure 2). A total of 15 koalas were observed during the 173 spotlighting sites and 12 of these were recorded in high quality koala habitat. Koala densities were significantly higher in mapped core habitat than in non-core habitat (chi-square=5.4161, df=1, p=0.01995). The remaining three were in vegetation communities not classified as high quality koala habitat. However, two of these three koalas were 150m or less from areas identified as high quality habitat. This is likely a reflection of under-mapping of the shale influenced vegetation types, which is coarser in the southern part of the study area.

Table 2: Spotlighting surveys undertaken and the number of koalas observed in core and non-core habitat with estimated densities.

	Number of 2ha Spotlight surveys	Number of koalas observed on spotlight	Estimated Koala Density/ha	Estimated koalas per 100ha
High Quality Habitat	83	13	0.078	7.8
Non-High Quality Habitat	90	3	0.017	1.7

Incidental koala sightings

Of the 582 valid koala records 499 (86%) of those were recorded in high quality habitat, confirming the findings of previous studies in the region (Figure 3). It should be noted that incidental records collated in BioNet are often biased with records over represented in areas with high human-wildlife interaction or visibility. However, sightings supported the assumptions underpinning the classification of vegetation communities as either high quality or non-high quality habitat for koalas.

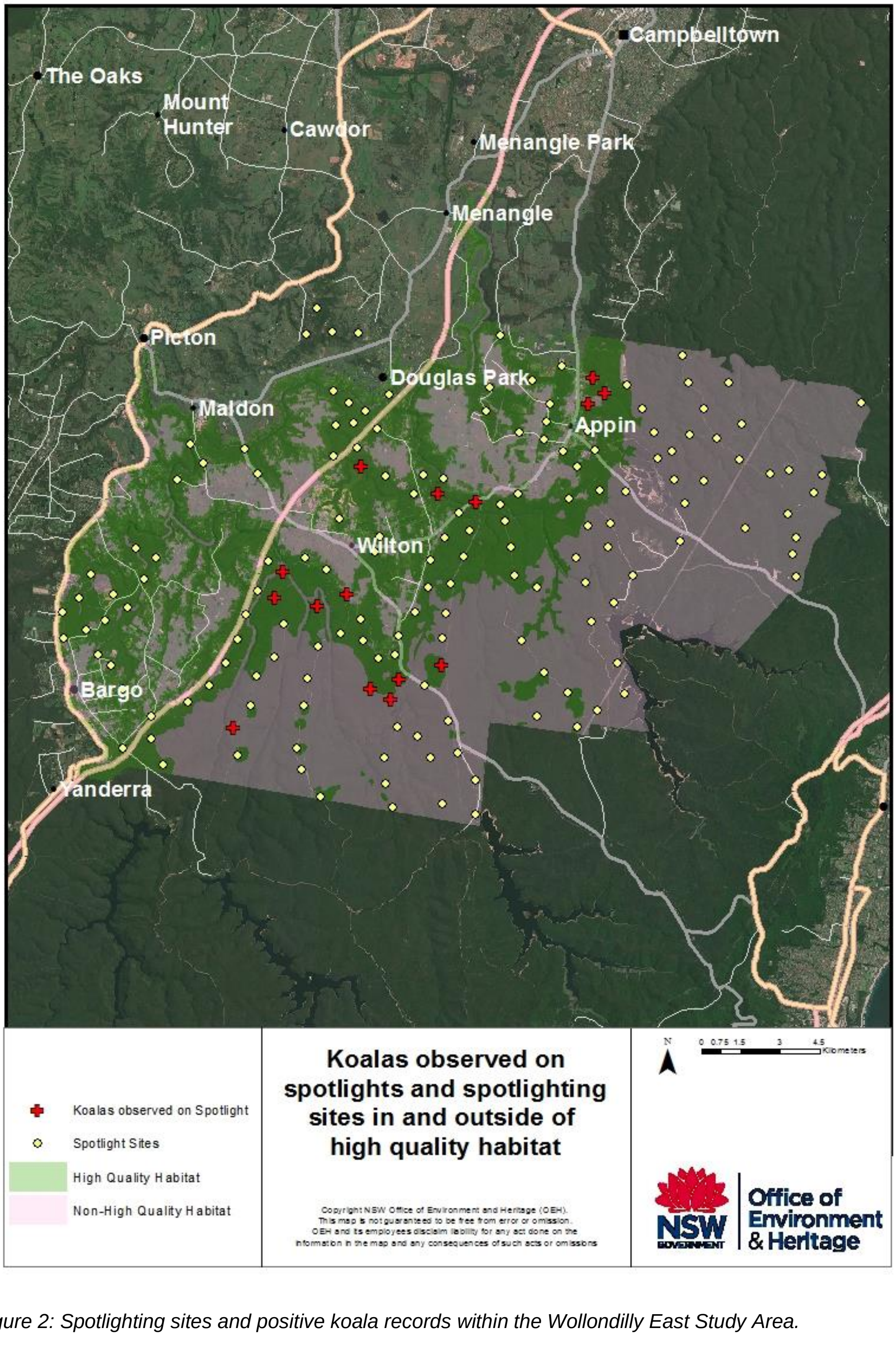


Figure 2: Spotlighting sites and positive koala records within the Wollondilly East Study Area.

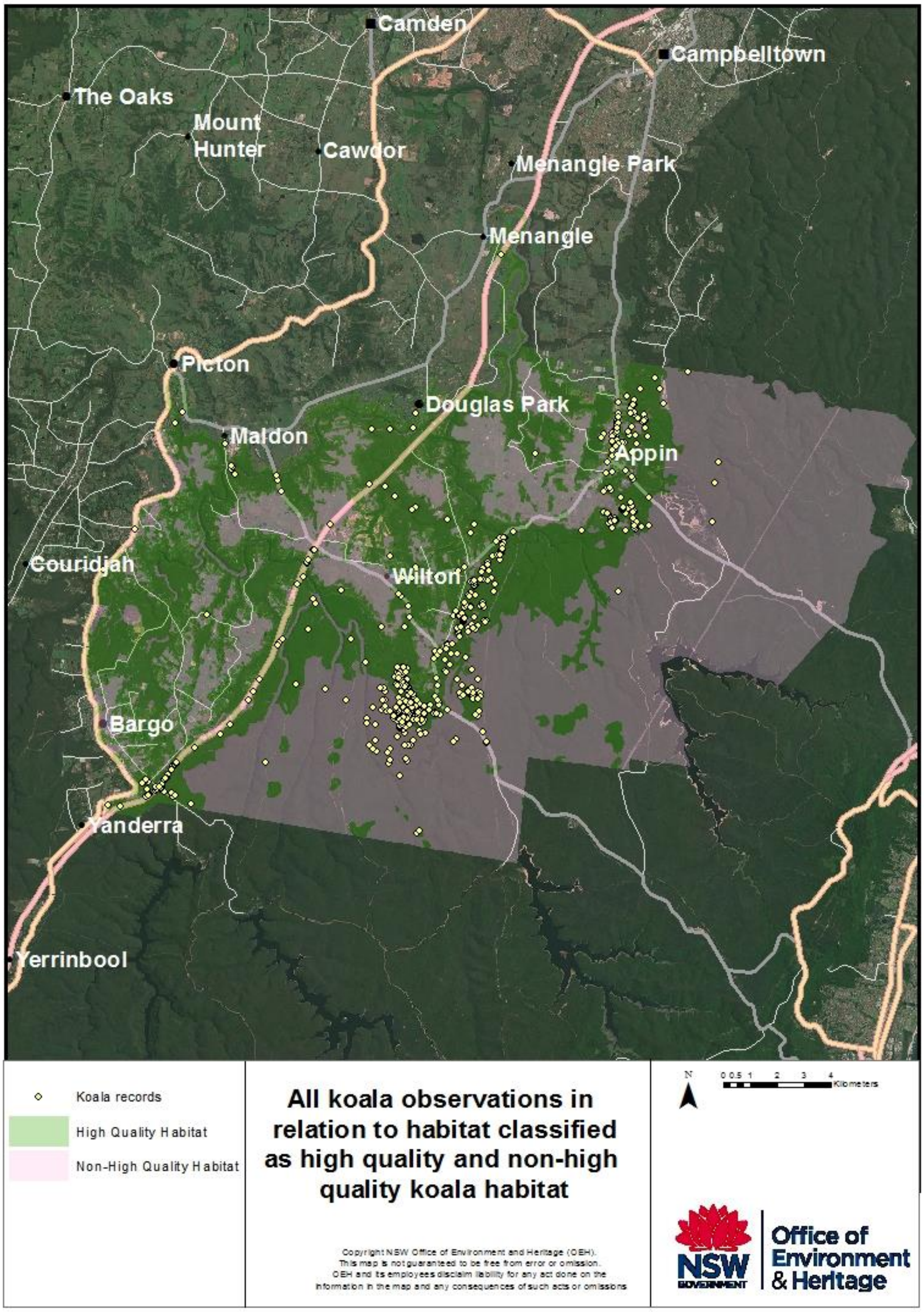


Figure 3: All koala records intersected with high quality and non-high quality koala habitat. Note that koala records are sightings and do not indicate koala densities.

Association with preferred koala use trees

A total of 243 observations of radio-tracked koalas revealed animals using 22 different tree species, with each animal using between 5 and 12 species (Table 3). The observations indicate that each radio-tracked koala used two to four preferred tree species (greater than 15% of observations by at least one koala). Using this measure, a total of seven preferred koala use trees have been identified so far from the koala radio-tracking work (Table 4).

Table 3: Observed and percentage tree use by individual koala.

