

Frederickton to Eungai

2018 Annual Ecological Monitoring Report

Roads and Maritime Services | March 2019



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Introduction

Purpose

This report provides an update on the ecological issues associated with the Frederickton to Eungai Pacific Highway upgrade. This report covers the period of 1 December 2017 to 30 November 2018. This report has been prepared in accordance with the Ecological Monitoring Program: Frederickton to Eungai (Roads and Maritime 2016), for submission to the Department of Planning and Environment and Environment Protection Authority (EPA). This report includes *Maundia triglochinos*, Hairy Joint Grass, Green-thighed Frog, aerial crossing, fauna underpass and road kill monitoring undertaken in 2018.

Statutory and planning framework

Approval for the Kempsey to Eungai Pacific Highway upgrade was granted by the State Government on 10 July 2008. Kempsey to Eungai Pacific Highway upgrade is being delivered in two stages with Stage One extending from Kempsey to Frederickton and Stage Two extending from Frederickton to Eungai. This report focuses on ecological monitoring associated with Stage Two, known as the Frederickton to Eungai project.

The Kempsey to Eungai Pacific Highway upgrade approval included the requirement to develop an ecological monitoring program:

*Prior to the commencement of construction, the Proponent shall develop and implement a Monitoring Program to target the effectiveness of the mitigation measures identified in Condition 2.10(d) for the listed threatened species directly impacted by the project. The program shall include (but not necessarily be limited to) the monitoring of *Maundia triglochinos*, Green-thighed Frog, Glossy Black Cockatoo and the Brush-tailed Phascogale. The Program shall be developed in consultation with the DECCW and suitably qualified ecologist(s) and shall include but not necessarily be limited to:*

- a) the monitoring of threatened species in and adjacent to the project footprint. The methodology shall be decided in consultation with DECCW;*
- b) an adaptive monitoring program to assess the effectiveness of the mitigation measures identified in Condition 2.10 (d) and allow their modification if necessary. The monitoring program shall include targets against which effectiveness will be measured;*
- c) monitoring shall be undertaken during construction (for construction-related impacts) and from opening of the project to traffic (for operation/ongoing impacts) until such time as the effectiveness of mitigation measures can be demonstrated to have been achieved over a minimum of three successive monitoring periods, or as otherwise agreed by the Director General in consultation with DECCW;*
- d) provision for the assessment of the data to identify changes to habitat usage and if this can be attributed to the project;*
- e) details of the contingency measures that would be implemented in the event of changes to habitat usage patterns directly attributable to the construction or operation of the project; and*
- f) provision for annual reporting of monitoring results to the Director General and the DECCW, or as otherwise agreed by those agencies.*

The Program shall be submitted to the Director General prior to the commencement of construction and shall be updated to incorporate the monitoring methodology for threatened species, once agreed to, in accordance with condition of this approval.

The initial Ecological Monitoring Program: Frederickton to Eungai was approved by the Department of Planning and Environment on 25 July 2013. This was updated in 2016 and approved by the Department of Planning & Environment on 30 June 2016.

The ecological monitoring program includes the provision for annual reporting to the Director General and EPA.

Appendix A Hairy Joint Grass



Hairy Joint Grass Monitoring 2017/2018

Frederickton to Eungai Pacific Highway Upgrade

Prepared for Roads and Maritime Services

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Cover photograph: Hairy Joint Grass, impact plot 1HE. Niche Environment and Heritage, summer 1 2017.

Executive Summary

Context

This report documents the fourth of five monitoring cycles for Hairy Joint Grass (HJG, *Arthraxon hispidus*), as required by the Frederickton to Eungai (F2E) Ecological Monitoring Program (EMP, RMS 2016).

Aims

The aims of this report are to summarise the methods and results of the 2017/2018 monitoring, provide an overall discussion of all monitoring events and determine if performance measures have been met, as per the EMP.

Methods

HJG populations are known to occur at two locations within the project corridor. In accordance with the EMP, these populations were monitored at four sites, including three potential impact sites and one control site.

Key results

During the 2017/2018 monitoring period HJG was recorded at two of the impact sites (1HE and 2HW), but was not recorded within site 3 control or impact quadrats. Flowering/seeding and recruitment was observed at both sites 1HE and 2HW where the species was detected. The species remained absent from impact site 3HN. A substantial decrease in HJG records and flowering/seeding over successive monitoring events was found for site 2HW.

Conclusions

The performance measure of success relating to flowering/seeding between monitoring events has been met for impact sites 1HE and 3HN but was not met for impact site 2HW. The performance measure of unsuccessful mitigation relating to flowering/seeding and extent over successive monitoring events has not been met for impact sites 1HE and 3HN but has been met for impact site 2HW. Substantial decreases were found for the quadrat records and flowering/seeding between successive monitoring events at this site. Substantial decreases observed at site 2HW cannot be attributed directly to the Project as the control site is not available for comparisons.

Management implications

A number of recommendations have been made, however it is noted that without concurrent management of the area immediately adjacent to site 2HW management outcomes are unlikely to be effective. Consideration should also be given to gaining access to the original control site. This would permit a comparison between the two sites and determine the importance of recommended management measures.

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1. Introduction

1.1 Context

As part of the Frederickton to Eungai (F2E) Pacific Highway Upgrade Project (the Project), Roads and Maritime Services (Roads and Maritime) have implemented an Ecological Monitoring Program (hereafter referred to as the 'EMP') in accordance with the Minister for Planning's Condition of Approval (MCoA) No. 3.1. This EMP (RMS 2016) combines the approval conditions provided within the MCoA and Statement of Commitments (SoC), and defines the mitigation and offsetting requirements for threatened species and ecological communities impacted by the Project.

Hairy Joint Grass (HJG, *Arthraxon hispidus*) was one threatened species identified as requiring mitigation and monitoring through the course of the Projects' construction and operational period. The monitoring requirements for this species are outlined within the EMP.

1.1.1 Legal status

HJG is listed as vulnerable under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and the New South Wales *Biodiversity Conservation Act 2016* (BC Act). HJG is in the family Poaceae (grasses) and has a global distribution. The genus *Arthraxon* contains about 25 species and is distributed across parts of Asia, India and Africa. HJG itself is considered an invasive weed in North America. In Australia the species is distributed from around Kempsey northwards.

1.1.2 Monitoring framework

The EMP states the following regarding monitoring.

"Monitoring would commence in the summer-autumn of 2014 and be undertaken three times a year up between the start of summer to the end autumn until 2019." [sic]

To date, these monitoring events have been reported on as follows:

- *February, April and May 2015*: Niche 2016.
- *December 2015, February and April 2016*: Niche 2017a.
- *December 2016, February and May 2017*: Niche 2017b.
- *December 2017, February and April 2018*: current report.

This report therefore represents the fourth of five necessary monitoring reports for HJG. The final round of monitoring is scheduled to commence at the end of 2018.

1.1.3 Baseline data

The EMP provides the following baseline data:

"1. Southern population occurs at chainage 24000 and occurred over a mapped extent of 3.71 ha in March 2012 (Richards 2012). The Project will remove approximately 0.55 ha with a further 0.27 ha retained within the Project corridor which may be subject of indirect impacts including weed invasion, sedimentation, changed in hydrology and soil eutrophication. The existing landuse is pasture production for beef and cattle grazing with this area supporting Kikuyu, Paspalum, Carpet Grass and Bladey Grass. Fertilizer applications in the form of super phosphate were historically applied to this area up until about 2007. The western boundary of the mapped extent extends into the North Coast Railway Corridor which contains rank grassland and early successional plants such as Acacia.

2. Northern population occurs at chainage 29500 and occurred over a mapped extent of 2.43 ha in March 2012 (Richards 2012). The Project was re aligned to avoid the majority of this population. Fence line clearing for the Project will remove approximately 0.007 ha. A further 0.027 ha is retained within the Project corridor which may be subject of indirect impacts. The existing landuse is pasture production for beef cattle grazing with this area supporting Paspalum, Carpet Grass and occasionally Kikuyu and White Clover. Fertilizer applications in the form of super phosphate are not known at this location.

At both locations, the plants occur sporadically throughout the mapped extend with Braun-Blanquet scale ranging from r (<<<1(solitary, insignificant cover) to 2 (10-25%) in 2 x 2 m quadrants (4m²).” [sic]

1.1.4 Purpose of this report

This report complies with the monitoring requirements described within the EMP and details the findings obtained from the fourth monitoring event.

