Wildlife Roadkill Mitigation Strategy for Lismore City Council

Stage 1: Assessment of Wyrallah Road Koala Roadkill Black-Spot and Mitigation Plan

Sandpiper Ecological

1/94 Main Street
Alstonville

sandpipereco.com.au

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Project team:

Dr B. Taylor (field survey, reporting)

Dr D. Rohweder (project management, review)

Report prepared for:

Lismore City Council

ABN: 82 084 096 828

PO Box 401
ALSTONVILLE NSW 2477
P 02 6628 3559 | E brendan@sandpipereco.com.au

Cover Photo: View south along Wyrallah Road from the Tucki Road intersection. (Photo: Sandpiper Ecological).

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1. Introduction

1.1 Background

Sandpiper Ecological Surveys (Sandpiper) was engaged by Lismore City Council (LCC) to develop a Wildlife Roadkill Mitigation Strategy (WRMS). The requirement to develop a WRMS arose out of recommendations in the Koala Habitat and Population Study (Biolink 2017). That study included an analysis of koala road strike within the area covered by the Lismore Comprehensive Koala Plan of Management (CKPoM), an area of approximately 20 000 ha in the south of the Lismore Local Government Area (LGA).

The Koala Habitat and Population Study (Biolink 2017) identified a temporal increase in reported koala road strikes for the period 2011-16 and identified five black-spots. Major black-spots were identified on Wyrallah Road; Alphadale Road and Cowlong Road intersection, Bruxner Highway; and Bruxner Highway at Goonellabah. Minor black-spots were identified at the intersection of Bruxner Highway and Tatham Road, Grennan and Graham Roads at Tregeagle; and a series of roads between Goonellabah and Tregeagle.

The aim of the WRMS is to reduce the incidence of wildlife roadkill, with a focus on koalas and other threatened fauna. The objectives of the WRMS are:

- To provide detailed recommendations and designs for mitigation measures to be implemented at selected roadkill blackspots identified in the Koala Habitat and Population Study (Biolink 2017)
- To identify additional wildlife roadkill black-spots across the LGA
- To provide a 'toolbox' of mitigation measures that LCC can use to reduce wildlife roadkill at identified black-spots
- To provide recommendations for ongoing monitoring, evaluation and data collection.

The WRMS will form part of LCC's Biodiversity Management Strategy (BMS) which was adopted in 2015 (LCC 2015). The BMS includes an action to respond to the threats to native wildlife caused by roads and vehicles in the Lismore LGA which features a 1000 km-long road network of major regional roads and minor sealed and unsealed rural roads. The BMS identified vehicle strike as a significant threat to wildlife, particularly koalas, across the Lismore LGA.

1.2 Scope of works

The scope of works for development of the WRMS features two stages:

- Stage 1: Undertake an assessment of the major koala roadkill black-spot on Wyrallah Road identified by Biolink (2017) and develop a mitigation plan tailored to the specific threat and topographical features of the site.
- Stage 2: Develop a Wildlife Roadkill Mitigation Strategy
    I. Identify and map additional vehicle strike black-spots throughout the LGA.
    II. Develop a 'toolbox' of vehicle strike mitigation measures that can be implemented at roadkill blackspots along both existing roads as well as during road construction or upgrade.
    III. Develop a works program for implementation of mitigation measures.

IV. Detail a monitoring program to evaluate the effectiveness of the mitigation measures.
V. Provide recommendations for ongoing data collection to monitor wildlife roadkill to enable Council to identify future blackspots.

The following report addresses stage one of the WRMS. It describes the black-spot assessment at Wyrallah Road and presents a mitigation plan tailored to that site. Although the focus of this report is on koalas, the road strike mitigation strategy presented here should also benefit other wildlife taxa. Benefits to other taxa will be discussed in greater detail in the Stage 2 report.

2. Methods

2.1 Site location, traffic data and koala road-strikes

The Wyrallah Road black-spot (identified as black-spot 2 in Biolink 2017) includes the southern part of Wyrallah Road, Tucki Road, Tuckurimba Road and Leslie Lane (Figure 1). The road sections cover a total length of 9km. Signed speed limits range between 60 and 80 km/h (Table 1). Road segments are sealed except for Leslie Lane which is gravel.

Traffic data for the Wyrallah Road black-spot area were sourced from LCC. The closest data recording locations on Wyrallah Road were 3.5-5km north and 4km south. Data sampling from 2010-11 recorded Average Annual Daily Traffic (AADT) in the order of 1860-2819 vehicles (Table 2). Data for Tuckurimba Road within the blackspot road section included an AADT of 251 vehicles and 258 vehicles and average speeds of 91.4 km/h for the recording station 300m south of the blackspot section (Table 2).

Thirty-five known koala road strikes have been reported at this locality for the period 2011-16 at a rate of 3.9 road strikes/km (Figure 1). The 1 km stretch south of the intersection between Tucki Road and Wyrallah Road featured the highest density of koala road strikes within the LGA, with 12 koala road strikes reported between 2011 and 2016 (Biolink 2017). Other high incidence sections include the road segment of Wyrallah Road approximately 1km south of Mathieson Lane (7-9 road strikes/km) and the southern end of Tuckurimba Road (4-6 road strikes/km).