Koala →	DAENERYS/ELLARIA		GENDRY		HODOR		ILYN PAYNE		JON SNOW		KHAL DROGO	
Tree Sp ↓	Obs	%	Obs	%	Obs	%	Obs	%	Obs	%	Obs	%
A. decurrens											8	15.1
A. floribunda											2	3.8
C. gummifera	1	3.2					1	2.6	1	2.6	1	1.9
E. amplifolia											3	5.7
E. beyeriana	2	6.5	1	3.3	3	5.7	1	2.6				
E. bosistoana					1	1.9					3	5.7
E. crebra			1	3.3	1	1.9					3	5.7
E. eugenoides											1	1.9
E. fibrosa	3	9.7	1	3.3	4	7.5	1	2.6				
E. globoidea	3	9.7	5	16.7	5	9.4	8	21.1			12	22.6
E. longifolia	2	6.5	9	30.0	23	43.4			1	2.6		
E. mollucana			1	3.3								
E. oblonga	2	6.5	3	10.0			5	13.2				
E. paniculata	5	16.1			1	1.9					3	5.7
E. pilularis	1	3.2							20	52.6		
E. piperita							2	5.3			1	1.9
E. punctata	6	19.4	8	26.7	15	28.3	18	47.4	13	34.2	8	15.1
E. quadrangulata	3	9.7										
E. resinifera			1	3.3			1	2.6	1	2.6		
E. sclerophylla	1	3.2					1	2.6				
E. sieberi	2	6.5										
E. tereticornis											8	15.1
Grand Total	31		30		53		38		38		53	

Table 4: Preferred koala use trees in the Wollondilly study area. Preferred use trees highlighted yellow.

Species	Common Name
E. punctata	Grey Gum
E. globoidea	White Stringybark
E. longifolia	Woollybutt
E. tereticornis	Forest Red Gum
E. paniculata	Grey Ironbark
E. pilularis	Blackbutt
A. decurrens	Green Wattle

The number of species of preferred koala use tree (PKT) was calculated for each vegetation community with a range of between zero and six PKT identified for each community (Appendix 1). There was a strong correlation between shale influenced vegetation communities and presence of PKT with 15 out of 16 shale influenced vegetation communities containing at least 1 PKT and an average of 2.4 PKTs. In contrast only 5 of 18 sandstone vegetation communities contained a PKT with an average number of PKT per vegetation community of 0.5 (Table 5).

Table 5: Vegetation communities divided into soil classification. The numbers given under 'Number of vegetation communities with PKT' are the numbers which support at least 1 preferred koala tree species (PKT). The average number of PKTs per vegetation community is also shown.

Soil classification of vegetation communities	Number of vegetation communities	Number of vegetation communities with PKT	Ave number of PKT per vegetation community
Shale	16	15	2.4
Sandstone	18	5	0.5

2.2.3 Koala movement corridors

The koala movement corridors are shown in Figure 4. The configuration of remaining core habitat in this region presents significant challenges for maintaining connectivity for the population. Adding large areas of residential development throughout much of the space between remaining core habitat will place significant pressure on smaller, narrower patches and their role in keeping the koala populations linked.

As with core koala habitat, the primary corridor for the persistence of koalas is through the continuously linked band that runs along the eastern edge of the Cumberland Plain from Campbelltown, through Wedderburn, the eastern part of Appin, crossing Picton Road south of Wilton and skirting the southern edge of the Wilton GA. These corridors do not extend into the sandstone country, because the native vegetation on sandstone derived soils is not high quality habitat for koalas. The primary corridor on the east is directly and continuously linked by primary corridors along the Nepean River, Allen's Creek and Cataract Creek north to Menangle. Secondary corridors link the Nepean corridor with the Georges River in the northern part of the area.

Koala movement corridors have been mapped and named in Figure 5. Each corridor has been ranked as either primary, secondary or tertiary, calculated based on quality and the area of core koala habitat it contains (Table 6).

2.2.4 Validation of koala movement corridors

The koala movement corridors validated well against the independently derived GLM of koala habitat/linkage. There was a high degree of overlap (approximately 80% although this was not formally calculated) between the GLM of koala habitat/linkage and the new corridor map despite different vegetation mapping base layers and koala presence information (**Figure 6**). It is noted that the GLM of koala habitat/linkage was completed at a larger scale, so would not include smaller corridors newly mapped.

Table 6: Extent of core koala habitat within koala movement corridors. Primary, secondary, and tertiary corridors are separately colour coded

Corridor Name	Corridor Rank	Habitat	Area of Core Habitat (ha)
Nepean	Primary	Core	1742.58
Allens	Primary	Core	1235.17
Wallandoola-Cataract	Primary	Core	1193.03
Avon-Nepean	Primary	Core	1089.23
Cordeaux	Primary	Core	628.64
Cascade	Primary	Core	605.28
Cataract	Primary	Core	381.38
			6,875.31
Ousedale-Mallaty	Secondary	Core	390.08
Simpsons-Elladale	Secondary	Core	255.31
Woodhouse-Menangle	Secondary	Core	220.33
Noorumba	Secondary	Core	122.01
Clements	Secondary	Core	107.86
			1,095.59
Stonequarry	Tertiary	Core	124.15
Myrtle	Tertiary	Core	84.48
Stringybark	Tertiary	Core	78.43
Leafs Gully	Tertiary	Core	34.52
			321.58
Grand total	**All**		**8,292.46**

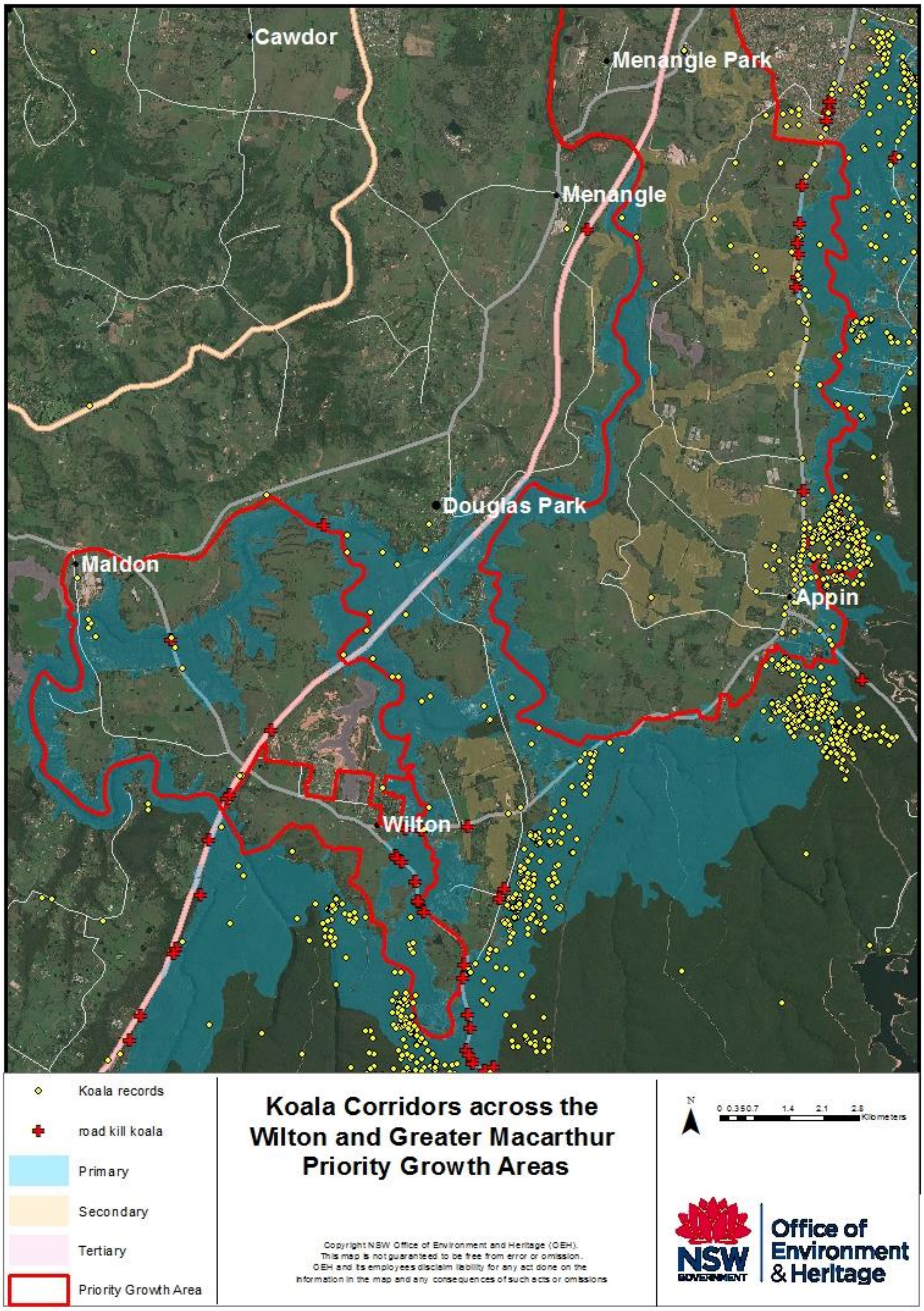


Figure 4: Koala corridors across the Wilton and Greater Macarthur Priority Growth Areas. Note that koala records are sightings and do not indicate koala densities.