The aims of this report are to summarise the methods and results of the 2017/2018 monitoring, provide an overall discussion of all monitoring events and determine if performance measures have been met, as per the EMP.

1.2 Performance measures

The EMP specifies the following performance indicators for HJG.

Indicators of success will focus on the following:

- *Exclusion fencing with signage identifying ‘no go’ zones (during construction).*
- *Sediment control fencing in place and working effectively (during the construction period).*
- *Review of the design of drainage and planning of works (during the construction period).*
- *Flowering and/or seeding is consistent with paired control or previous monitoring results.*

Signs of the habitat protection procedure not working will be based on the following:

- *Breached exclusion fencing (during construction).*
- *No signage identifying the sensitive nature of the location as threatened species habitat (during construction).*
- *A significant (if statistics are used) or substantial difference (i.e. 15% allowance) between the paired monitoring sites or impact only monitoring sites with regard to flowering/seeding and overall extent or recruitment.*

1.3 Monitoring timing

As per the EMP, monitoring is to be undertaken three times a year, between the start of summer and the end of autumn.

1.4 Reporting

Annual reporting of monitoring results will outline:

- A description of the monitoring methodology employed.
- Results of the monitoring surveys.
- A discussion of the results, including how the results compare against key performance criteria.
- The need for any corrective actions/contingency measures and any general recommendations.

All reports prepared under the EMP will be submitted to the Director General of the NSW Department of Planning and Environment and the NSW Environment Protection Authority (EPA).

1.5 Limitations

The following limitations were present during the current monitoring period:

- The 3CN control site is considered to be unsuitable to be used in statistical comparisons with the other sites due to the difference in the condition treatment of this site (3CN site is grazed) that may itself result in any differences seen.
- Due to the broad cover abundance range within each Braun-Blanquet score, it is not possible to determine whether a substantial difference has occurred between sites where the Braun-Blanquet Scale score of '3' (i.e. 5-25% cover) or above has been applied, as the percent range exceeds the 15% threshold for detecting change. A smaller percent cover score (e.g. 1-5% increments) should be considered for future monitoring to improve the detectability of change.

2. Survey Methods

2.1 Survey sites

Six monitoring sites were originally identified for HJG monitoring (Lewis 2013). These included three potential impact sites (located within the Project boundary) and a paired control site (located outside of the Project boundary). However, following the completion of the first (February 2015) surveys (where all six sites were monitored), two of the three paired control sites could not be surveyed as landholder agreements for access had not been secured. In accordance with the EMP these two control sites have been removed from the monitoring program. The locations of the four remaining monitoring sites are provided in Figure 1 and detailed in Table 1. Future monitoring of the 3CN control site is subject to landowner agreement (RMS 2016).

Table 1: Details of potential impact sites and control site

Monitoring site	Chainage/ Location	Easting	Northing	Site type	Side of Carriageway	No. 2 x 2m Quadrats	Landholder Access Agreement Status
1HE	24000	487175	6576696	potential impact	East	10	Not required
2HW	24000	487173	6576695	potential impact	West	10	Not required
3HN	29500	491349	6580096	potential impact	North	10	Not required
3CN	29500	491261	6580161	control	North	10	Access granted

2.2 Survey method

Monitoring was undertaken in December 2017 (summer 1), February 2018 (summer 2) and April 2018 (autumn). At each site ten 4 m² quadrats were surveyed and the following information was recorded for each 4 m² quadrat:

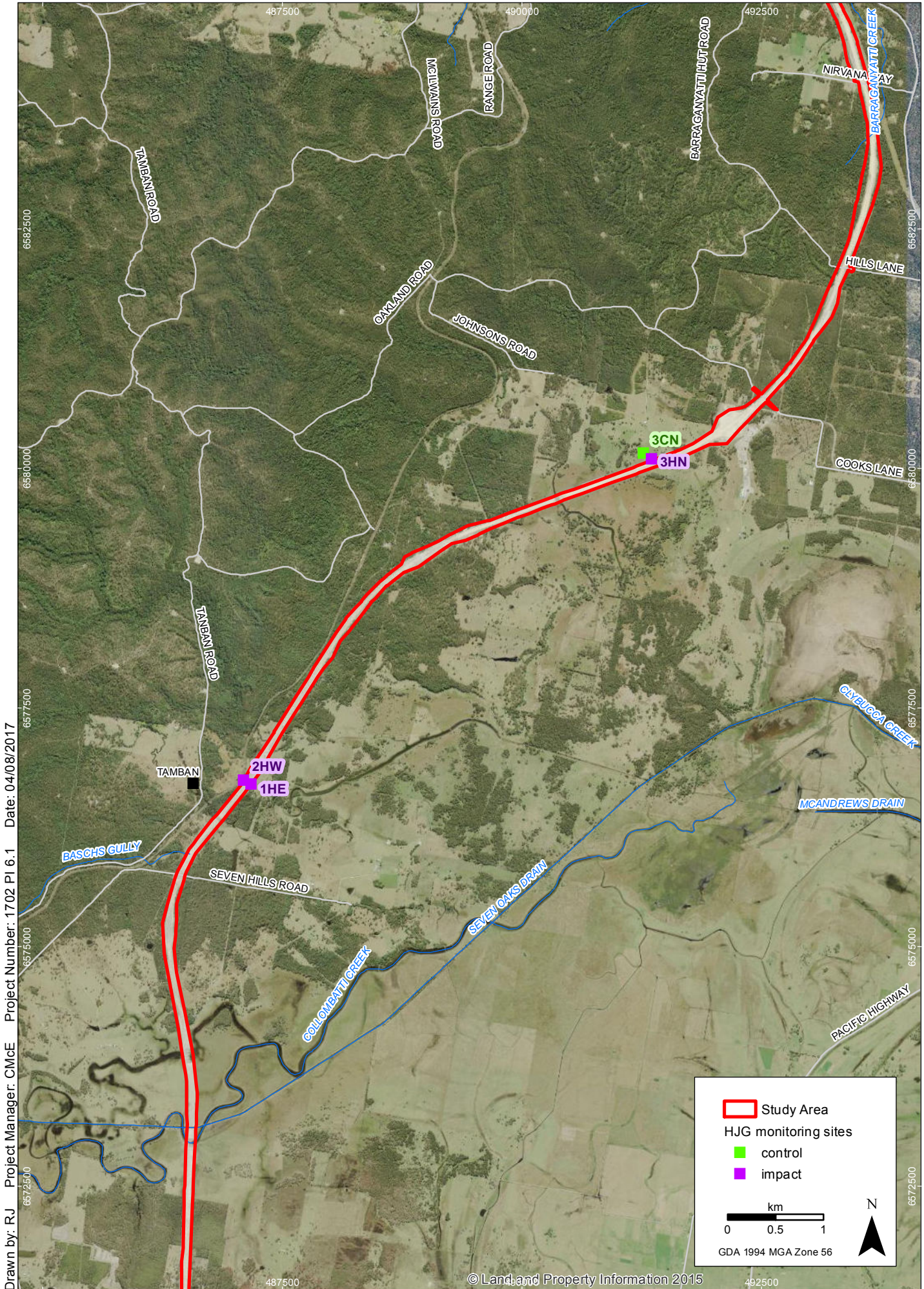
- Plant species present and relative cover of all species using the Braun-Blanquet scale (Table 2).
- The extent of flowering and/or seeding HJG.
- Signs of disturbance (i.e. cattle), sedimentation and to what extent/area.
- A photo taken from a designated photo point.

Table 2: Braun-Blanquet cover abundance scale used in each 4 m² quadrat

Score	Cover Abundance Category
1	1-5% cover – rare
2	1-5% cover – common
3	6-25% cover
4	26-50% cover
5	51-75% cover.
6	76-100% cover

2.3 Analysis of data

Statistical analyses have not been performed due to the lack of paired control sites. In addition, the 3CN control site is considered to be unsuitable to be used in statistical analyses due to the difference in the condition treatment of this site (3CN site is grazed) that may itself result in any differences seen. Instead, the latest monitoring results for each of the four sites are compared with previous monitoring results and assessed for substantial differences (15% allowance) in flowering/seeding and overall extent or recruitment. It should however be noted that due to the broad cover abundance range within each Braun-Blanquet score, it is not possible to determine whether a substantial difference has occurred using the Braun-Blanquet Scale score of '3' (i.e. 5-25% cover) or above between neighbouring scores, as the percent range exceeds the 15% threshold for detecting "substantial change". As such, these scores cannot be used to determine a change. Instead, where appropriate and possible, the difference in the percentage of quadrats recording HJG, flowering/seeding and recruitment has been calculated and used to determine a substantial change between monitoring years.