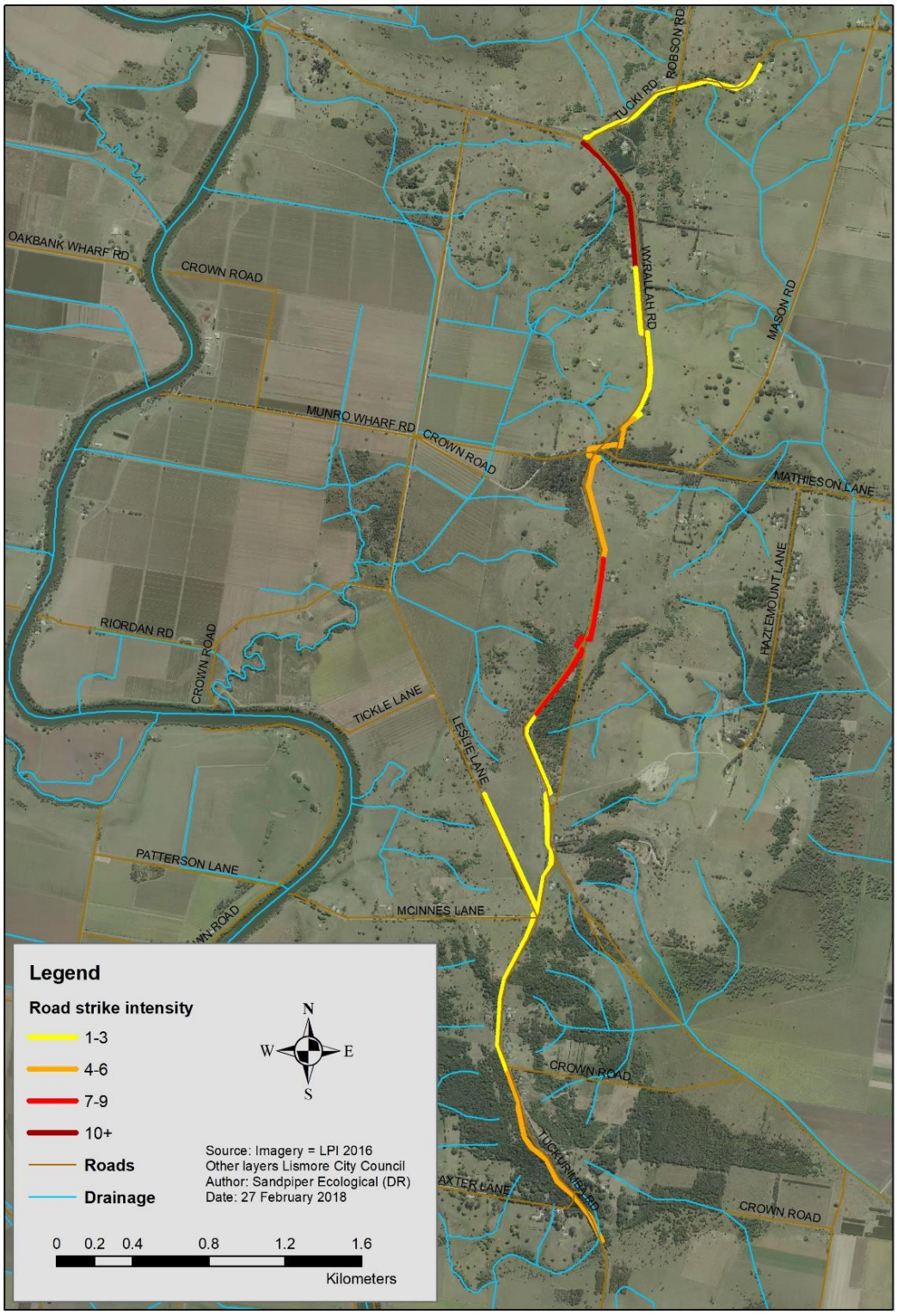

Figure 1: Extent and rate of koala road strike (2011-16) at the Wyrallah Road black-spot (Data source: Lismore City Council; Biolink 2017).

Table 1: Road segment lengths, speed limits and road surface features of the Wyrallah Road blackspot.

Road Segment	Length (km)	Signed Speed Limit (km/h)	Surface
Tucki Road	1.2	Unsigned	Sealed
Wyrallah Road	4.1	80	Sealed
Tuckurimba Road	2.5	80 & 60	Sealed
Leslie Lane	1.2	Unsigned	Unsealed

Table 2: Traffic data from sites within and near the Wyrallah Road black-spot area. AADT = Average Annual Daily Traffic (Source: Lismore City Council)

Road	Location	Station No.	Year Sampled	AADT	Average Speed (km/h)
Wyrallah Road	5km north of Tucki Rd	101	2011	2644	na
Wyrallah Road	3.5km north of Tucki Rd	96	2010	2819	na
Wyrallah Road	4km south of Tuckurimba Rd	92	2010	1860	na
Tuckurimba Road	20 m north of Paffs Ln	55	2013	258	91.4
Tuckurimba Road	200m south of McIness Ln	54	2002	251	na

2.2 Site inspection

A site inspection of the Wyrallah Road black-spot was undertaken on 19 January and 19 February 2018. During the inspection notes were taken on signage, road contours, roadside vegetation and driver visibility.

2.3 Mitigation options investigation

A desktop investigation into koala road strike mitigation options was undertaken between 15 January and 22 February 2018. The investigation included:

- Online keyword searches of Google Scholar and Google Chrome.
- Discussions with:
    - koala road-strike mitigation researchers;
    - Friends of the Koala (FOK) representative;
    - animal road-strike mitigation suppliers;
    - Environmental Officers in surrounding LGA's about Council's koala road-strike mitigation strategies; and
    - Myall Koala and Environment Group about Vehicle-Activated koala signs.