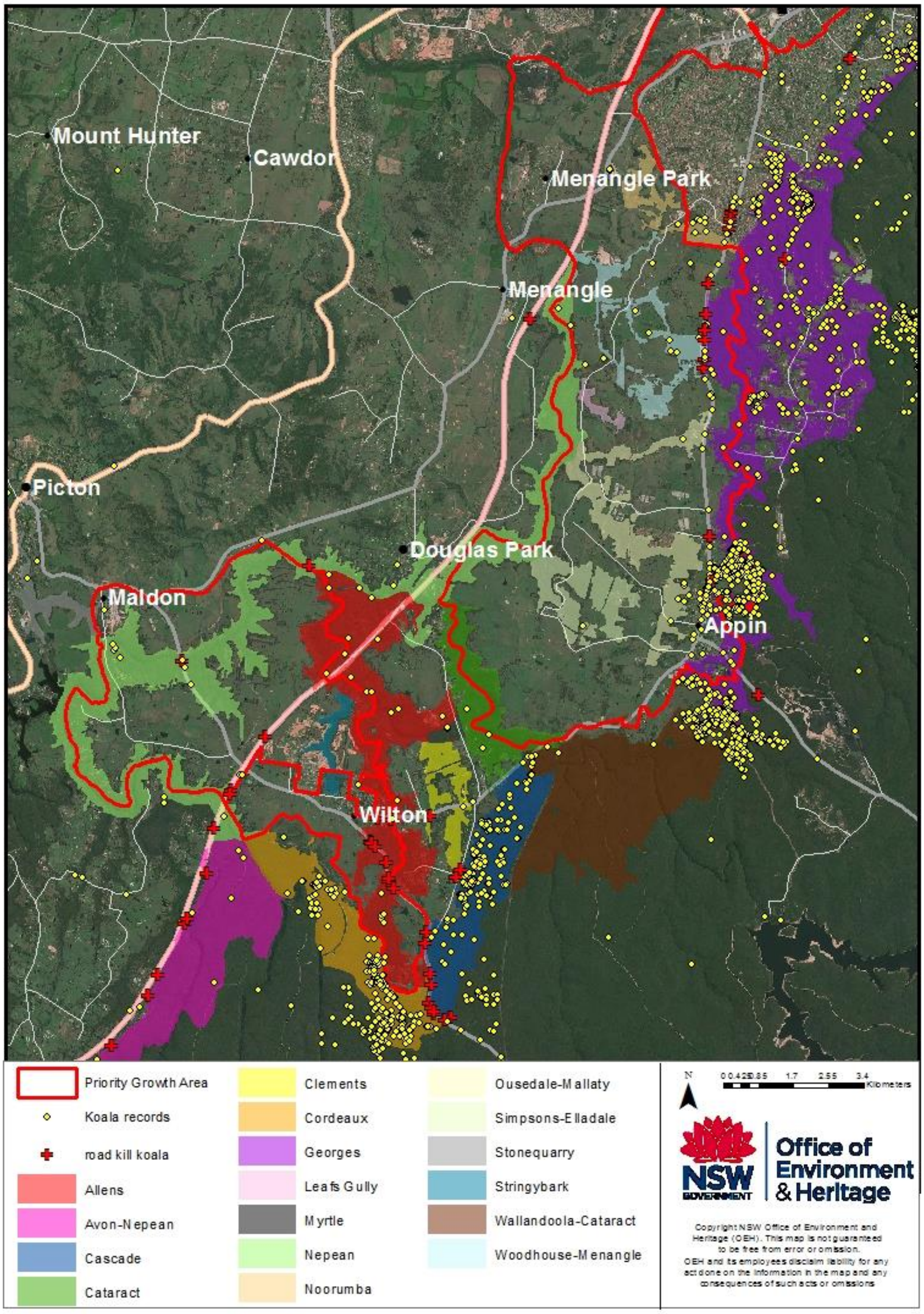


Figure 5: Koala corridors as named in Table 7. Note that koala records are sightings and do not indicate koala densities

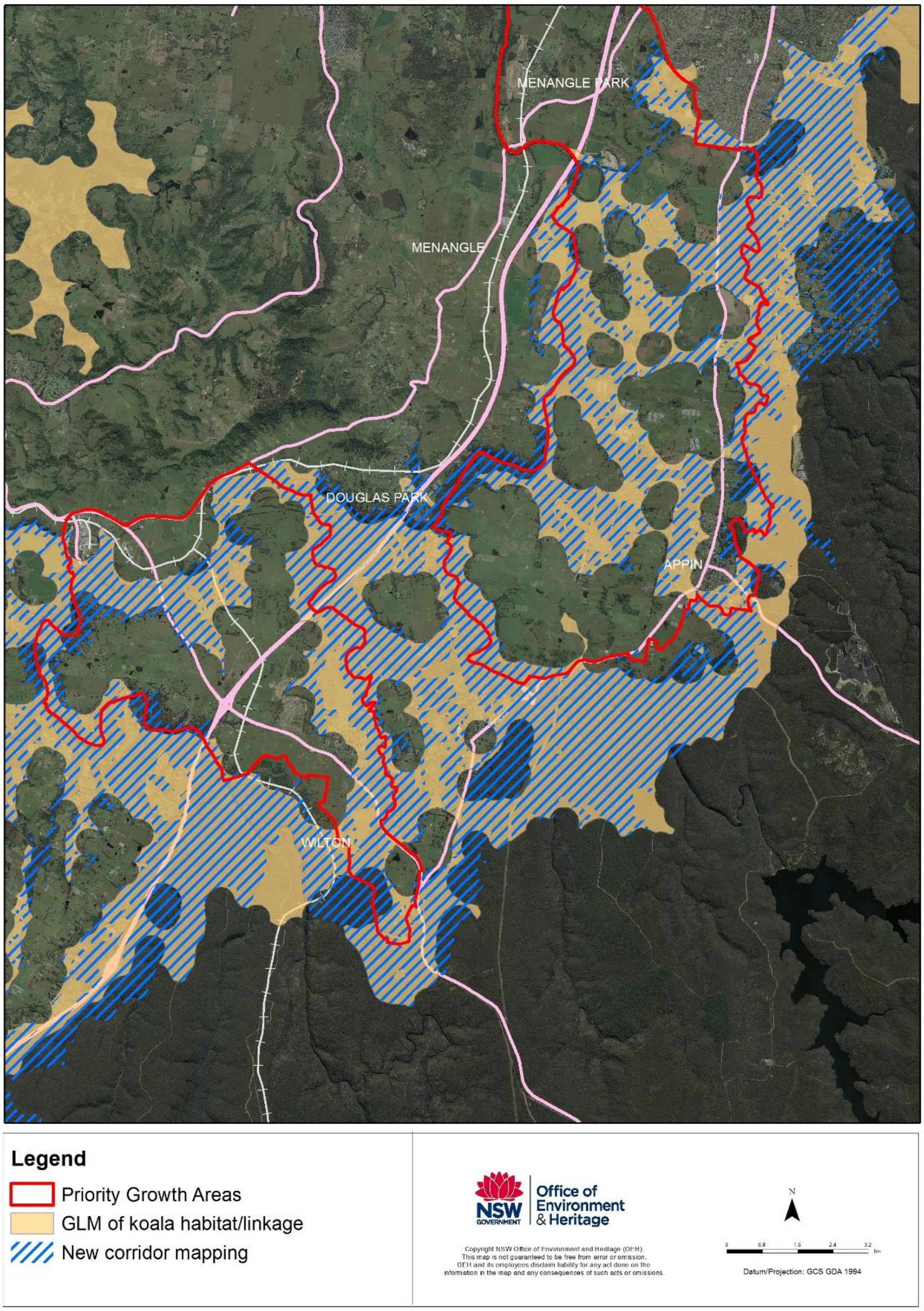


Figure 6: Comparison of the Generalised Linear Model of koala habitat/linkage and the new corridor map

3 Koala densities and the number of koalas in corridors

3.1. Methods

To demonstrate the relative importance of the individual movement corridors for koalas, we extrapolated koala numbers potentially supported in each of the movement corridors based on the amount of habitat available in them. Extrapolations were based from a density estimate made from data collected from 67 systematic, 2 ha spotlights surveys undertaken within the identified corridors as part of the Wollondilly Koala Conservation Project (Figure 7). The koala density was calculated based on koalas directly observed in the 2 ha survey areas, not indirectly via scats, and scratches, with the density derived by dividing the total number of koalas observed (7 koalas) by the search area (67 x 2 ha).

Cleared land, scattered trees and regrowth areas around core koala habitat areas were excluded for these calculations although they will be used by koalas. Thereby, this is a conservative, minimum estimate of koala numbers for corridors. Note that figures for the Georges River corridor were not calculated as this is mostly outside the Wollondilly LGA where new research has been occurring; thus, there were insufficient presence-absence spotlighting sites to derive a figure.

3.2 Results

Table 7 shows the amount of core koala habitat and estimates of koala numbers potentially supported by each identified movement corridor based on available habitat in them. Primary corridors together contained a significant amount of core koala habitat (6,875.31 ha), providing habitat for at least 359 koalas. Secondary and tertiary corridors contained less core koala habitat in comparison to primary corridors. Primary corridors are therefore key for their extent of habitat and stretches of contiguous habitat. They need to be protected and enhanced not only for their value in connectivity, but as important koala habitat it their own right.

For communication purposes Figure 5 shows the names and locations of the individual koala corridors identified in Table 7. The most important corridor in terms of the amount of core koala habitat, the highest numbers of koala potentially supported, and largest and longest link across the GAs was the Nepean corridor (1,742.58 ha and 91 koalas, respectively). The Allen's Creek and Cataract corridors, which are key links between the Nepean corridor and the intact bushland to the east (towards the Cordeaux, Cascade, and Wallandoola-Cataract corridors), also contained large amounts of core koala habitat and potentially supported 64 and 20 koalas, respectively. Although this analysis was not undertaken on the Georges corridor, this corridor is known to be important as it is a kay component of the main north-south corridor which links the known Campbelltown koala population with the Wollondilly koala population and the Southern Highlands population further south.