F2E Hairy Joint Grass 2016/2017 Monitoring Locations
Pacific Highway Upgrade – Frederickton to Eungai

FIGURE 1



Imagery: (c) LPI 2014-09-18

3. Results

3.1 Monitoring results

Field data is provided in Annex 1 and a summary of the results is provided in Table 3 and Table 4. Substantial decreases between successive monitoring events (> 15%) are highlighted in bold. Results of photo monitoring are provided in Annex 2.

3.1.1 HJG presence/cover abundance

HJG was recorded at two of the impact sites (1HE and 2HW) during the 2017/2018 monitoring period but was not recorded within site 3 control or impact quadrats.

Site 1HE

HJG has been recorded at site 1HE during at least one survey each monitoring year. Cover abundance and total quadrats recording HJG (from 0 to 5 quadrats during any one survey) have been consistently low over successive years. There was a substantial clump of HJG recorded just outside one of the monitoring quadrats during summer 1 surveys.

Site 2HW

HJG has been recorded at this site during all monitoring events, with a relatively consistent cover abundance score. Total quadrats recording HJG has decreased over the 2014/2015 (n = 25, 83%), 2015/2016 (n = 23, 77%), 2016/2017 (n = 20, 67%) and 2017/2018 (n = 9, 30%) monitoring events. **This equates to a substantial decrease (>15%) in the HJG records between the 2014/2015 and 2017/2018 monitoring events and again between the 2016/2017 and 2017/2018 monitoring events.** Graph 2 illustrates a general decreasing trend in average cover abundance at this site. Substantial decreases observed at site 2HW cannot be attributed directly to the Project as the control site is not available for comparisons.

Site 3HN

HJG remained absent from impact site 3HN. The site contained thick introduced grass cover consistent with the results of the previous monitoring periods (see Annex 2).

Site 3CN

While data is not available for all surveys during previous monitoring events due to private property access restrictions, as per the 2016/2017 monitoring **there has been a substantial decrease in the detection of HJG at the control site.** HJG was recorded in only a single quadrat in the 2016/2017 surveys and not at all in the current surveys, compared to at least nine quadrats in each of the previous years' surveys. Site 3CN has been heavily grazed. It is unclear if changes in private land management practices have coincided with the absence of this species from monitoring plots.

Clumping and matting of grasses, such as whisky grass (*Andropogon virginicus*) and dense growth of grasses such as *Imperata cylindrica* may provide competition with HJG and prevent its growth. Graph 1 and Graph 2 show the average cover abundance score for three dominant species (*I. cylindrica*, *Pteridium esculentum*, and *A. virginicus*) recorded at sites 1HE and 2HW, where HJG is still being recorded. As there is substantial variation in cover abundance scores these graphs act only to illustrate a general trend in average scores. It is apparent that both *I. cylindrica* and *P. esculentum* have increased in cover abundance at both sites while *A. virginicus* appears to have decreased in cover abundance. While low abundance levels of HJG have been consistent at site 1HE, levels have decreased substantially at site 2HW. It is difficult to observe a trend and

any interaction effects at site 1HE with an initial low abundance, however decreasing levels at site 2HW may be caused by increasing dense grassy growth. While it is not possible to directly attribute this decrease to works associated with Project due to the lack of a paired control site, the decreasing abundance at site 2HW over progressive monitoring events should be addressed.

3.1.2 Flowering/seeding and recruitment

During the 2017/2018 monitoring flowering/seeding and recruitment was observed at both sites 1HE and 2HW where the species was detected. Substantial decreases between successive monitoring events (> 15%) are highlighted in bold.

Site 1HE

Flowering/seeding was recorded in autumn only in the two quadrats where it was recorded. Recruitment was observed during all surveys in each of the quadrats where the species was recorded. Previously, when recorded, flowering/seeding and recruitment has only been recorded in single quadrats.

Site 2HW

Flowering/seeding and recruitment has been recorded during all monitoring events at site 2HW. However, total quadrats recording flowering/seeding has decreased over the 2014/2015 (n = 8, 27%), 2015/2016 (n = 6, 20%), 2016/2017 (n = 2, 7%) and 2017/2018 (n = 1, 3%) monitoring events. **This equates to a substantial decrease (>15%) in the flowering/seeding records between the 2014/2015 and 2016/2017 and the 2014/2015 and 2017/2018 monitoring events.** Recruitment at this site also decreased between 2015/2016 (n = 10, 33%) and 2016/2017 (n = 4, 13%) but increased in 2017/2018 (n = 8, 27%). While there was a substantial decrease in recruitment between the 2015/2016 and 2016/2017 monitoring, the increase recorded during the current monitoring period has resulted in no overall substantial decrease in recruitment. Substantial decreases observed at site 2HW cannot be attributed directly to the Project as the control site is not available for comparisons.

Site 3HN

Flowering/seeding and recruitment has not been recorded at this site during any monitoring event.

Site 3CN

While data is not available for all surveys during previous monitoring events due to private property access restrictions, flowering has been recorded during a single survey at site 3CN which resulted in a **substantial decrease in the flowering/seeding recorded between 2015/2016 (n = 8, 27%) monitoring and the 2016/2017 (n = 0) and 2017/2018 (n = 0) monitoring periods at the control site.** Similarly, recruitment was previously recorded during a single survey in 2015/2016, but has not been recorded since at the control site. These changes relate to the apparent absence of the species from this site since 2015/2016. The land management activities at this site preclude the use of site 3CN as a control site for comparison. As such, changes at this site have not been used in the discussion of outcomes at the impact sites.

Table 3: Summary of Hairy Joint Grass monitoring results – presence/abundance

Site	Number of quadrats containing HJG												Cover abundance scores for quadrats with HJG (mean ± se)											
	2014/15			2015/16			2016/17			2017/18			2014/15			2015/16			2016/17			2017/18		
	Summer 1	Autumn 1	Autumn 2	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn	Summer 1	Autumn 1	Autumn 2	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn
1HE	1	1	1	0	1	5	4	0	1	1	1	2	2	2	1	0	0.2±0.2	1.1±0.4	1.5±0.3	0	1	3	2	1.5±0.5
2HW	9	8	8	6	8	9	8	7	5	5	2	2	2.5±0.2	1.9±0.2	1.1±0.2	0.9±0.3	2±0.3	2.4±0.4	1.9±0.1	1.9±0.3	1	1.6±0.2	1.5±0.5	2±0.0
3HN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3CN	10	ND	ND	9	10	10	1	0	0	0	0	0	1.5±0.2	ND	ND	1.7±0.3	3.4±0.2	2.8±0.2	1	0	0	0	0	0

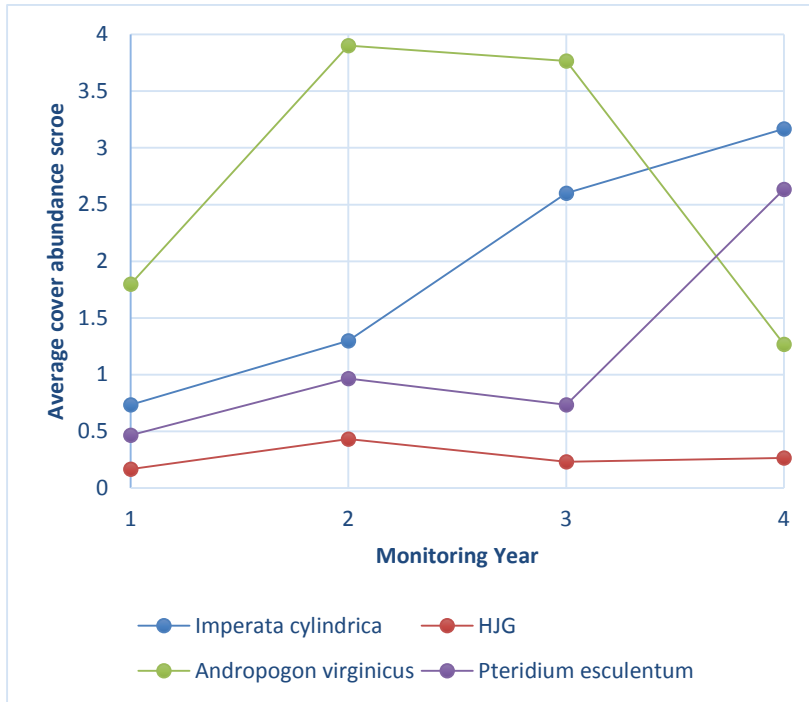
ND = No data due to private property access restrictions.