Mitigation options were collated and, where possible, approximate costings derived. Each option was then scored for feasibility, cost and evidence of effectiveness.

3. Results

3.1 Site features

Black-spot road segments all feature undulations, bends and straights (Figure 1; Plate 1-3). Road visibility varies considerably from 'high' along relatively flat and open straight sections (e.g. northern section of Wyrallah Road) to 'poor' or restricted along road crests and sections featuring bends and thick roadside vegetation (e.g. southern section of Tuckurimba Road). Roadside vegetation configuration varies from open grassland (e.g. south of Mathieson Lane), narrow roadside tree rows (e.g. along Tucki Road; Plate 1) to closed forest either side of the road corridor (e.g. Tuckurimba Road around Baxter Lane).

Plate 1: Tucki Road looking west on the approach to Wyrallah Road intersection.

Plate 2. Looking south along Wyrallah Road from the Tucki Road intersection.

Plate 3. Looking south along Tuckurimba Road at the beginning of the 60 km/h section.

3.2 Mitigation options

A list of feasible mitigation options was generated from interrogation of online search results, relevant literature and discussions with other road-strike mitigation researchers, FOK representative, product suppliers and local council environment officers. Each of these options are detailed below and the advantages, disadvantages and approximate costs (where known) described.

3.2.1 Koala warning signs and speed reductions

Wildlife warning signs are amongst the most frequently used roadkill mitigation measure (Huijser *et al.* 2015). The intent is to alert drivers to the possibility of encountering wildlife on or near the road and thus make the driver more vigilant and reduce speed (Bond & Jones 2013). Standard or static warning signs have typically featured line images of wildlife against a yellow background (Plate 4). In more recent years, enhanced or dynamic signs such as vehicle activated signs (VAS) and variable message signs (VMS) have emerged (Plate 5 & 6).

Plate 4. Static koala sign on Wyrallah Road adjacent Mathieson Lane.

Enhanced warning signs are reportedly more frequently observed and recalled by drivers than standard static signs (Bond & Jones 2013; Huijser *et al.* 2015). Their effectiveness may be further improved if they are located at roadkill black-spots and targeted at a specific time of day or season, referred to as 'temporal signs' (Huijser *et al.* 2015). For example, temporal signs reportedly reduced deer road-strike by 9-45% although their effectiveness appeared to diminish over time (e.g. Found & Boyce 2011; Sullivan *et al.* 2004). Conversely, a seasonal speed reduction trial using static signs to reduce koala road-strike in Redlands, Brisbane reported no significant reduction in vehicle speeds or koala road-strike but did report slightly higher survivorship for koalas struck on roads with lower speed limits (Dique *et al.* 2003).

Improved koala survivorship on roads with lower speed limits is an important point and is consistent with evidence that the risk of experiencing a collision increases exponentially with increasing vehicle speed (Huijser *et al.* 2015). Indeed, reduced roadkill rates of eastern quoll and Tasmanian devil in central Tasmania was attributed to a reduction in vehicle speeds although increased vigilance from signage may have been a contributing factor (Jones 2000). Further, vehicle-activated signs (e.g. flashing 'slow down' on activation) reportedly reduced vehicle speeds by 2-20 km/h and road accidents by up to 33% on rural roads in the UK (Winnett & Wheeler 2002). The combination of a variable message sign and pavement treatment on Clothiers Creek Road in Tweed LGA reportedly reduced the number of drivers exceeding the speed limit by 12% over a two-year period (S. Hetherington pers. comm.). This suggests that vehicle-activated signs and/or variable message signs

could assist in reducing vehicle speeds and increasing driver vigilance at koala blackspots in the Lismore LGA and thereby reduce road strike and improve survivorship.

Plate 5. Koala Vehicle-Activated Signs (VAS) manufactured by Pioneerz Safety and installed on Bagotville Road in the Ballina LGA (left). Another version of koala VAS manufactured by HIVIS Group installed at Hawksnest on the mid-north coast (right). Signs are set to activate on a set speed (e.g. 5 km/h below the signed speed limit).

Plate 6. A constantly scrolling Variable Message Sign (VMS; not vehicle activated) manufactured by HIVIS Group and installed on Clothiers Creek Rd in the Tweed LGA (Source: S. Hetherington).

Another recommendation emerging from research on warning signs is that a sign should relate to a relatively short section of road to reduce the likelihood that a driver will forget and discontinue their vigilance (Huijser *et al.* 2015). Similarly, standard signs installed at numerous locations and left indefinitely will become increasingly ignored by drivers over time as they habituate to their presence (Huijser *et al.* 2015).

Advantages:

- Relatively low cost.
- Low maintenance.
- Easily relocated.
- Variable Message Signs may reduce likelihood of habituation.
- Vehicle-Activated Signs can record vehicle speed, which assists in determining their effectiveness.

Disadvantages:

- Effectiveness may be short term, particularly for static signs.
- Risk of vandalism.

Cost:

- Standard static koala sign (www.hivis.com) = $103 + delivery + installation
- Vehicle-activated koala sign (www.hivis.com) = $10,714 (exc. GST; delivered) + installation
- Vehicle-activated koala sign (www.pioneerzsafety.com) = approx. $13,000 (exc. GST; delivered) + installation ($4,000 by supplier)
- Koala Zone Variable Message Sign (www.hivis.com) = approx. $15,000 (exc. GST; delivered) + installation.