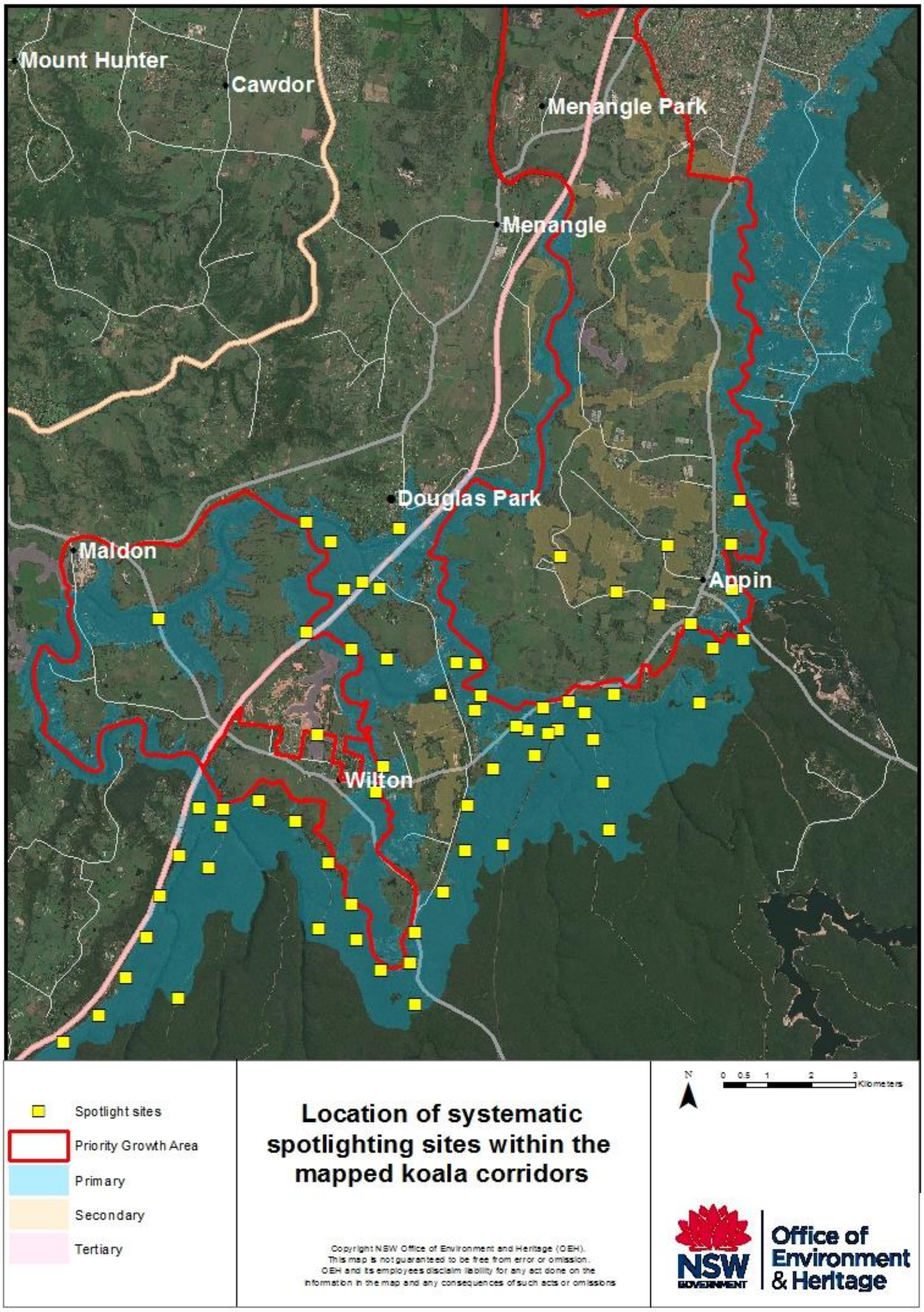


Figure 7: Location of systematic spotlight surveys for koalas within the corridors of the Wilton and Greater Macarthur Priority Growth Areas used to extrapolate koala numbers in corridors based on the amount of habitat available within them

Table 7: Extent of core koala habitat and estimated koala numbers within corridors based on a density estimate of 0.052 koalas/ha. Primary, secondary, and tertiary corridors are separately colour coded

Corridor Name	Corridor Rank	Habitat	Area of Core Habitat (ha)	Extrapolated koala numbers based on habitat extent
Nepean	Primary	Core	1742.58	91
Allens	Primary	Core	1235.17	64
Wallandoola-Cataract	Primary	Core	1193.03	62
Avon-Nepean	Primary	Core	1089.23	57
Cordeaux	Primary	Core	628.64	33
Cascade	Primary	Core	605.28	32
Cataract	Primary	Core	381.38	20
			6,875.31	**359**
Ousedale-Mallaty	Secondary	Core	390.08	20
Simpsons-Elladale	Secondary	Core	255.31	13
Woodhouse-Menangle	Secondary	Core	220.33	12
Noorumba	Secondary	Core	122.01	6
Clements	Secondary	Core	107.86	6
			1,095.59	**57**
Stonequarry	Tertiary	Core	124.15	6
Myrtle	Tertiary	Core	84.48	4
Stringybark	Tertiary	Core	78.43	4
Leafs Gully	Tertiary	Core	34.52	2
			321.58	**16**
Grand total	**All**		**8,292.46**	**433**

4 Principles for the conservation of koalas in Wollondilly and Campbelltown and management recommendations

South-western Sydney is facing large-scale land-use change with the development of the Wilton and Greater Macarthur GAs. The proposed change from rural to low/medium density residential development across the GAs has significant implications for the koalas of this area.

Notwithstanding the implementation of measures to avoid, minimise and reduce impacts, major residential development in the GAs would result in:

- The direct loss of core and supporting koala habitat, and potentially habitat fragmentation, for the upgrade of existing principal roads into the new residential areas, as well as for new roads and other urban development
- An increased urban interface with koala populations
- Increased traffic volumes
- Increased indirect impacts to koala habitat through more frequent fire, weed incursion, feral pests, domestic animals, light spill, noise and rubbish dumping.

The direct loss of core and supporting koala habitat and any subsequent habitat fragmentation would have the biggest impact on koalas in the area. It has been demonstrated that as areas of habitat for koalas are reduced, koala population sizes fall and the chance of extinction increases. The survival of metapopulations (a group of spatially structured populations of sub-populations connected by dispersal) relies on the ability of animals to recolonise habitat patches where a sub-population has gone extinct. For koala populations to thrive and avoid genetic bottlenecks, habitat must remain intact for koalas to move and disperse.

However, increased urban interfaces, traffic volumes, and disturbance would also significantly impact koalas. Increased urban interfaces would lead to a rise in interactions with people, houses, pools, domestic dogs and vehicles, in turn potentially leading to koala stress, injury, or death. Increased traffic volumes would result in a greater risk of koala-vehicle collisions and koala roadkill. Increased disturbance would result in koala stress, potentially reducing individual koala's fitness and its ability to hold off diseases such as chlamydia. This is supported in the literature. The most rapid declines in koala numbers in NSW and Queensland have been in the high density urban and remnant source populations which are undergoing rapid conversion from agriculture to urban (McAlpine et al, 2006a, Adams-Hosking, 2017). High rates of mortality associated with development and dogs were found for radio-tracked koalas undertaken in an urban area of Queensland (Redlands City; de Oliveira et al, 2013). Koalas were unable to successfully disperse through urban areas in a study in Queensland due to attacks by domestic dogs and collisions with vehicles in these areas (Dique et al. 2003). McAlpine et al. (2017) found that landscape change influences the susceptibility of koala to disease, and that urbanisation is associated with an increase in chlamydia. The impact of chlamydia on koala populations may not be identified for several years until the disease has an impact on reproductive success.

OEH has assessed existing and new information on koalas, including the identification of core koala habitat and koala movement corridors in southern Campbelltown, and around Appin and Wilton (Section 2), as well as the relative importance of koala corridors in terms of their positions in the landscape and numbers of koalas potentially supported based on the amount of core koala habitat available within them (Section 3). In combination with this information, and an assessment of the known threats to koalas in the area and the extent of proposed development in the GAs and their impacts, OEH has identified a strategy to conserve the koala metapopulations in the Wollondilly and Campbelltown LGAs.

Underlying the strategy are four key principles. These are:

1. Avoid new residential development within core koala habitat and primary corridors
2. Separate residential development and koala populations to minimise ongoing threats from domestic dogs and vehicles
3. Identify critical revegetation zones that will augment and strengthen core habitat and corridors
4. Identify koala road kill hotspots requiring road kill mitigation fencing and/or underpasses to allow safe passage of koalas.

The principles generally align with existing koala principles or guidelines, such as the *Planning Guidelines for Koala Conservation and Recovery: A Guide to Best Planning Practice* (McAlpine et al. 2006b) prepared to assist land managers plan for the long-term conservation of koalas:

- In the guideline, the maintenance and protection of networks of koala habitat patches and corridors linking blocks of koala habitat is of highest priority.
- The guidelines state that approval bodies should ensure development does not further fragment koala habitat areas, either through habitat/linkage area removal or the imposition of significant threats to koalas.
- As the presence of koalas is greatly reduced by high road densities, especially in areas within or adjacent to koala habitat, the guideline recommends that development and roads are separated from koala habitat, and potential conflict between threats such as dogs are minimised.
- The guideline recommends that approval bodies for development encourage koala habitat restoration, and avoid both internal fragmentation of koala habitat patch and linkages and reductions in tree density. Also, that sufficient structural diversity in koala habitat is maintained. While feed trees, soil fertility, and water availability are the most important determinants of koala habitat quality, the presence of factors such as large trees, species diversity, and structure can enhance koala habitat quality.
- The guideline states that the larger the koala habitat patches and wider the corridors the better. Patches should have low perimeter to area ratios to decrease edge effects since for koalas, edge effects may lead to increased predation risk by dogs or increased stress leading to disease.
- The guideline recommends that blocks of koala habitat and corridors linking these be kept free from barriers to koala movement. Where there are known black spot areas, it recommends constructing exclusion fencing.

The following sections outline OEH’s strategy and management recommendations to conserve the koala metapopulations in the Wollondilly and Campbelltown LGAs in line with the four key principles.

4.1 Avoiding development within core habitat and primary corridors

As outlined above, the direct loss of core koala habitat and habitat fragmentation would have the biggest impact on koalas in the area. Koala populations operate at the landscape level and require habitat connectivity for animal movement, particularly in the spring breeding season, and for the dispersal of young animals or animals recolonising areas where a metapopulation has gone extinct. Therefore, all development within core koala habitat and primary corridors should be avoided.

Primary corridors, particularly to the east of Appin Road adjacent to the Greater Macarthur GA and in the south-east section of the Wilton GA, are currently mapped adjacent to cleared areas (see Figures 5 and 6). These cleared areas have been excised from the primary corridors as they do not currently support core koala habitat and koala records; they have been historically cleared of core koala habitat. Nevertheless, koalas will traverse cleared areas, and in this context, cleared areas adjacent to primary koala corridors could be informally considered part of primary corridors (outside of criteria used to categorise corridors).

Given this, development in currently cleared areas adjacent to primary corridors should also be avoided. Key areas of cleared land adjacent to primary corridors to be avoided include those to the east of Appin Road along the entire eastern length of the Greater Macarthur GA and in the south-east section of the Wilton GA.