Table 4: Flowering/seeding and recruitment

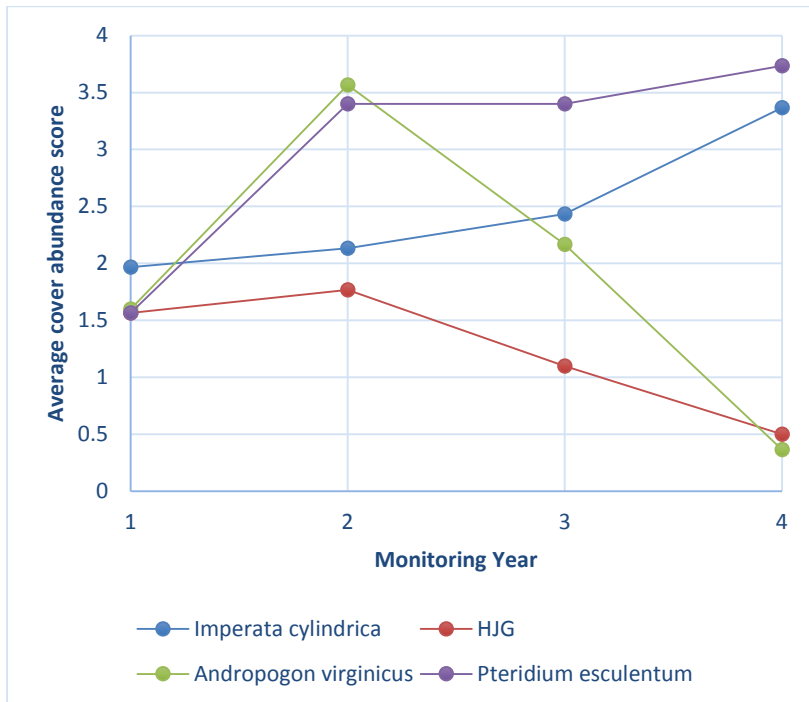
Site	Flowering/seeding (no. of quadrats)												Recruitment (no. of quadrats)											
	2014/15			2015/16			2016/17			2017/18			2014/15			2015/16			2016/17			2017/18		
	Summer 1	Autumn 1	Autumn 2	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn	Summer 1	Autumn 1	Autumn 2	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn
1HE	0	1	0	0	0	1F	0	0	0	0	0	2F	0	0	0	0	0	1	0	0	0	1	1	2
2HW	0	8	0	0	0	6S	1F	0	1F	0	0	1F	0	0	3	6	0	4	1	3	0	2	2	2
3HN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3CN	0	ND	ND	0	0	8S	0	0	0	0	0	0	0	ND	ND	0	0	3	0	0	0	0	0	0

S=Seeding, F=Flowering, ND = No data due to private property access restrictions.

Graph 1: Average annual cover abundance of dominant species at impact site 1HE



Graph 2: Average annual cover abundance of dominant species at impact site 2HW



4. Discussion

4.1 Performance measures

A discussion of the 2017/2018 monitoring results in relation to the performance measures is provided in Table 5. As discussed previously (Section 2.3), the 3CN control site is considered to be unsuitable to be used in statistical comparisons due to the difference in the management of this site (3CN site is grazed) that may itself result in any differences seen, as such control site 3CN has been excluded from the discussion of performance indicators. Instead, the latest monitoring results for each of the four sites are compared with previous monitoring results and assessed for substantial differences (15% allowance) in flowering/seeding and overall extent or recruitment.

Table 5: Indicators of Success

Indicators of success	Discussion
Exclusion fencing with signage identifying 'no go' zones (during construction).	This performance indicator no longer applies as the construction period is complete and this section of the highway is now operational.
Sediment control fencing in place and working effectively (during the construction period).	This performance indicator no longer applies as the construction period is complete and this section of the highway is now operational.
Review of the design of drainage and planning of works (during the construction period).	This performance indicator no longer applies as the construction period is complete and this section of the highway is now operational.
Flowering and/or seeding is consistent with paired control or previous monitoring results.	This performance indicator has been met for all sites except Site 2HW. At site 2HW total quadrats recording flowering/seeding has decreased over the 2014/2015 (n = 8, 27%), 2015/2016 (n = 6, 20%), 2016/2017 (n = 2, 7%) and 2017/2018 (n = 1, 3%) monitoring events, with a substantial decrease observed between 2014/2015 monitoring and both 2016/2017 and 2017/2018 monitoring.

Table 6: Signs of the habitat protection procedure not working

Signs of habitat protection procedure not working	Discussion
Breached exclusion fencing (during construction).	This performance indicator no longer applies as the construction period is complete and this section of the highway is now operational.
No signage identifying the sensitive nature of the location as threatened species habitat (during construction).	This performance indicator no longer applies as the construction period is complete and this section of the highway is now operational.
A significant (p<0.05) or substantial difference (i.e. 15% allowance) between the paired monitoring sites or impact only monitoring sites with regard to flowering/seeding and overall extent or recruitment.	Comparisons between control and impact sites cannot be made due to the sites being exposed to different treatments which may confound the results (see Section 2.3). Comparisons between impact sites are similarly not suitable due to differences in site treatments and ecological variables. Between monitoring event comparisons of the same sites have therefore been used to detect differences in HJG presence/seeding and recruitment over time. To this end, this performance indicator of unsuccessful mitigation has not been met for sites 1HE and 3HN (i.e. there was no substantial difference in presence, flowering/seeding or recruitment between successive surveys) however it has been met for Site 2HW. There were substantial decreases in the HJG quadrat records and the flowering/seeding for 2HW between the 2014/2015 and both the 2016/2017 and 2017/2018 monitoring events, while recruitment increased from the previous monitoring period.

5. Recommendations

As stated previously, control site 3CN has not been used for impact-control statistical comparisons within monitoring events. Likewise, overall seasonal trends observed for control site 3CN cannot be used to recognise and compare non-impact related trends due to the differences in landuse between this site and the impact sites and the lack of other control sites. As such, recommendations provided below are based only on within-site data and comparisons.

5.1 Contingency measures

The EMP lists potential problems and contingency measures for various components of the monitoring program. Those that are considered to be relevant to the HJG monitoring program are listed and discussed in Table 7.

Table 7: Potential problems and contingency measures proposed for HJG

Potential Problem	Contingency Measures proposed in EMP	Relevance of contingency measure
Significant difference ($p < 0.05$ level) in flowering/seeding and/or extent of relative cover between control sites and treatment sites, or over consecutive monitoring events with impact only monitoring sites.	Review drainage (local hydrological patterns) Review the need for additional management such as mowing and removal of mulch.	This contingency measure is considered relevant to Site 2HW only. Substantial decreases were found for the HJG quadrat records and flowering/seeding between successive monitoring events at this site.

5.2 Corrective actions to meet performance criteria

The recommendations provided in Table 8 were also made after the 2016/2017 monitoring period and were taken into consideration by RMS. RMS concluded that *“Given that the original control site is located immediately adjacent to 2HW and the density of weeds and Pteridium esculentum on that site, RMS does not consider the proposed action will be sustainable or effective.”*, and proposed to *“to review the ongoing monitoring before consideration to any actions would be taken.”* This proposal was accepted by the EPA and management actions at site 2HW have not been undertaken.