3.2.2 Rumble strips

Rumble strips are raised rubber strips that cause a sound and car vibration when a vehicle passes over them (Plate 7). The intent of the rumble strip is to alert drivers. They are often used along road shoulders to alert errant/drowsy drivers before they run off the road. Rumble strips have been shown to substantially reduce the rate of run-off accidents and may be effective at reducing vehicle speed (Corkle *et al.* 2001). It has been suggested that use of rumble strips to increase driver alertness may reduce wildlife vehicle collisions (EDI Environmental Dynamics 2015).

Advantages:

- Low cost.
- Low maintenance.

Disadvantages:

- Noise may disturb nearby neighbours.

Cost:

- $15.40/500mm strip (www.barriergroup.com.au) + installation costs.

Plate 7. Rumble strips (Source: www.barriergroup.com.au)

3.2.3 Wildlife threshold pavement marking

Wildlife threshold pavement marking/painting is typically used to identify the start and/or end of signed significant wildlife conservation areas (Plate 8). The intent of the threshold treatments is to complement the entry signs into a significant wildlife conservation area/black-spot area and advise drivers they should modify their driving behavior and reduce their speed where required.

The concept has been applied at two koala black spots within the Tweed LGA. At the Clothiers Creek Road site, post-treatment monitoring revealed an 8% reduction in vehicles driving above the speed limit (S. Hetherington, pers. comm.). This rose to an average of 12% over a two-year monitoring period after the addition of variable message signs (Plate 6).

Advantages:

- Relatively low cost
- Low maintenance.

Disadvantages:

- Requires periodic re-application.
- Most effective if used in combination with other measures which adds to costs.

Cost:

- Approx. $1,800 - $2,250/treatment (i.e. $45/m x 40-50m^2) + traffic control.

Plate 8. 'Koala Zone' pavement marking (left) and associated VMS sign (right) on Clothiers Creek Road, Tweed LGA.

3.2.4 WID-activated signage system

This signage system is based on catching and placing Wireless Identification (WID) ear tags on koalas residing near a roadkill black-spot. If a tagged individual moves close to the road edge, dataloggers detect their presence and activate nearby warning signs (Figure 2). Warning signs can also feature audio (e.g. an alarm signal). The system is distributed by Brisbane-based company *Wildspy* (www.wildspy.com.au).

Advantages:

- Highly targeted to koalas.
- Reduced likelihood of driver habituation to signage.
- Field trials demonstrate dataloggers effective in detecting WID tags.

Disadvantages:

- Requires capture of local koalas (and recapture at end of WID battery life).
- System only applies to tagged individuals.
- Battery life of WID ear tags ranges between 0.5 – 2.8 years depending on frequency of transmission.
- Would require inclusion of accelerometers in ear tags so tagged koalas resting in roadside trees within range of a datalogger do not continually activate sign.
- Activated sign feature of system yet to be trialed so effectiveness unknown.
- Theft of data loggers.

Cost:

- $40,000 – $100,000/km for signage & datalogger (depends on type and frequency of signs and frequency of dataloggers).
- Add cost of installation

- Add cost of capture/tagging of koalas which may be substantial depending on number of individuals.

Figure 2. WID ear tag (left) and schematic of WID-activated signage system (right). (Source: www.wildspy.com.au).

3.2.5 Break-the-beam dynamic wildlife warning system

The technology works on roadside sensors detecting animal movement. Two different options are available:

1) Roadside fencing directs animals/koalas to designated crossing locations. Sensors at these crossing locations detect animal movement and activate LED warning signs which alert drivers to animals crossing (Figure 3).
2) In the absence of roadside fauna fencing, a series of sensors are placed along the roadside to create a 'virtual' fence. When an animal is detected by a sensor it activates an LED warning sign.

The company promoting the technology claim reductions in wildlife road mortality in the order of 95% at locations in Europe where it has been installed, presumably for option 1. No information was available about option 2 trials or effectiveness. It is yet to be trialed in Australia. The system is distributed by German company *Prowild* (www.prowild.net).

Advantages:

- May be appropriate for a range of species, including koalas.
- Capture of koalas not required.

Disadvantages:

- Requires fencing of road corridor (option 1).
- Requires ongoing maintenance to retain clear line-of-sight between sensors (option 2).
- Unmaintained roadside vegetation may cause false-triggers.
- Not yet trialed in Australia so effectiveness for koalas unknown.
- Theft of sensors.

Cost:

- Approx. $90,000/km (option 2)
- Uneven and winding roads require a higher frequency of sensors which increases costs.