4.2 Separating koala habitat areas and movement corridors from areas of residential development

Residential development poses a suite of direct and indirect threats to koalas. Facilitating koala access into residential areas exposes them to greater threats such as domestic dogs, cars and swimming pools than they would be exposed if they could not access these areas. The ever-present threats of domestic dogs, cars and swimming pools mean that koalas cannot survive in urban settlement in the long term. ‘Koala friendy urban design’ which has been trialed in other locations is not recommended.

Keeping koalas out of future residential areas in the GAs will minimise the direct and indirect threats associated with residential development. Koalas should be excluded in two ways. Firstly, residential subdivision should be designed to limit the interface between core habitat and corridors. The integrity of corridors is increased by increasing width, so avoiding housing infill within primary corridors to provide maximum movement potential and minimal disturbance is critical.

Secondly, where development proceeds next to core koala habitat and movement corridors, fencing and other barrier solutions should be installed to separate koalas from houses and their occupants. Creating access points for residents to enjoy the bush is important to link communities with their landscape, but identifying a smaller number of well-considered places will limit the likelihood that koalas will wander into danger in the suburbs.

Figure 8 provides indicative areas where development and core koala habitat/ corridors can be separated in the Wilton and Greater Macarthur GAs.

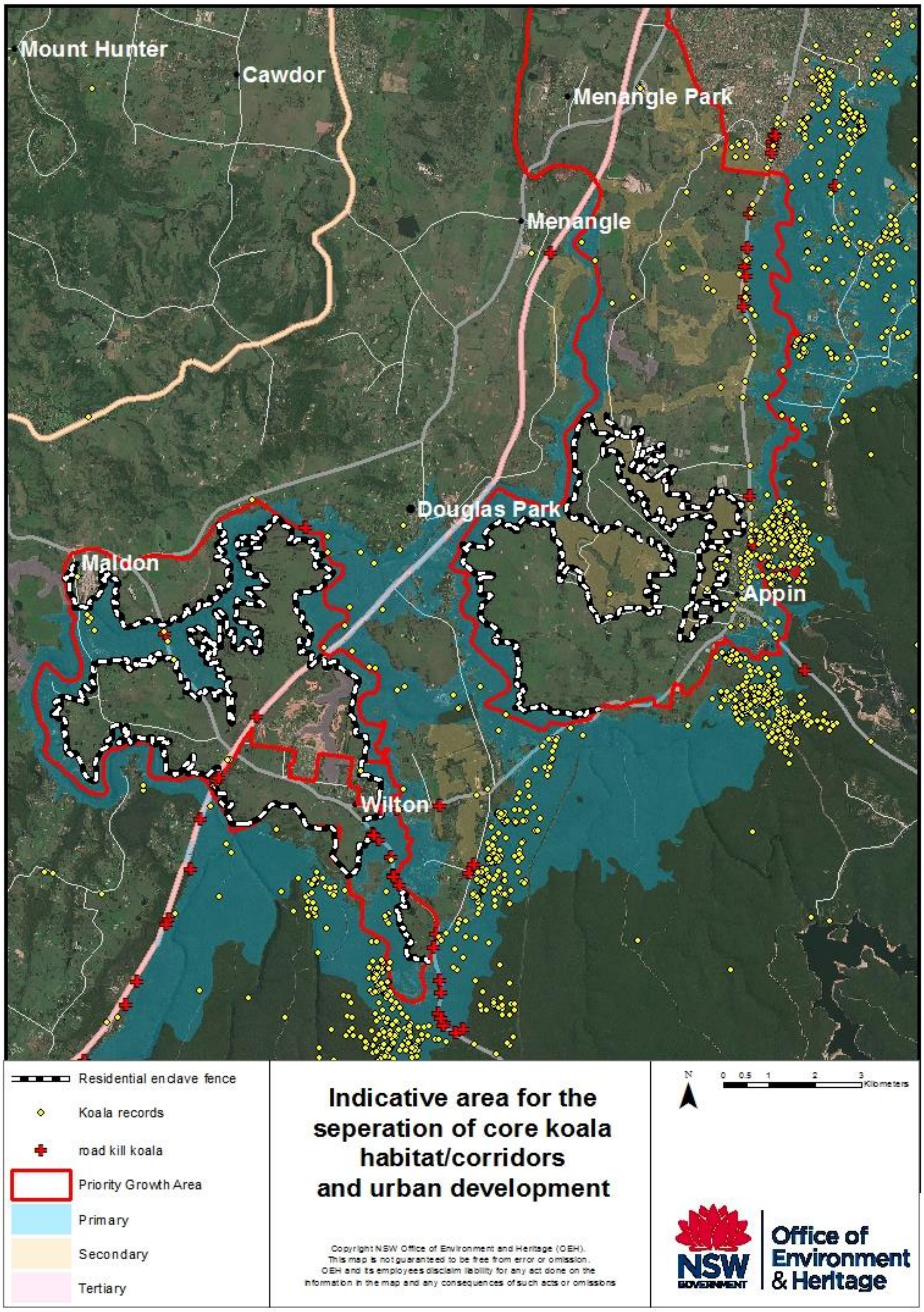


Figure 8: Indicative areas where development and core koala habitat/corridors can be separated in the Wilton and Greater Macarthur Priority Growth Areas. Note that koala records are sightings and do not indicate koala densities

4.3 Habitat restoration and revegetation to augment and strengthen core koala habitat and koala movement corridors

Wider corridors and larger areas of habitat are better than narrow corridors and smaller areas of habitat, partly since the former have lower perimeter to area ratios than the latter (less edge effects). Some habitat linkages are compromised or incomplete in some areas due to historical clearing. As such, where areas of core habitat can be augmented and strengthened to widen corridors and increase the area of core habitat, restoration and revegetation is effective in filling gaps.

When considered along with the principle of separation of urban development and koala habitat and corridors, clear priorities for habitat restoration in the Wilton and Greater Macarthur GAs emerge. The highest priority in the Wilton GA is in the south-east section, where core koala habitat surrounds an almost fully encloses cleared land at the start of the primary corridor along Allen's Creek (Allen's corridor) (Figure 9).

Regarding the Greater Macarthur GA, there are many high priority restoration areas. The most obvious areas are along the length of the eastern side of the GA, to the east of Appin Road, directly adjacent to the Georges River corridor (Figure 9). Other areas (not shown in Figure 9) include areas to the east of the Ousedale-Mallaty corridor to complete a corridor connection (on both ends) for a secondary corridor currently connected to a primary corridor at one end.

If cleared land was developed rather than restored, this would introduce significant threats and compromise the adjacent corridor values. The conservation of the regional koala population would be greatly enhanced by returning the identified cleared areas to high quality habitat, an outcome that would consolidate and double the width of the existing Allen's and Georges primary corridors and result in a far more sensitive urban design outcome. While there would be a time lag for trees to grow, koalas are known to use saplings. Indeed, younger trees often have higher nutrient levels in their leaves than older trees.

The protection of the vegetation and restoration of the degraded areas could potentially be funded through offsetting arrangements for other development in western Sydney, and to meet other offset requirements arising from major projects or under the new *Biodiversity Conservation Act 2016* and delivery of offsets by the newly established Biodiversity Conservation Trust. There is strong demand in the market for biobank/ biodiversity stewardship agreement sites in Western Sydney.

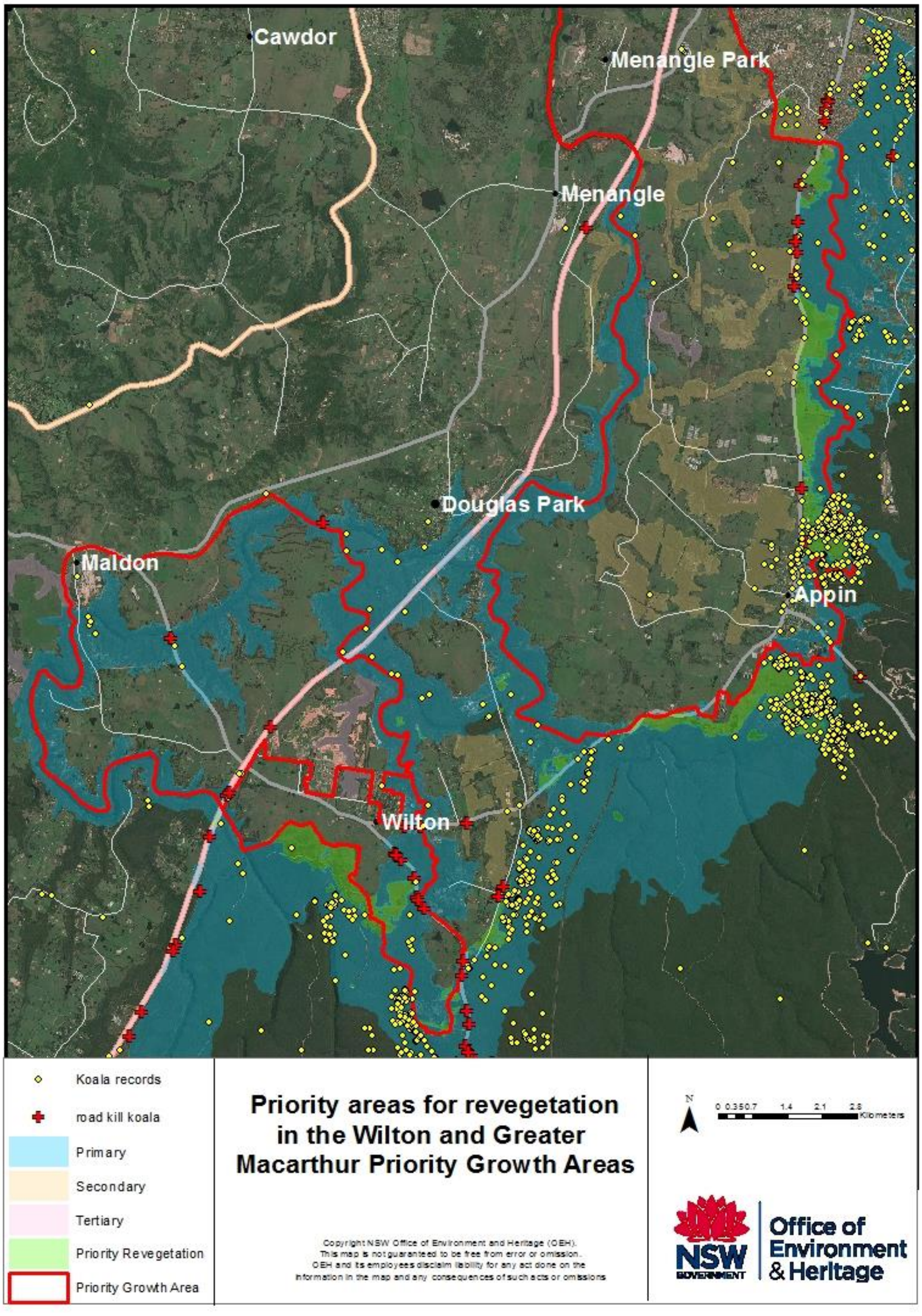


Figure 9: Priority areas for restoration in the Wilton and Greater Macarthur Priority Growth Areas. Note that koala records are sightings and do not indicate koala densities