Niche note that without concurrent management of the area immediately adjacent to site 2HW management actions are unlikely to be effective. In addition, substantial decreases observed at this impact site cannot be attributed directly to the Project as the control site is not available for comparisons. Consideration should also be given to gaining access to the original control site. This would permit a comparison between the two sites and determine the importance of previously recommended management measures. It should be noted that the 2018/2019 monitoring period will be the final monitoring period required by the EMP and would there provide a single year comparison between the control and impact site if access were granted

Table 8: Recommendations

Relevant contingency measure or performance indicator	Application	Recommendations
Review drainage (local hydrological patterns).	Site 2HW	Local drainage cannot be changed at the site.
Review the need for additional management such as mowing and removal of mulch.	Site 2HW	<p>The following recommendations would be required at the site and in the surrounding area in order to be effective.</p> <p>Consideration should be given to requesting access to the adjacent area (original control site) to determine the presence of HJG and permit a comparison. RMS should continue to review the monitoring before further considering any previously recommended mitigations (Niche 2017b) given the condition of the original control site.</p>
Flowering and/or seeding is consistent with paired control or previous monitoring results.	Site 2HW	
A significant ($p < 0.05$) or substantial difference (i.e. 15% allowance) between the paired monitoring sites or impact only monitoring sites with regard to flowering/seeding and overall extent or recruitment.	Site 2HW	

6. References

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Annex 1. Results

Impact site 1HE (*Exotic species) (numbers represent Braun-Blanquet scale cover abundance scores: 1 = present but uncommon; 2 = <5%; 3 = 6-20%; 4 = 21-50%; 5 = 51-75%; 6 = >75%)

Species	Summer 1 (December 2017)										Summer 2 (February 2018)										Autumn (April 2018)										
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	
<i>Anagallis arvensis</i> *									2																						
<i>Andropogon virginicus</i> *					3			3	3	3				4							3		4	4					3	4	4
<i>Arthraxon hispidus</i>							3													2			1						2		
<i>Axonopus fissifolius</i> *																4				3	2		4							2	3
<i>Bidens pilosa</i> *																				1											
<i>Carex</i> sp.										1				1						1											
<i>Casuarina glauca</i>				5					4	5	3		3			3					3										
<i>Centella asiatica</i>				2					2						3					2											
<i>Cirsium vulgare</i> *								1												1											
<i>Convolvulus</i> sp.															1	1							2								
<i>Conyza bonariensis</i> *	1	1	3					3	3		2		2	2	4					2			1		1	2	2	1	1	1	
<i>Cyperus brevifolius</i> *										2																					
<i>Dichelachne micrantha</i>																							2								
<i>Dichondra repens</i>	2							1												2			2								
<i>Echinopogon ovatus</i>			3											2					2						2						
<i>Eriochloa procera</i>			2	2																											
<i>Gamochoeta americana</i> *										1																					
<i>Glycine tabacina</i>									1				1							1	1		1		1		2	2	3	1	1
<i>Hibbertia scandens</i>		2																				4									
<i>Hydrocotyle peduncularis</i>													1		2	2				2		1	2	2							1
<i>Imperata cylindrica</i>	4	3	3	5	6	4	5				4	4	5		4	5	5	4		4	5	3	3	5	4	3	4	3			
<i>Lantana camara</i> *										3																					
<i>Microlaena stipoides</i>	4	3		3	3	2	3	4	4	4			3	2	1			3	3	1	3	3	2	2		3	3	3	3	3	

Species	Summer 1 (December 2017)										Summer 2 (February 2018)										Autumn (April 2018)										
Quadrat	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	
<i>Oplismenus aemulus</i>									4			4								3						3	2	3	3		
<i>Oxalis exilis</i>																				1									1		1
<i>Parsonsia straminea</i>																		1													1
<i>Paspalum dilatatum</i>			3	4		2				5					4				3	3		2			3					2	
<i>Pennisetum clandestinum*</i>								3																							
<i>Plantago lanceolata*</i>	2				3			2	3	3	2							2		2	1							2	1	1	2
<i>Pteridium esculentum</i>	3	3	4		3	3	6					5	4	4				3	3	4	5		4	3	2	5	5	5	5		
<i>Senecio madagascariensis*</i>					3	2		2							3			3	3	3				1	3	3			2	1	2
<i>Setaria pumila*</i>	3		4					3	4		3		3	4	3	3	3	4	5												
<i>Sida rhombifolia*</i>		3											1										2								
<i>Solanum mauritanium*</i>					1																										
<i>Solanum nigrum*</i>								2																						3	
<i>Sporobolus fertilis*</i>	2																									3					
<i>Sonchus oleraceus*</i>																															1
<i>Stellaria flaccida</i>																														1	
<i>Verbena rigida*</i>	3	2					4	3			2	3	3					3			3	4	3			3	3	3	3	4	
<i>Viola hederacea</i>																														2	
<i>Veronica sp.</i>												1														1	2				

Impact site 2HW (*Exotic species) (numbers represent Braun-Blanquet scale cover abundance scores: 1 = present but uncommon; 2 = <5%; 3 = 6-20%; 4 = 21-50%; 5 = 51-75%; 6 = >75%)

Species	Summer 1 (December 2017)										Summer 2 (February 2018)										Autumn (April 2018)									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
<i>Anagallis arvensis</i> *				1																										
<i>Andropogon virginicus</i> *	2	3					1														3									2
<i>Arthraxon hispidus</i>	2		1		2	2		1			1					2					2						2			
<i>Austrostipa scabra</i>							1																				3	3		
<i>Axonopus fissifolius</i> *							1	2							2		4	3											3	
<i>Calochlaena dubia</i>																								2	3	2		2	3	
<i>Carex</i> sp.											1						1	1												
<i>Casuarina glauca</i>																		1	2	3		3								
<i>Centella asiatica</i>							1		2		2									2										
<i>Commelina cyanea</i>					2	1										1	1									1		1		
<i>Convolvulus</i> sp.																		2											2	1
<i>Conyza bonariensis</i> *			1	1	2			2		1	2									2			1							
<i>Conyza canadensis</i> *						2																								
<i>Cyperus brevifolius</i> *																									1	2	1			
<i>Cyperus eragrostis</i> *						1																								
<i>Dichelachne micrantha</i>												2																		
<i>Dichondra repens</i>				1	1	2	2				2			2				1			1		2	1				2		
<i>Echinopogon ovatus</i>	3	2	4																											
<i>Entolasia marginata</i>																		2												
<i>Eragrostis leptostachya</i>							2																							
<i>Eragrostis tenuifolia</i> *																											1			
<i>Ehrharta longifolia</i>																									1				2	
<i>Geranium solanderi</i>																	1										1			
<i>Glycine tabacina</i>				1		1									1	1		1	1	1				1		1	2		1	
<i>Hydrocotyle peduncularis</i>																				2						1				
<i>Imperata cylindrica</i>	4	4	5	6	3	2	2		6	6		2	5	5	5		4	4	5	4		4	5	4	4	2		4	3	3

Species	Summer 1 (December 2017)										Summer 2 (February 2018)										Autumn (April 2018)										
Quadrat	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	
<i>Lantana camara</i> *																											1				
<i>Melaleuca quinquenervia</i>																			2			2	2								
<i>Microlaena stipoides</i>	2				2	2		4		3			1		2		2		3	2				2	2	3		2	2	3	1
<i>Oplismenus aemulus</i>													2	2		1		2												2	
<i>Oxalis exilis</i>			1																			1									
<i>Paspalum dilatatum</i>					2		2				3														1						
<i>Pennisetum clandestinum</i> *																												2			
<i>Plantago lanceolata</i> *	2	2	2	2	3	3	3	3	3	3	1					1		1				1									
<i>Pratia purpurascens</i>							2					2						1					1	1						1	
<i>Pteridium esculentum</i>	4	3	5	3	3	3	3	5	3	1	3	6	4	5	4	4	6	4	4	3			4	4	5	4	4	4	3	4	4
<i>Senecio madagascariensis</i> *			1		3	3		3			3					3	2			3								2			
<i>Setaria pumila</i> *				4	3	4	4	4	3	3	5							2								3		2		3	2
<i>Solanum nigrum</i> *		1								1							1														
<i>Sporobolus fertilis</i> *					2	3	5	4									4											3			
<i>Verbena rigida</i> *	3	3	2	3	3	2	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3	4	3	3	3	3

Impact site 3HN (*Exotic species) (numbers represent Braun-Blanquet scale cover abundance scores: 1 = present but uncommon; 2 = <5%; 3 = 6-20%; 4 = 21-50%; 5 = 51-75%; 6 = >75%)