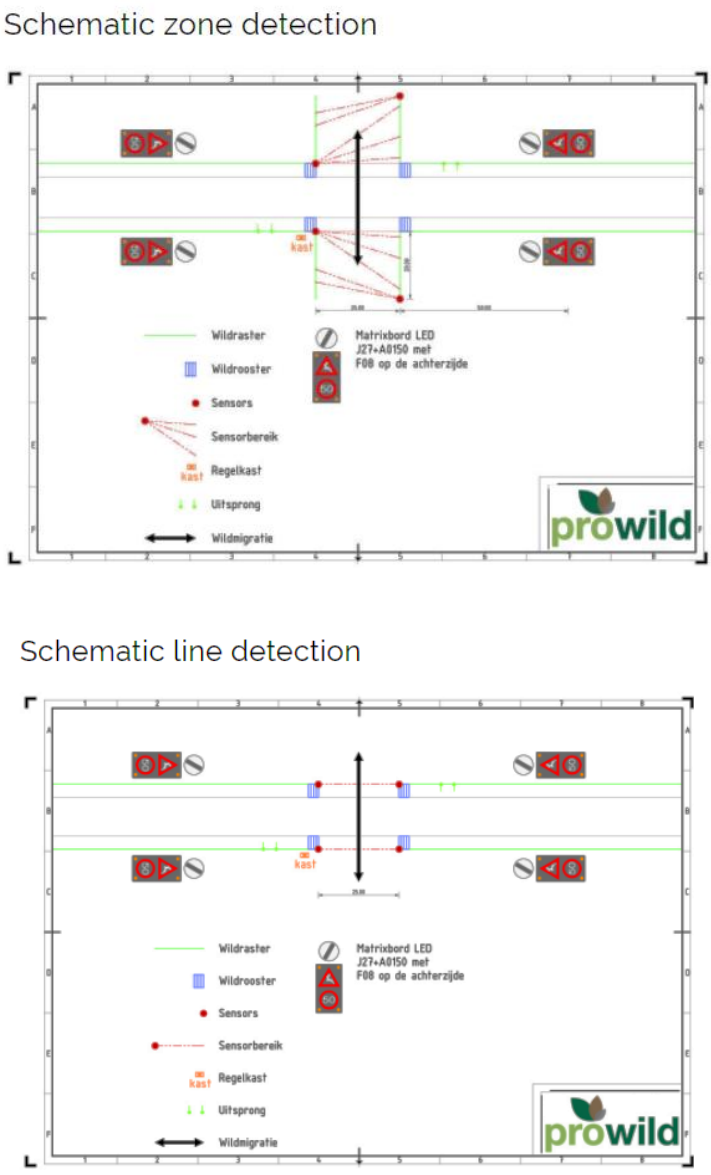

Figure 3. Dynamic Wildlife Warning System. Schematic Zone Detection (Option 1 - top) consists of roadside sensors that detect animal movements at designated crossing locations/gaps in fauna fence which in turn activate warning signs alerting drivers. Schematic line detection (Option 2 - bottom) relies on a virtual fence rather than a fauna fence (Source: www.prowild.net).

3.2.6 Virtual fencing

Virtual Fencing is promoted as an active electronic protection system that aims to prevent animals from crossing the road when a vehicle is approaching at night. The devices are activated by approaching headlights causing them to emit sound and light stimuli intended to alert, repel and prevent animals from entering the road (Figure 4). A device every 25m for the length of the road treatment is recommended. At trial sites in Tasmania, road mortality was reportedly reduced by 60-70% although the report does not state which species this applied to.

The company sales representative claimed the devices would repel and/or stop koalas from entering the roadway. Other koala ecologists and researchers we consulted did not think the system would prevent koalas from entering the roadway (S. Fitzgibbon, A. Gillett, M. Matthes pers. comm.). A koala roadkill mitigation trial using virtual fencing is due to commence in early 2018 at Noosa, Queensland. The system is distributed in Australia by Wildlife Safety Solutions (www.wildlifesafetysolutions.com.au).

Advantages:

- May be appropriate for a range of fauna.
- Low maintenance.

Disadvantages:

- Not yet trialed on koalas so effectiveness unknown.
- Theft of units.
- Possible habituation by animals residing in the road corridor near the units.

Cost:

- $7,800/km (40 units) + installation + posts.

Figure 4. Virtual Fencing is distributed in Australia by Wildlife Safety Solutions. Approaching car headlights activate the sensor which emits sound and light to deter animals from crossing the road. (Source: www.wildlifesafetysolutions.com.au)

3.2.7 Fauna fencing (and crossings structures)

Well designed and maintained fauna fencing (e.g. floppy top or 1500mm high chain mesh with 500mm wide metal flashing) prevents koalas from accessing the roadway (Plate 9). Fencing, however, is a barrier to movement and landscape permeability and should only be installed in conjunction with crossing structures such as land bridges, bridge underpasses or box culverts (Plate 9). Despite documented use of such structures by koalas (e.g. Taylor & Goldingay 2003; Dexter *et al.* 2016), retrofitting box culverts and/or land bridges into an existing road is prohibitively expensive. Rope bridges are a less expensive crossing option, but koalas have not been recorded using such structures (Plate 10; Goldingay & Taylor 2017). Similarly, a metal gantry-style structure with wooden poles laid within it was installed over a road in Redlands, QLD but was not reportedly used by koalas (Plate 10).

Advantages:

- Well designed and maintained fauna fencing is effective in preventing koala access to roadway.
- Fencing combined with underpasses is known to provide safe passage for koalas.
- Low risk of theft/damage.

Disadvantages:

- Fencing is a barrier to movement/landscape permeability in the absence of crossing structures.
- Retrofitting crossing structures into an existing road is very expensive.
- Loss of fence integrity if gates left open or koala grids breached.
- Requires ongoing maintenance to repair breaches, clear debris.
- Resistance by local landholders to fence/gate/grids along property boundaries.

Cost:

- Approximately $80 – 100,000/km (both sides of road) to install floppy top fence.
- Add cost of crossing structures (e.g. box culverts).
- Add cost of koala grids at road/driveway crossings and gates.

Plate 9. Example of koala floppy top fencing (& refuge pole) to prevent road incursions and to direct fauna to a box culvert underpass (left). Box culvert under the Pacific Highway at Glenugie used on several occasions by koalas (right).

Plate 10. Above road crossing structures targeting koalas – '3-sided' rope bridge on grounds at Southern Cross University (left) and a metal gantry with leaning timber poles over Mt Cotton Road, southeast QLD (right; source: Dexter et al. 2016). Monitoring at both sites did not detect use by koalas.