4.4 Preventing koala road kill

Koala roadkill is a highly visible and increasing threat to koalas in the Campbelltown and Wollondilly LGAs. Much of the remaining core koala habitat is intersected by major roads, with the Hume Motorway, Picton Road, Wilton Road, MacArthur Drive and Appin Road all traversing areas of core habitat and primary corridors. Traffic on Picton and Appin Roads has rapidly increased over the last five years and with this there has been an increase in the number of roadkilled koalas. With land-use change and further increases in traffic, unless there is significant investment in roadkill mitigation, the number of koalas being hit, injured and killed will continue to rapidly increase, potentially affecting the viability of the population. This has been demonstrated for koala populations elsewhere (Polak et al. 2014). Widening and upgrades of major arterial roads provides an opportunity to implement roadkill mitigation measures. Mitigation measures will slow the decline of koalas in the area (Polak et. al 2014).

Road kill hotspots have been identified based on collation of records in the NSW Wildlife Atlas (OEH 2017; Figure 9). Hotspots have been identified as stretches of road with greater than four roadkilled koalas within a two kilometre stretch. Hotspots are along Picton Road between Cordeaux Dam and Wilton, MacArthur Drive, the eastern end of Wilton Road, and Appin Road between Appin and Campbelltown. Another important hotspot occurs on the Hume Motorway at the Bargo exit, just south of the Wilton GA. All identified hotspots occur where a major road intersects a primary koala corridor, typically at the headwaters of a watercourse.

Options to reduce koala mortality on these roads include exclusion fencing, with improved road underpasses installed along existing gully line underpasses such as on Allen's Creek to retain connectivity (Figure 10). Exclusion fences could also be installed on the east side of Appin Road (Figure 10). Exclusion fencing and underpasses would require ongoing maintenance; however, fencing is considered the most effective road-kill mitigation measure on major roads. OEH does not consider signage as an effective road kill mitigation measure on major roads.

4.5 Outcome if management recommendations implemented

Should the management recommendations outlined in Section 4.1 to 4.4 be implemented, the extent of core koala habitat would increase and koala movement corridors would be consolidated. Koalas would be separated from future residential areas in the GAs and existing roadkill hotspot locations, reducing the threats associated with residential areas and major roads.

Figure 11 illustrates consolidated koala movement corridors post-revegetation and all recommended mitigation measures to minimise threats associated with residential areas and major roads. It is noted that as currently cleared areas adjacent to the Wilton GA were restored, additional exclusion fencing would be required. This additional fencing is indicated in Figure 11.

Exclusion fencing progressively built along Appin Road would prevent east-west koala movements across the Greater Macarthur GA. Underpass structures would need to be built to provide east west access to koalas. However, OEH does not consider the east-west corridors to be essential for the long-term survival of the regional koala population. Koalas could continue to move through the landscape via primary movement corridors, rather than via the east-west secondary corridors. The distance from the top of the Georges corridor to the Cataract corridor is approximately 15 km and is within the distance that koalas can disperse. Allowing koalas access to the secondary corridors would expose koalas to threats associated with residential areas without fencing around corridors, and be inconsistent with Principle 2 (to separate koalas from residential areas).

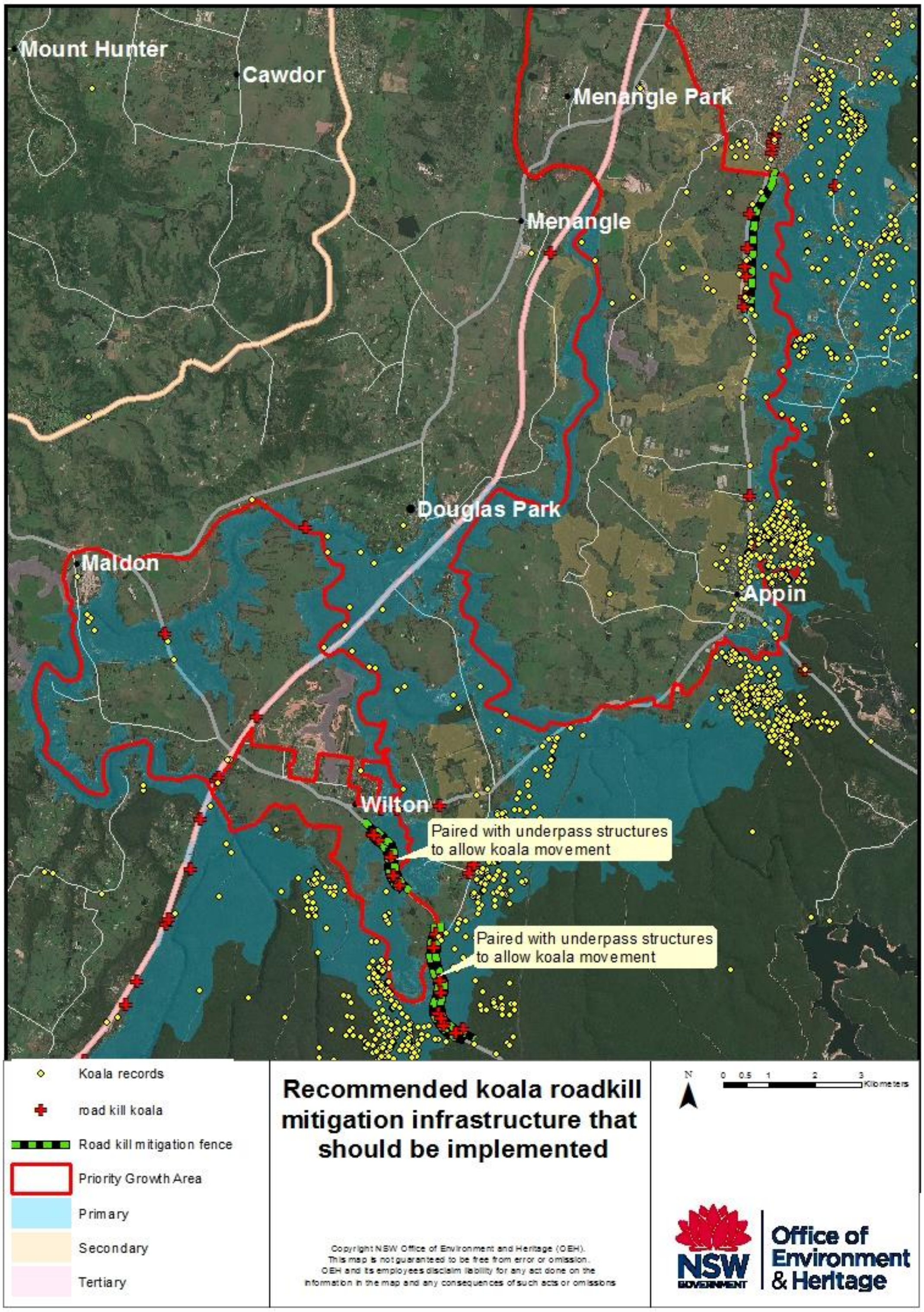


Figure 10: Recommended koala roadkill mitigation infrastructure that should be implemented in the Wilton and Greater Macarthur Priority Growth Areas. Note that koala records are sightings and do not indicate koala densities