Species	Summer 1 (December 2017)										Summer 2 (February 2018)										Autumn (April 2018)										
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	
<i>Andropogon virginicus*</i>																									3						
<i>Arthraxon hispidus</i>																															
<i>Axonopus fissifolius*</i>							4	3			3			3	3		3			3		5	5	4	3	3			3	3	
<i>Casuarina glauca</i>																				1											
<i>Centella asiatica</i>	3	3	4	2	4	3	3	3	3			2	1			2	1						2			2			2	1	2
<i>Commelina cyanea</i>													2		2	1		1												1	
<i>Cyperus brevifolius*</i>								1														1									
<i>Galium sp.</i>	5	4	5	4	4	4	5	4	6	5																					
<i>Hydrocotyle peduncularis</i>											3	3	3	2	2	2	1	1	2			3		2	3	2	2	2	1	2	2
<i>Hypericum gramineum</i>																	1														
<i>Hypochaeris radicata*</i>																							3								
<i>Juncus continuus</i>												1		1			1	1													
<i>Juncus usitatus</i>	2	3	3	3		2	2	2	2	2												1								1	
<i>Lolium perenne*</i>																				3											
<i>Lotus corniculatus*</i>											3	3	3	3	3	3	2	3	3	3		2	2	2	3	3	3	3	3	3	3
<i>Parsonia straminea</i>																									1					1	
<i>Paspalum dilatatum</i>	5	4	6	6	6	6	5	5	5	6	4	5	5	5	5	4	3	3	5	4		4	4	5	5	4	4	4	4	3	3
<i>Pennisetum clandestinum*</i>	5	4					4	3		3	2	2	3									3	4					5	4	6	6
<i>Plantago lanceolata*</i>						2	2			2	2	2		2	2	2	2		2	1					1			1	1		2
<i>Ranunculus inundatus</i>			2													2										2		1	1	1	
<i>Senecio madagascariensis*</i>			3	5	5	4		3	2	3		3	3	2	3	1		3	3	3		1	1	2		3		4			3
<i>Setaria pumila*</i>	3	6	6	4	4	4	3	4	5	4	4	4	4	4	5	6	6	4	6	5				3	4	5	4	3	3	3	3
<i>Spiranthes australis</i>			2																												
<i>Sporobolus fertilis*</i>																				2											
<i>Taraxacum officinale*</i>																															2
<i>Verbena rigida*</i>					2																										







Control site 3CN (*Exotic species) (numbers represent Braun-Blanquet scale cover abundance scores: 1 = present but uncommon; 2 = <5%; 3 = 6-20%; 4 = 21-50%; 5 = 51-75%; 6 = >75%)

Species	Summer 1 (December 2017)										Summer 2 (February 2018)										Autumn (April 2018)									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
<i>Arthraxon hispidus</i>																														
<i>Axonopus fissifolius*</i>	6	6	6	6	6	6	3	2	2		3	5	4	4	5	5	5	4	5	5	3	4	3	4	3	3	4	3	4	3
<i>Bidens pilosa*</i>												1																		
<i>Bromus sp.</i>	2																													
<i>Calotis cuneifolia</i>	2																													
<i>Centella asiatica</i>		2	2	2			2			1					2	2	2	3	3	3		2			1	2	2		2	2
<i>Conyza bonariensis*</i>							1																							
<i>Cotula sp.</i>								1																						
<i>Cynodon dactylon</i>															2															3
<i>Cyperus brevifolius*</i>	2			2	2	2	1																							
<i>Cyperus eragrostis*</i>																					1			1	1				1	
<i>Cyperus sp.</i>															1		1													
<i>Dichondra repens</i>	2	2			2		2																							
<i>Fimbristylis dichotoma</i>								2	3																					
<i>Hydrocotyle peduncularis</i>													1	1					2	2				2						
<i>Hypochaeris radicata*</i>	2	3	3	2	2			2			3	2			1		1	1	2				2		2			2		
<i>Juncus continuus</i>																														2
<i>Juncus sp.</i>	3	2	3	3		2	2	1	2	3																				
<i>Juncus usitatus</i>				1	2	1		2	2	3	1	1		2		1	3	2	2	3		1			1	1	1	2	2	
<i>Lolium perenne*</i>	3	3	3	4	5	5	5	4	4	4																				
<i>Lotus corniculatus*</i>														1		2					2									
<i>Microlaena stipoides</i>																					2									
<i>Oplismenus aemulus</i>													1																	
<i>Paspalum dilatatum</i>		2	3	3			2	2			4	3	4		4	3			4	4	5	4	4	5	6	5	5	4	5	5
<i>Pennisetum clandestinum*</i>							2	4	2	3	6		4	6	5	4	4	5			2		5		3		3	4		4

Species	Summer 1 (December 2017)										Summer 2 (February 2018)										Autumn (April 2018)									
Quadrat	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
<i>Plantago lanceolata</i> *	3		4		3	3	3	3	3	3	2	2	3		1		2			2	2	2	2	2	2	2	2	2	2	
<i>Pratia purpurascens</i>																						2	2							
<i>Ranunculus inundatus</i>																	1	1		2			1				1	1	2	2
<i>Senecio madagascariensis</i> *	2	2	3			3	2		2	3	2		1	3	2	3		2	3	3	3	3		2	3	2	2	2	2	2
<i>Setaria pumila</i> *							2	3	5	3	3						3				3	3	3		3		3	3	3	3
<i>Spiranthes australis</i>	2		1																											
<i>Sporobolus fertilis</i> *						2			2		2																			
<i>Taraxacum officinale</i> *				1																	1	2	2							
<i>Trifolium dubium</i> *	2	2	2	2	2	2	2	2	2	2	1	2	2	2	3	3	3		3		2	2	2	2				2	2	
<i>Trifolium repens</i> *																					2						1			
<i>Verbena rigida</i> *		1																												

Annex 2. 2017/2018 photo monitoring

Site ID	Summer 1 (December 2017)	Summer 2 (February 2018)	Autumn (April 2018)
1HE impact site			
2HW impact site			

Site ID	Summer 1 (December 2017)	Summer 2 (February 2018)	Autumn (April 2018)
3HN impact site			
3CN control site			

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Appendix B *Maundia triglochinodes*



Maundia triglochinoidea Monitoring 2017/2018

Frederickton to Eungai Pacific Highway Upgrade

Prepared for Roads and Maritime Services

July 2018

Document control

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Cover photographs: Maundia triglochinos impact site M104

Executive summary

Context

This report documents the 2017/2018 monitoring period (December 2017, February 2018 and April 2018) for *Maundia triglochinooides* as required by the Frederickton to Eungai (F2E) Ecological Monitoring Program (EMP, RMS 2016).

Aims

Roads and Maritime Services is required to manage and monitor the effectiveness of the biodiversity mitigation measures implemented as part of the Project. This includes monitoring of *Maundia triglochinooides* which occurs within the Project area. The aims of this report are to summarise the methods and results of the 2017/2018 monitoring, provide a discussion of monitoring events and determine if performance measures have been met, as per the EMP.

Methods

The 2017/2018 monitoring methodology is consistent with the methods developed and used in 2016, based on a 50 m x 2 m belt transect (i.e. 100 m²) within *Maundia triglochinooides* habitat at each site to improve the data analysis.

Five paired impact-control and six impact-only monitoring sites were surveyed in accordance with the monitoring method specified in the EMP. In addition, three reference sites have been included in the monitoring program.

Key results

Cover Abundance

Maundia was recorded on at least one occasion at three of the five paired impact sites and at four of the five paired control sites, at all three reference sites and on at least one occasion at all of the six impact-only sites during the 2017/2018 monitoring period. As in 2016/2017, *Maundia* was not detected at MI06 and MI10 during the 2017/2018 monitoring period.

Recruitment and Flowering/Seeding

Recruitment was recorded at two paired impact sites and two of the paired control site, at Reference sites 11 and 12 and at three of the impact-only sites.

Flowering was recorded at two of the five paired impact sites and at three of the paired control sites. It was not recorded at any reference site, and was recorded at four of the six impact-only monitoring sites.

Conclusions

Performance measures of success relating to flowering/seeding between paired impact-control sites have not been met for site MI05 and between monitoring events for sites MI02, MI03W, MI08 and MI09.

Performance measures of unsuccessful mitigation relating to flowering/seeding and recruitment between paired impact-control sites have been met for sites MI01, MI02 and MI05 and between successive monitoring events for site MI02 and MI10.

Management implications

A number of recommendations to meet performance criteria should be considered and include:

- Review ongoing monitoring and consider recommendations made in the 2016/2017 report (Niche 2017b).
- Where possible, cattle should be excluded from the control sites.
- If the substantial differences persist after the final monitoring event (2018/2019), consideration should be given to the possibility of re-establishing the plant via seed at relevant sites.

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1. Introduction

1.1 Context

As part of Frederickton to Eungai (F2E) Pacific Highway Upgrade Project (the Project), Roads and Maritime Services (Roads and Maritime) have implemented an Ecological Monitoring Program (hereafter referred to as the EMP) in accordance with the Minister for Planning's Condition of Approval (MCoA) No. 3.1. This EMP (RMS 2016) combines the approval conditions provided within the MCoA and Statement of Commitments (SoC), and defines the mitigation and offsetting requirements for threatened species and ecological communities impacted by the Project.