3.2.8 Roadside reflectors and audio deterrents

Other mitigation technologies include roadside reflectors and car-mounted audio deterrents. Reflectors are designed to deter animals from attempting road crossings by deflecting light from oncoming vehicle headlights into the roadside habitat to provide a visual warning (Fig. 5). Wildlife audio deterrents, such as ShuRoo, mount to the front of the vehicle and emit high frequency sound meant to alert and drive off animals on the roadway (Figure 6).

The manufacturers of ShuRoo promote a range of anecdotal evidence of their effectiveness in reducing kangaroo road strike on their website. However, there is no published scientific evidence supporting the effectiveness of audio deterrents or roadside reflectors in reducing wildlife road mortality (D'Angelo and van der Ree 2015). Moreover, we are unaware of any trials of either type of technology specifically targeting koalas.

Advantages:

- Relatively low cost.
- Relatively low maintenance.

Disadvantages:

- No robust evidence supporting their effectiveness.
- Theft of roadside reflectors.
- Audio deterrents require uptake by drivers.

Cost:

- Approximately $7,600/km for Swareflex (i.e. 80 units/km @ $95/unit).
- ShuRoo: $565/unit + installation.

Figure 5. Swareflex roadside reflectors (left) and other reflector types (middle, right) (Source: D'Angelo and van der Ree 2015).

Figure 6. Audio deterrents such as the ShuRoo mount to the front of a vehicle and emit a pattern of high-frequency sounds intended to alert kangaroos and other wildlife of an approaching vehicle (Source: www.shuroo.com.au).

4. Discussion

4.1 Landscape context

The Wyrallah Road koala blackspot presents a familiar and challenging scenario for road managers. How do you prevent or reduce koala road strike along long stretches of moderate use road corridors that feature productive roadside habitat within a mostly cleared and modified landscape? Overlaying this are koala population densities in the order of 0.34 koalas/ha and occupancy rates in the order of 50-77% (Biolink 2017). The Biolink (2017) study pressed that given the relatively high and stable population density within the CKPoM planning area, the emphasis of management should be on ensuring that the terrain remains permeable to koala movement to enable ongoing population processes. Concomitant with maintaining landscape permeability is managing koala encounters with roads and vehicles. Road-strike accounted for 17.5% of known koala mortalities in the Lismore LGA for the 2011-16 period (Biolink 2017). Indeed, koala road mortality has been increasing annually since at least 1998 (Biolink 2017).

4.2 Mitigation options assessment

The mitigation technologies described in Section 3 offer a range of approaches aimed at reducing koala road mortality. Their respective feasibility, costs and proven effectiveness vary considerably and are summarised in Table 3. The relative merits of each are discussed according to these three criteria.

Most options rate high on feasibility except WID-activated signs, break-the-beam warning systems, virtual fence, fencing/crossing structures and audio deterrents. Apart from audio deterrents, the technologies that scored low on feasibility present considerable logistical challenges to implement and are relatively high cost. Audio deterrents rate low on feasibility because they are reliant on uptake by motorists.

The least expensive technologies (per unit) include static signs, rumble strips, pavement treatments and audio deterrents. VAS and VMS signage and virtual fence are moderate cost options whereas WID-activated signs, break-the-beam systems and fencing/crossing structures score as very high cost. It should be noted that cost is largely scale-dependent.

Table 3: Feasibility, cost and proven effectiveness of various road-strike mitigation technologies. Rating metric: very low (+), low (+ +), moderate (+ + +), high (+ + + +), very high (+ + + + +).

Technology	Feasibility	Cost	Proven Effectiveness
Static signs	+ + + + +	+	+
Vehicle-activated signs (VAS)	+ + + + +	+ + +	+ + +
Variable message signs (VMS)	+ + + + +	+ + +	+ +
Rumble strips	+ + + + +	+	+ +
Pavement treatments	+ + + + +	+ +	+ +
WID-activated signs	+ + +	+ + + + +	+
Break-the-beam warning system	+ +	+ + + + +	+ + + +
Virtual fence	+ + +	+ + +	+
Fencing & crossing structures	+ +	+ + + + +	+ + + + +
Roadside reflectors	+ + + +	+ + +	+
Audio deterrents	+ + +	+	+

Evidence of effectiveness (proven effectiveness), while critical to informing choice of mitigation technology, is in many instances difficult to quantify. Most mitigation technologies have not been subjected to well-designed trials and much of the evidence supporting their effectiveness or otherwise is either anecdotal, lacking appropriate design or collected over short time periods. Exceptions to this are break-the-beam systems that have undergone extensive trials in Europe and well-maintained fauna fencing and crossing structures which have been shown at numerous sites to prevent koala road-strike whilst enabling landscape permeability (e.g. Taylor & Goldingay 2003; Dexter *et al.* 2016).

There is emerging evidence in support of VAS to reduce both vehicle speed and wildlife road mortality. Less has been done on VMS but there is some evidence that they lower vehicle speeds. There is strong evidence of speed reductions in response to rumble strips but we are not aware of reports on its application to road-kill mitigation. Despite this, the use of rumble strips may assist in supporting other technologies such as pavement treatments or signage by providing an auditory cue. Virtual fence and WID-activated signs have potential but their application to koalas is yet to be demonstrated. Both technologies are costly to deploy over long road distances, particularly WID-activated signs.