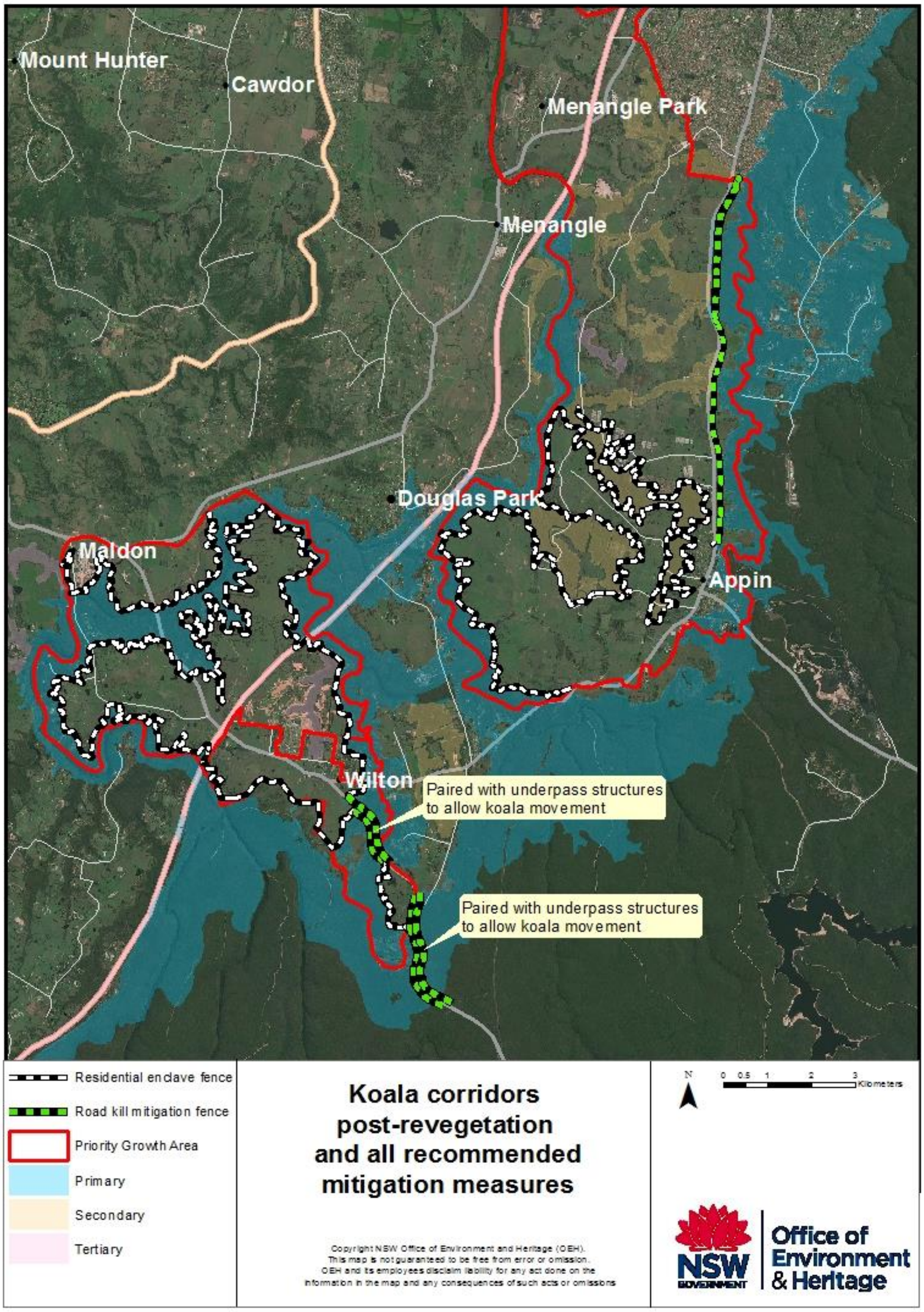


Figure 11: Koala movement corridors post-revegetation and all recommended mitigation measures in the Wilton and Greater Macarthur Priority Growth Areas. Note that koala records are sightings and do not indicate koala densities

Glossary

High quality koala habitat: All shale and shale-enriched vegetation types in the area around the Wilton and Greater Macarthur GAs.

Medium quality koala habitat: Eucalypt-dominated riparian sandstone communities and regenerating acacia scrubs on shale in the area around the Wilton and Greater Macarthur GAs.

Low quality koala habitat: Low-fertility sandstone vegetation communities including heaths, heathy woodlands, swamps and rocky woodlands in the area around the Wilton and Greater Macarthur GAs.

Core koala habitat: Large patches (>100 ha) of high quality koala habitat that contain known koala feed tree species, as determined through OEH's Wollondilly and Southern Highlands Koala Conservation Projects, and records of koalas. Note that the SEPP44 definition of core koala habitat is not used in this document given koalas in the area use a range of tree species not listed in SEPP44.

Koala movement corridors: Areas of habitat (often but not always linear), which koalas can move through and potentially use to recolonise other core habitat patches where a metapopulation has gone extinct. Note that koala movement corridors do not need to be a strip of core koala habitat surrounded by cleared areas. Surroundings may be other intact vegetation that are not favoured by koalas, such as open woodland on sandstone.

Primary corridors: are the most important linkages of koala habitat for the regional koala population in the local area around the Wilton and Greater Macarthur GAs. They contain patches of 'core' koala habitat which are contiguous (gaps between trees are less than 100 m) and together contain over 380 ha of core habitat. They are the most important koala habitat in which the bulk of koalas in the area live and breed. The breaking or weakening of primary corridors will have serious ramifications on the long-term viability of the koalas in the area, and thereby, the regional koala population.

Secondary corridors: contain patches of 'core' koala habitat and scattered trees separated by more than 100 m, are narrow or have pinch points of less than 50 m wide, and together contain between 100 ha and 380 ha of core habitat. Otherwise, if containing greater than 380 ha of habitat or are not narrow, secondary corridors are those that do not connect to primary corridors on both ends. The retention of secondary corridors is not critical to the long-term viability of the regional koala population; however, they could be enhanced to further support primary corridors and core koala habitat.

Tertiary corridors: contain patches of 'core' koala habitat that are poorly linked to primary corridors, together contain between 30 ha and 100 ha of core habitat, and do not connect to primary corridors on both ends. Otherwise, if containing greater than 100 ha of habitat, tertiary corridors are those that lead away from other corridors. Tertiary corridors may be enhanced to provide greater connectivity and habitat for the koalas in the local area around the Wilton and Greater Macarthur GAs, but they are the least valuable connectivity asset to retain for koalas and the regional koala population.

Regional koala population: the single, contiguous koala population extending from Campbelltown, through Wollondilly, to Wingecarribee.

Metapopulation: a group of spatially structured populations of sub-populations connected by dispersal. In this document, the term is applied to koalas in the Campbelltown and Wollondilly LGAs i.e. the Campbelltown koala metapopulation and the Wollondilly koala metapopulation.

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Appendix 1

List of all mapped vegetation communities in the study area with canopy floristics, preferred koala feed trees, soil classification, koala habitat quality and status.

Vegetation Community	Ha extant	Canopy floristic (Preferred koala use trees **bolded**)	Number of preferred tree sp	Soil Classification	Habitat Quality	Koala Habitat Status
Cumberland Plain Alluvial Woodland	445	E. amplifolia, **E. tereticornis**, A. floribunda, E. deanei, E. eugenioides, A. subvelutina, E. moluccana, **E. globoidea, E. punctata**, E. baueriana, C. maculata, E. elata, E. piperita, E. sclerophylla	3	Shale	HQH	Core
Cumberland Plain Shale Hills Woodland	809	E. moluccana, **E. tereticornis**, E. crebra, E. eugenioides, E. amplifolia. A. floribunda, C. maculata, A. subvelutina, E. fibrosa	1	Shale	HQH	Core
Cumberland Plain Shale Plains Woodland	462	E. moluccana, **E. tereticornis**, E. crebra, E. eugenioides, E. fibrosa, A. floribunda, A. subvelutina, C. maculata, E. amplifolia, **E. punctata**, E. baueriana, **E. globoidea**, E. longifolia, **E. paniculata**	4	Shale	HQH	Core
Cumberland Plain Shale Sandstone Transition Forest (High Sandstone Influence)	5067	**E. punctata**, E. crebra, E. eximia, E. notabilis, E. beyeriana, E. fibrosa, C. gummifera, A. bakeri, E. eugenioides, **E. pilularis**, C. maculata, **E. globoidea**, A. floribunda, E. oblonga, **E. tereticornis**, A. costata, E. resinifera, E. sclerophylla, **E. longifolia,** E. moluccana	5	Shale transition	HQH	Core
Cumberland Plain Shale Sandstone Transition Forest (Low Sandstone Influence)	718	**E. tereticornis**, E. eugenioides, E. crebra, E. fibrosa, **E. punctata**, E. moluccana, A. floribunda, **E. globoidea**, C. maculata, A. bakeri, E. resinifera, C. gummifera, **E. pilularis**, E. saligna, E. sideroxylon	4	Shale transition	HQH	Core
Eastern Gully Forest	292	A. costata, C. gummifera, E. piperita, E. seiberi	0	Sandstone	MQH	Non-Core
Exposed Sandstone Scribbly Gum Woodland	8679	E. Sclerophylla. E. racemosa, E. haemastoma, C. gummifera, E. oblonga, E. seiberi, E. piperita, A. costata	0	Sandstone	LQH	Non-Core

Highlands Shale Tall Open Forest: Form C Tall Open Variant	17	E. piperita, **E. globoidea**, E. radiata, E. obliqua, E. cypellocarpa, E. quadrangilata, E. elata, E. agglomerata, **E. punctata**, E. amplifolia, E. dives, E. smithii, E. ovata	2	Shale	HQH	Core
Moist Shale Woodland	348	**E. tereticornis**, E. moluccana, E. crebra, C. maculata	1	Shale	HQH?	Non Core
Nattai Sandstone River Peppermint Forest	47	E. elata, E. piperita, E. cypellocarpa, E. oreades	0	Sandstone	LQH	Non-Core
Nepean Enriched Sandstone Woodland	302	C. gummifera, **E. globoidea**, E. oblonga, E. eugenoides, E. piperita, E. seiberi, **E. punctata**	2	Shale enriched sandstone	HQH	Core
Nepean Gorge Moist Forest	6	E. elata, E. agglomerata, **E. punctata**, E. piperita, C. gummifera	1	Sandstone	MQH	Non-Core
O'Hares Creek Shale Forest	9	**E. globoidea**, E. piperita, A. costata, C. gummifera, E. seiberi	1	Shale transition	HQH	Core
Riparian Forest	184	E. botryoides, E. benthamii, A. subvelutina, E. elata, A. floribunda, E. baueriana, E. saligna X botryoides, **E. tereticornis**	1	Shale transition	HQH	Core
Riparian Scrub	133	A. costata, **E. pilularis**	1	Sandstone	LQH	Non-Core
Rock Pavement Heath	2	None	0	Sandstone	LQH	Non-Core
Rock Plate Heath-Mallee	19	E. stricta, E. apiculata, E. multicaulis, E. sclerophylla, E. seiberi, C. gummifera, E. oblonga	0	Sandstone	LQH	Non-Core
Sandstone Gully Apple-Peppermint Forest	907	A. costata, E. piperita, C. gummifera, E. seiberi	0	Sandstone	MQH	Non-Core
Sandstone Gully Peppermint Forest	1022	E. piperita, C. gummifera, E. seiberi, **E. globoidea**	1	Sandstone	MQH	Non-Core
Sandstone Heath-Woodland	37	E. haemastoma.racemosa, E. seiberi, E. oblonga, C. gummifera	0	Sandstone	LQH	Non-Core
Sandstone Ridgetop Woodland	766	C. gummifera, E. sclerophylla, **E. punctata**, A. costata, E. Oblonga, E. piperita, A. bakeri, E. sieberi, **E. globoidea**, E. agglomerata, E. haemastoma, E. parramattensis, **E. pilularis**, E. squamosa,	3	Sandstone	LQH	Non-Core