Maundia triglochinos (Maundia) was one threatened species identified as requiring mitigation and monitoring through the course of the Projects' construction and operational period. The monitoring requirements for this species are outlined within the approved EMP.

1.1.1 Legal status

Maundia is listed as vulnerable on the New South Wales *Biodiversity Conservation Act 2016* (BC Act). Monitoring of the species is required under the Project's approval.

1.1.2 Monitoring framework

The approved EMP states the following regarding monitoring.

"Monitoring would commence in the summer of Year 2014 and be undertaken three times a year up until Year 2019 of the project."

To date, these monitoring events have been reported as follows:

- *February, April, May 2015*: Niche 2016.
- *December 2015, February, April 2016*: Niche 2017a.
- *December 2016, February, May 2017*: Niche 2017b.
- *December 2017, February 2018, April 2018*: current report.

This report therefore presents the results of the fourth of five required monitoring cycles.

1.1.3 Baseline data

The EMP provides the following background information for the Maundia populations within and adjacent to the Project in relation to the known locations:

"Maundia triglochinos populations are known from at least 36 locations within the vicinity (i.e. <2 km) of the Project extending from CH14200 to CH31100 (Lewis 2013). Combined, this mapped extent was estimated at 29.86 ha in March-August 2012. Individual location data is provided in Appendix A (Table A1 and A2)".

No data detailing relative cover abundance (i.e. Braun Blanquet scores), incidence of flowering/ seeding or recruitment was provided as part of this baseline information.

1.1.4 Purpose of this Report

This report complies with the monitoring requirements described within the approved EMP and details the findings obtained from the fourth monitoring event. This report therefore represents the fourth of five required reports.

The aims of this report are to summarise the methods and results of the 2017/2018 monitoring and determine if performance measures have been met, as per the EMP.

1.2 Performance measures

The approved EMP specifies the following performance measures for Maundia.

Indicators of success will focus on the following:

- *Exclusion fencing in place with signage identifying these as 'no go' zones (during construction).*
- *Sediment control fencing in place (during construction).*
- *Flowering and/or seeding is consistent with paired control and/or nearest reference site.*
- *Flowering and/or seeding at impact site is consistent with previous monitoring results.*

Signs of the habitat protection procedure not working will be based on the following:

- *Breached exclusion fencing (during construction).*
- *No signage in place identifying the sensitive nature of the location as threatened species habitat (during construction).*
- *A significant (if statistics are used) or substantial difference (i.e. 15% allowance) between paired monitoring sites (those within and those outside of the Project Area boundary) with regard to flowering/seeding and overall extent or recruitment that cannot be attributed to environmental factors.*
- *A significant (if statistics are used) or substantial difference (15% allowance) between impact monitoring sites over subsequent monitoring events that cannot be attributed to environmental factors.*

1.3 Monitoring timing

The monitoring program specifies that monitoring surveys commence in the summer of Year 2014 (construction phase) and be undertaken three times a year between the beginning of summer and the end of autumn until Year 2019 (operational phase) of the Project.

1.4 Reporting

Annual reporting of monitoring results outline:

- A description of the monitoring methodology employed.
- Results of the monitoring surveys.
- A discussion of the results, including how the results compare against key performance criteria.
- The need for any corrective actions/contingency measures and any general recommendations.

All reports prepared under the EMP will be submitted to the Director General of the NSW Department of Planning and Environment and the NSW Environment Protection Authority (EPA).

1.5 Limitations

The following limitations were encountered during the current monitoring period:

- Detection of *Maundia triglochinos* was not possible in areas where access was limited or water depth was relatively high. The number and cover abundance of seedling and recruiting individuals could not be recorded in such areas.
- Other variables, including shade, soil quality, water temperature, width of the habitat at each monitoring site, flora competition or water flow rate, that may impact upon the population were not recorded as part of the monitoring program.
- Between year comparisons for cover extent were limited to a range estimate derived from the Braun-Blanquet scale in 2014/2015 surveys.

2. Survey Methods

2.1 Survey sites

Monitoring design is consistent with that specified in the approved EMP. Five paired impact-control sites and six impact-only sites were monitored. Each paired site includes one impact location within the Project boundary and one control location outside the Project boundary. Due to access restrictions (Niche 2016), the revised EMP (RMS 2016) has excluded control sites MC03E, MC03W, MC04, MC07, MC08 and MC09 from the program. These locations are to be monitored via an impact site only. Site locations are shown in Figure 1, Figure 2 and Figure 3, with details provided in Table 1.

Table 1: Monitoring sites

Site	Chainage (Location)	Easting	Northing	Paired Control plot for potential impact plot	Easting of Control Plot	Northing of Control Plot
1	15360 (East)	487671	6568746	100 m downstream	487723	6568775
2	17360 (East)	486650	6570499	50 m downstream	486727	6570489
3E	19200 (East)	486461	6572090	Impact only	n/a	n/a
3W	19200 (West)	486546	6572155	Impact only	n/a	n/a
4	19950 (West)	486484	6572948	Impact only	n/a	n/a
5	20100 (East)	496604	6573123	100 m downstream	496604	6573123
6	20850 (East)	486531	6573953	100 m downstream	486564	6573899
7	23800 (East)	487058	6576563	Impact only	n/a	n/a
8	24425 (East)	487403	6577089	Impact only	n/a	n/a
9	24450 (West)	487352	6577162	Impact only	n/a	n/a
10	30275 (South)	492027	6580246	50 – 100 m downstream	491981	6580190

n/a = not applicable

All sites were surveyed during the three monitoring events in 2017/2018. Three external reference sites (Table 2) were also surveyed. These sites are independent of the Project area with the purpose of comparative monitoring of *Maundia* populations in the broader area. It is assumed that any change detected at these sites would be unrelated to the impacts of road construction or operation. Due to access restrictions (Niche 2016), the revised EMP (RMS 2016) excluded site 13- Old Stock Dam from future monitoring, and the previous Site 14 (Tamban Road) has become the “new” Site 13 in the EMP. For comparative purposes across monitoring / reporting events, reports will continue to refer to this site as Site 14 (Tamban Road).

Table 2: Reference sites

Site	Easting	Northing	Reference site name
11	490652	6581695	Cols Causeway
12	484393	6571941	Collombatti-Tamban Road
14	486641	6576627	Tamban Road

2.2 Survey method

As per the modified methodology in Niche 2016, the 2017/2018 monitoring was undertaken within a 50 m x 2 m belt transect (i.e. 100 m²) within Maundia habitat at each site. Cover abundance was recorded as percent cover using 5% increments to be able to identify a “substantial difference” (i.e. 15% allowance, as per the EMP) between paired monitoring sites. This modified methodology was presented in Niche 2016 and allows for improved data collection and analysis whilst still complying with the EMP. The modified methodology is consistent with Native Vegetation Interim Standard (NVIS) for estimating number of stems and percentage cover of plant species along a transect. Every 2 m, a 2 m x 2 m quadrat was established along the transect (i.e. at 0 m to 2 m, 2 m to 4 m etc.) where the number of Maundia individuals, flowering, seeding and percent cover were recorded. The following data was collected at each of the monitoring sites:

- Number of Maundia individuals
- The extent of flowering or seeding
- Signs of recruitment (i.e. recruiting individuals)
- Percent cover of Maundia using 5% increments
- Average water depth
- Signs of disturbance (i.e. cattle) and to what extent/area
- Photo from installed specific photo point.

Where a 50 m belt transect could not be achieved due to site geometry or boundary limitations, the transect was extended as far as possible and recorded.