4.3 An integrated approach

It is apparent from the preceding discussion that short of lining the road corridor with fauna fencing and retrofitting underpasses at regular intervals, no single technology will eliminate the incidence of koala road strike at Wyrallah Road (and other road-strike black-spots). Permeable landscapes mean that koalas will continue to encounter roads and traffic. Roadkill mitigation efforts, therefore, should aim to increase driver vigilance and reduce vehicle speed to reduce the likelihood that koala road encounters end in koala road deaths.

In light of this, we propose a plan that adopts an integrated approach featuring several technologies. The proposed approach is similar to that developed by Tweed Shire Council to mitigate koala road strike at black-spots on Clothiers Creek Road, Cabarita and Coronation Avenue, Pottsville. The Tweed

strategy has reportedly been successful in reducing vehicle speeds and reducing koala road-strike although koala road strike before data were incomplete (S. Hetherington pers. comm.). The approach centered on delineating the two black-spots as 'koala zones' and utilising a combination of static signs, variable message signs (VMS), slow points, pavement treatments and before/after traffic monitoring. Tweed City Council also promoted the 'koala zones' in a 'slow down for koalas' marketing strategy focusing on schools and local media.

Importantly, the landscape context of the two black-spots in Tweed Shire are very different to the Wyrallah Road black-spot. The Tweed black-spots occur at locations where the subject road traverses an urban forest corridor for 500m (Coronation Avenue) and a large forest block for 2.5km (Clothiers Creek Road). By contrast, the Wyrallah Road blackspot is 9km of road embedded within a highly modified rural landscape featuring numerous roadside tree rows, scattered paddock trees and clustered vegetation. The mitigation plan for this site must accommodate a very different landscape type, much larger scale of road corridor and a higher density koala population largely residing within the road corridor.

4.4 Wyrallah Road black-spot Mitigation Plan

The proposed Wyrallah Road black-spot mitigation plan utilises 'koala zone' pavement marking, rumble strips, static signs and Vehicle-Activated Signs (VAS). It also requires initial use of LCC data loggers at particular locations and promotion of the 'koala zones' in local media and Lismore LCC marketing. Details of the proposed plan are provided in Table 4 and Figure 7. The precise placement of treatments will require some onground assessment and consideration of ecological and engineering requirements.

Pavement treatments, rumble strips and static 'Koala Zone' signs should be installed concurrently. Data loggers at V1 and V2 should be installed at least one month prior to VAS installation to capture 'before' treatment vehicle speeds. Data loggers should remain in place until installation of VAS which records vehicle speeds.

The 'Koala Zone' pavement marking and associated sign would mark the extent of the Wyrallah Road and Tuckurimba Road road-strike sections. The design of the 'Koala Zone' signs should be discussed with environmental staff and road engineers to ensure specification compliance and branding consistent with LCC policy. The Queensland Department of Transport and Main Roads (QDTMR), who developed the specifications for the pavement marking and which was approved for use in Tweed LGA, suggest the associated sign should inform and reinforce the pavement marking (QDTMR 2015). A single rumble strip should be installed within the lane approaching the 'Koala Zone' and 5m prior to the pavement marking. The intention is to provide an auditory stimulus to reinforce the visual sign.

Vehicle-Activated Signs are recommended at the two highest road-strike cluster locations – Wyrallah Road south of Tucki Road and Wyrallah Road 1km south of Mathieson Lane. The intention is to slow down speeding vehicles and improve driver vigilance. Road engineers should be consulted to determine precise installation locations.

The 'Koala Zone' branding should be promoted via LCC marketing and local media. It should highlight that 'Koala Zones' are road strike black-spots. This should be nested within the broader message of drivers to be koala (wildlife) aware on local roads and the link between speed and an increased likelihood of hitting a koala (wildlife). The intention is to utilise 'Koala Zone' pavement marking at other Lismore LGA koala black-spots during Phase 2 of the WRMS.

It may be useful to link the 'Koala Zone' branding with that occurring in Tweed LGA to develop a broader, consistent narrative. Tweed City Council environment officers have also conducted promotion of 'Koala Zone' and 'Slow down for koalas' in local schools. A similar strategy should be considered for Lismore LGA schools.

Table 4: Mitigation treatments and costings for Wyrallah Road black-spot. Treatment locations are marked on Figure 7. NB = northbound lane. SB = southbound lane. * = Placement to be determined by ecologist and road engineers because side of road koala strikes occurred were not evident in Biolink/FOK data.

Mitigation Treatment	Approx. Cost (exc. GST)	Other Costs	Notes
'Koala Zone' pavement marking • Locations Z1, Z3, Z4, Z5 (single lane) • Location Z2 (both lanes)	$10 125	Traffic control	Includes cost of paint & application.
Rumble strip • Locations Z1, Z3, Z4, Z5 (single lane) • Location Z2 (both lanes)	$660	Installation	Complete during 'Koala Zone' pavement marking. Single strip 10m before pavement marking.
Static 'Koala Zone' sign • Locations Z1 (SB), Z3 (NB), Z4 (SB), Z5 (NB) • Location Z2 (NB & SB)	$1 800	Installation	Modified version of Tweed 'Koala Zone' sign.
Vehicle-Activated Sign (VAS) • Location V1* • Location V2*	$18 000 $18 000	Installation Installation	Consider capacity for sign(s) to be relocated if required.
Data loggers • Location V1* & V2*	In-kind		At least 1 month prior to installation of VAS sign(s)
Promotion of 'Koala Zones' in local media & Lismore CC marketing	In-kind		