Sandstone Riparian Scrub	326	A. costata, E. piperita, **E. punctata, E. pilularis**	2	Sandstone	LQH	Non-Core
Sheltered Sandstone Blue-leaved Stringybark Forest	1200	C. gummifera, **E. punctata**, E. piperita, E. agglomerata	1	Sandstone	LQH	Non-Core
Transitional Shale Dry Ironbark Forest	1350	E. crebra, E. fibrosa, **E. paniculata, E. globoidea**, E. eugenoides, **E. punctata**, E. moluccana, E. bosistoana, **E. tereticornis, E. longifolia**, C. gummifera, **E. pilularis**, E. oblonga, E. sparsifolia, E. resinfera, E. beyeriana, A. floribunda,	6	Shale transition	HQH	Core
Transitional Shale Open Blue Gum Forest	36	E. salignaXbotryoides	0	Shale transition	HQH	Core
Transitional Shale Stringybark Forest	252	**E. globoidea**, E. eugenoides, **E. punctata**, C. gummifera, E. crebra, E. piperita, E. sclerophylla	2	Shale transition	HQH	Core
Upland Swamps: Banksia Thicket	6	E. racemosa/haemastoma/sclerophylla, E. oblonga, E. seiberi	0	Sandstone	LQH	Non-Core
Upland Swamps: Fringing Eucalypt Woodland	264	E. sclerophylla, C. gummifera, E. seiberi	0	Sandstone	LQH	Non-Core
Upland Swamps: Sedgeland-Heath Complex	138	none	0	Sandstone	LQH	Non-Core
Upland Swamps: Tea-Tree Thicket	7	none	0	Sandstone	LQH	Non-Core
Upper Georges River Sandstone Woodland	3416	**E. punctata**, C. gummifera, **E. globoidea**, E. oblonga, E. racemosa, A. costata, E. eugenoides, E. pierita, E. seiberi, E. fibrosa	2	Shale enriched sandstone	HQH	Core
Western Sandstone Gully Forest	1934	**E. pilularis, E. punctata**, A. costata, C. gummifera, E. piperita, E. agglomerata, A. floribunda	2	Shale enriched sandstone	HQH	Core
Western Sydney Dry Rainforest	73	C. maculata, **E. tereticornis, E. pilularis**	2	Shale	MQH	Non-Core

Woronora Tall Mallee-Heath	1	E. luehmanniana, C. gummifera, E. racemosa	0	Sandstone	LQH	Non-Core
Regenerating Vegetation	14				LQH/MQH	Non-Core
Weeds and Exotics	13				LQH	Non-Core
Exposed Rock	4				LQH	Non-Core

Attachment 1 - Peer Review 1

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Associate Professor Mathew Crowther
School of Life and Environmental Sciences

18 December 2017

Dear Liza Schaeper

Office of Environment and Heritage

RE: Review of Office of Environment and Heritage (OEH) Draft "Conserving koalas in Wollondilly and Campbelltown LGAs – additional justifications"

I have been commissioned by OEH to review provide a scientific review and analysis of Conserving koalas in Wollondilly and Campbelltown LGAs – additional justifications relating to the following two key points:

1. To review and comment on the koala conservation report's key principles and recommendations to conserve the regional koala population, and
2. • To review and comment on the methods used to derive corridors for koalas and koala estimates included in OEH's koala conservation report.

I will first outline my experience and qualifications with koala research, comment on the documents provided and provide my recommendations.

I am an Associate Professor in wildlife ecology and evolution in the School of Life and Environmental Sciences at the University of Sydney. I have researched on koalas in NSW since 2006, including publishing over 10 scientific papers on koalas. I have also contributed to koala management by contributing to the NSW Koala Recovery Plan, and am a current expert advisory member on the NSW Save Our Species Koala Panel. I have a history of reviewing documents concerning koala management. My CV is attached.

In regards to the report's key principals and recommendations to conserve the regional koala population, the document appears sound. The areas considered by the report are being rapidly developed and hence threats to the regional koala population will increase. This does not even take into account the possible impacts of increased urbanisation interacting with the impacts of climate change, such as increased heatwaves and bushfires.

The report is correct in that development needs to be avoided in both core habitat and primary corridors. With increasing development in the area, these core habitat and

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corridor areas need protection. Cleared areas near the corridors also need protection, as koalas spend much of the time on the ground. When koalas are moving areas, they are particularly vulnerable to threats such as dog attack. Hence the recommendations of increasing corridor widths, and the use of barriers to separate koala habitat areas and corridors from residential areas are appropriate.

Habitat restoration and revegetation of cleared areas are essential. Many of the corridors depicted in the maps are very narrow and hence vulnerable to edge effects. Revegetation has to be well planned, and needs a mixture of local shelter trees (often non *Eucalyptus* species) and local feed species. Koalas use a large variety of *Eucalyptus* species in the area, and plantings must be appropriate for soil type. Tree planting is a long-term management action, as trees are not usable by koalas for many years. There are a number of research projects on tree use in this area, both published and unpublished reports and theses, and these need to be consulted for appropriate trees for planting.

The recommendations for mitigation of the impacts of widened roads and increased traffic, although correct, could be made stronger. Effective mitigation of the impacts of roads on koala populations is an expensive exercise, and needs a combination of fencing and underpasses. Signage, as reported, has been shown to be ineffective in mitigating against road deaths. Hence more details on the true cost of development in the area could be emphasised with more details on the fencing and underpasses.

Although briefly mentioned, I think there is more need for mitigation measures from chlamydia. The Campbelltown populations is currently free of chlamydia, while the Southern Highlands has chlamydia within its populations. Introduction of chlamydia to a population that was previously chlamydia-free can result in a rapidly increasing prevalence within a few years. Such a phenomenon was observed on the Liverpool Plains koala population, surrounding the town of Gunnedah, which had an extremely low, if not absent, prevalence of chlamydia a decade ago. There is a risk of corridors actually increasing the movements of chlamydia infected individuals into chlamydia-free areas. Possible mitigation measures for this would be increased veterinary checks of koalas in corridor areas, and possible barriers of certain corridors if they are problematic.

In regards to the determination of corridors for koalas, the methods seem to be sound. Generalised linear models and Geographical Information Systems are well-tested methods in determining habitat. The criteria in determining corridors was also appropriate and had a high overlap with the modelling approach. The details of the modelling and criteria are probably not as important as the quality of the data. The models and corridor criteria are based on very detailed and accurate vegetation mapping, and extensive koala spotlighting data. Hence, the models are likely to have a high predictive power.

Koalas have been VHF and GPS tracked in the local area for the last few years. Movements of some of these animals could be useful in determining koala corridor use, as well as the models and spotlighting data.

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Determining densities and numbers of koalas is extremely difficult. Some reports have based density estimates on scat counts (usually using the SAT procedure), but these estimates are not universally accepted, and can be affected by decay rates and koala densities. The most accurate way of determining koala densities is distance-sampling, where the probability of detection is accounted for, with covariates of weather and habitat, as well as distance away from the observer. Estimates include confidence intervals, which can be quite large. The main issue with distance sampling is the sample size required to get reasonably accurate and precise estimates. These are a minimum of 75 koala observations per area, which is not feasible in some areas. Hence the method employed in this report, with a large number of systematic surveys (67), and being conservative in the area selection (i.e. leaving out cleared areas that koalas used), gives a reasonable minimum of koalas in the area.

In summary, the recommendations for protecting the koala core areas and habitat, as well as mitigating against future declines by roadkill are reasonable. The methods used in determining koala corridors and koala numbers are also reasonable. Future use of distance sampling, plus more details on disease surveillance, would help in providing more robust recommendations in the future.

Sincerely,

M Crowther

Associate Professor Mathew Crowther

Attachment 2 - Peer Review 2

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30th January 2018

Re: Review of Revised Draft Report: Conserving koalas in Wollondilly and Campbelltown LGAs.

Dear Liza

Thanks for the opportunity to review and comment on more recent revisions to the draft report.

The revised document provides recommendations for koala conservation in Western Sydney, to which end it is clear that the majority of the areas identified as habitat are appropriately located and essential for koala survival. That the outcomes of the report remain conservative is also a positive aspect and because of this I am comfortable in offering qualified support for the report as it currently reads.

However, while I agree with the principles and application of science that has been used to inform the report, I do remain at odds with some aspects of the terminology and data analyses, especially that which relates to the identification of preferred trees. Consistent with my earlier feedback, I remain of the opinion that further work in this area will be valuable and reiterate my earlier offer of assistance with statistical analyses of the associated data.

The proposed mitigation measures of enclaving, fencing and underpasses are appropriate and reflect best practice measures. Because of the conservative approach that has been taken however, I remain concerned at the longer-term conservation implications of the report should the recommendations proceed without further expansion. Specifically, the recommendations insofar as they relate to the southern habitat areas need to be extended to the north as well (*i.e.* South Campbelltown / Macarthur PGA) where optimal levels of occupancy by koalas have been identified within identified linkage areas and there is an obvious need for east –west connectivity to be maintained, rather than discounted. Because of this I am strongly of the opinion that the report has yet to effectively accommodate the conservation needs of koalas in the Macarthur Priority Growth Area and that further work is required to effectively future-proof this important population. Hence the best-practice concepts articulated so well for the southern population need to be expanded into the northern area to which end measures such as fencing and the inferred lack of provision for connectivity will need to be reviewed.

Attachment 2 - Peer Review 2 *cont*.

I hope the preceding comments are of some value. Please don't hesitate to contact me if any of the matters I have raised require further clarification, to which end I am keen to offer any further assistance as may be required to resolve any of the issues that remain outstanding.

Yours Sincerely

Dr. Stephen Phillips
Managing Director / Principal Research Scientist.