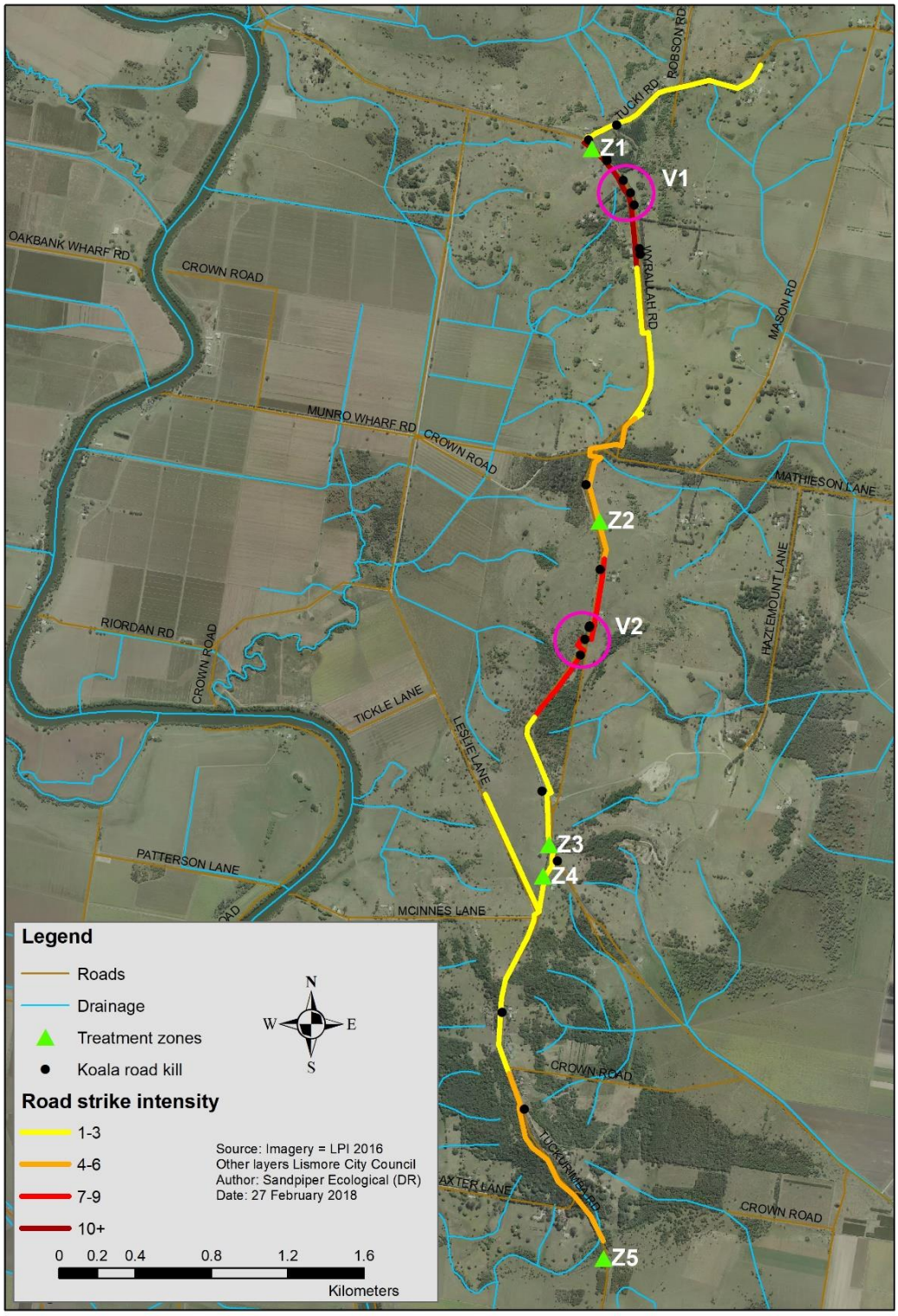

Figure 7: Location of proposed road-strike mitigation treatments at Wyrallah Road koala black-spot. Z = 'Koala Zone' pavement treatment and sign. V = Vehicle-Activated Sign. Road strike intensity data for 2011-2016 (Source: Biolink 2017).

4.5 Performance review

Collection of road-strike data should continue as it has to date. That is, via call outs to FOK and incidental observations reported to LCC by local people or road maintenance staff. A detailed Koala (wildlife) Road-strike Proforma will be developed in Stage 2 of the project with the intention of standardizing reporting and improving the capture of road and landscape attributes at road-strike locations.

The Stage 1 mitigation plan should be reviewed annually along with other strategies implemented as part of Stage 2. The Wyrallah Road black-spot mitigation plan should be assessed against the following Performance Indicators:

1. Increase in proportion of vehicles travelling at or below the signed speed at locations V1 and V2 after installation of mitigation treatment measures (Figure 8) compared to before installation.
2. Reduction in annual number of reported koala road strikes at the Wyrallah Road black-spot compared to average over previous two koala generations (i.e. 10 years).

In reviewing the performance of the Wyrallah Road black-spot mitigation plan, corrective actions will need to be considered in response to poor performance. In so doing, the plan should be regarded as adaptive and able to respond to broad changes in road and/or landscape conditions (e.g. bushfire) and the emergence of other black-spot location(s) within the focal area. In this regard, all signs should have the capacity to be relocated if required. The plan should also be adaptive to the emergence of alternative mitigation technologies and new information on the performance of road mitigation strategies at other locations.

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Appendix A

Figure A1. Wildlife Zone pavement treatment specifications provided by Department of Transport and Main Roads (Qld). These specifications were adopted for pavement treatment on Clothiers Creek Road, Tweed LGA (refer Plate 8).