2.3 Analysis

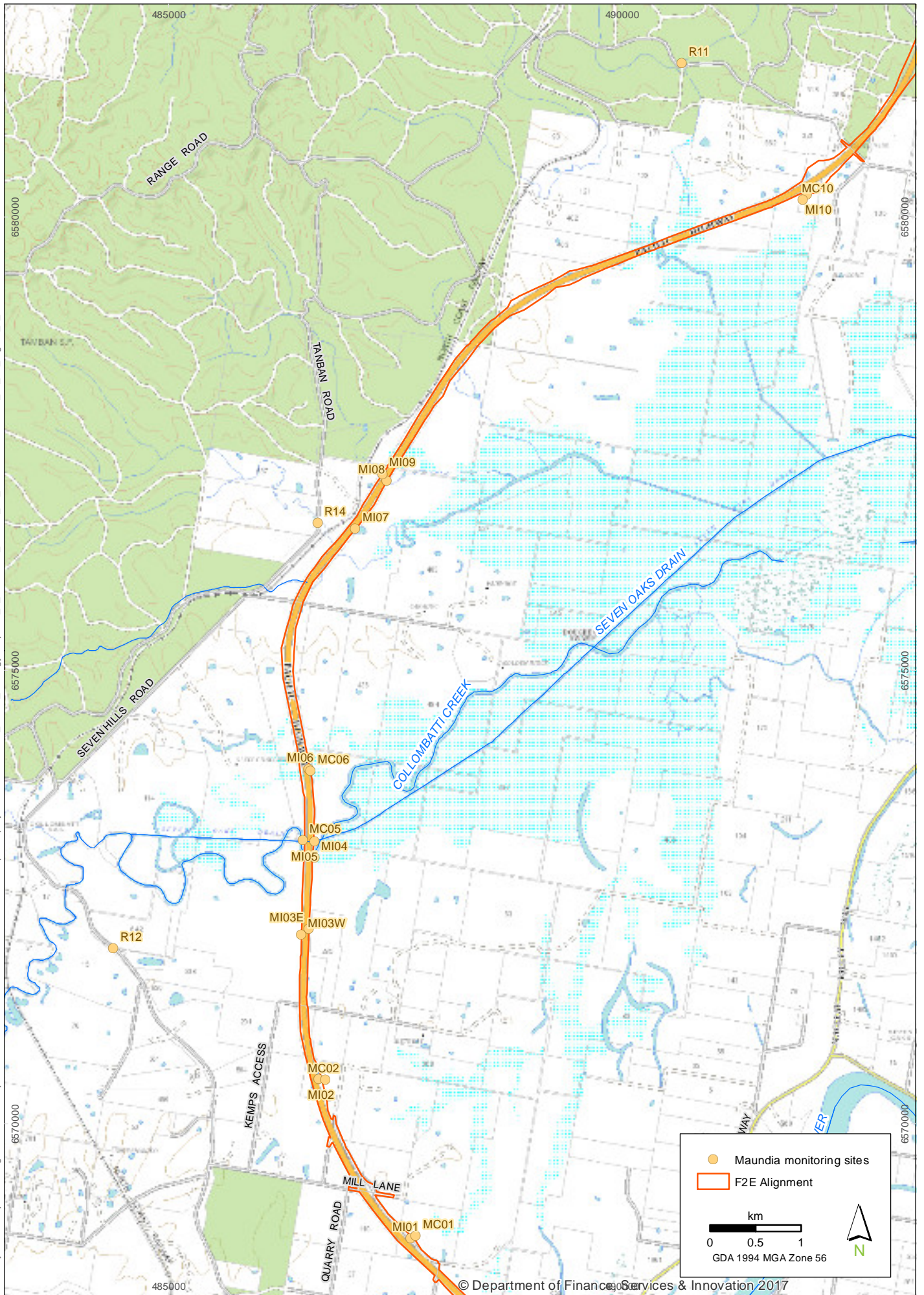
The EMP specifies the following approach to the data analysis.

“For those sites subject to paired impact, control monitoring, a paired t test or a non-parametric equivalent (i.e. Mann Whitney) will be used to explore the usefulness of statistics in comparing the data set.”

Despite the existence of statistical tests that can analyse non-parametric data, most statistical tests assume that you have a sample of independent observations (including Mann Whitney), meaning that observations must be independent in space and time. Many of the paired impact-control sites established in the EMP are spatially close to each other and are unlikely to be independent. Control sites located downstream of their paired impact site and would also be subject to upstream impacts. This lack of independence means that the use of statistical analyses for these data is not appropriate and a substantial difference (i.e. 15% allowance) (as per the performance measures provided in the EMP) has been used as the basis for identifying changes.

In addition, land use and management practices may vary between control and impact sites, such as exposure to grazing. Differences in land use and management may influence any observed changes.

Drawn by: R.J. Project Manager: RM Project Number: 1702 PL6.2 Date: 24/05/2018 T:\spatial\projects\1700\1702_OH2K_Ecology\Maps\PL6_EcoMonit_F2E\PL62_Maundia2018\1702_PL62_Figure_1_Overview.mxd



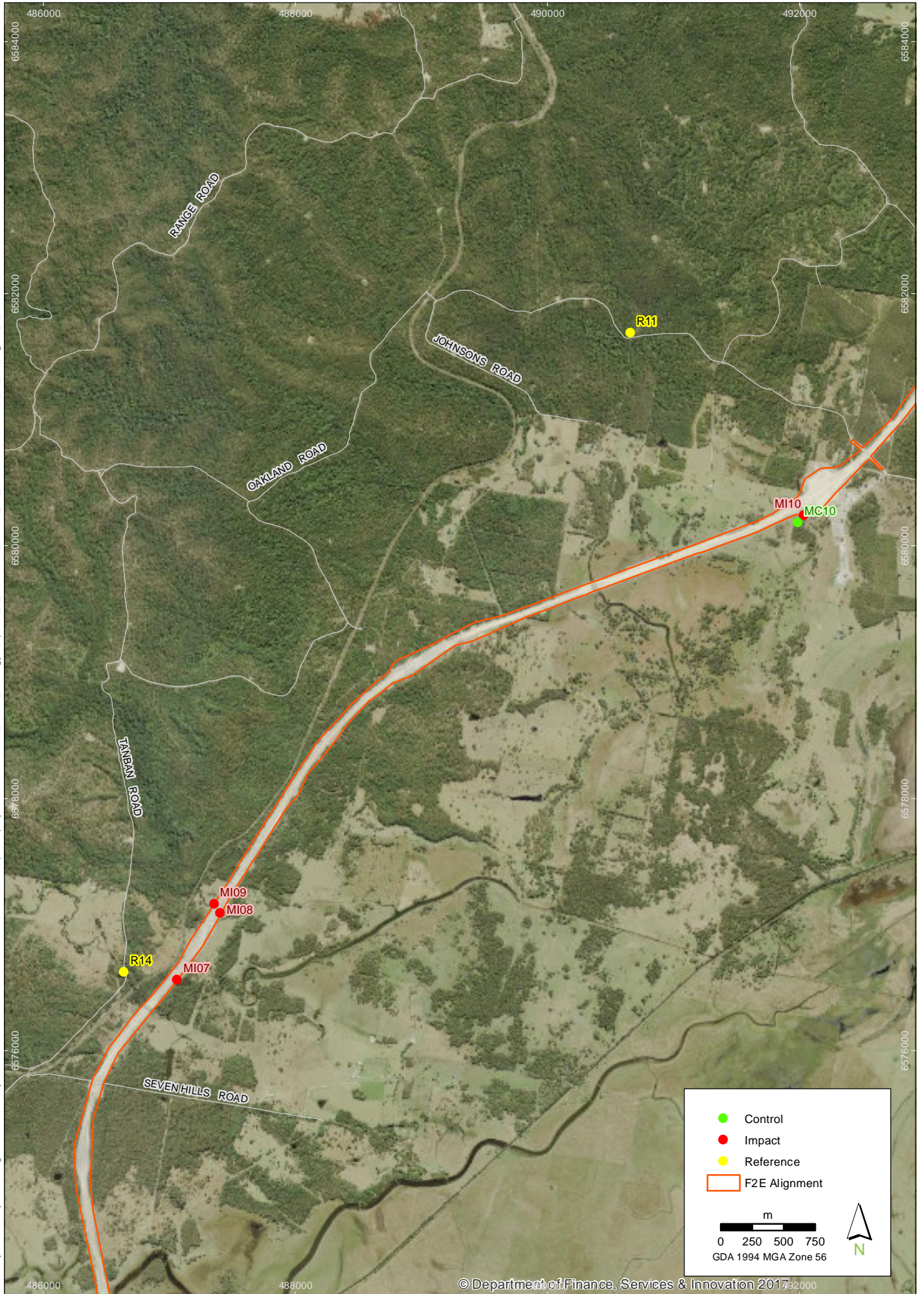
© Department of Finance, Services & Innovation 2017

F2E Maundia monitoring locations: Overview

Pacific Highway Upgrade: Frederickton to Eungai

FIGURE 1

Project Number: 1702 PI6.2 Date: 24/05/2018 T:\spatial\projects\1700\1702_OH2K_Ecology\Maps\PL6_EcoMonit_F2E\PI_62_Maundia\2018\1702_PL_62_Figure_2_Nth.mxd
Drawn by: R.J Project Manager: RM



Legend:

- Control (green dot)
- Impact (red dot)
- Reference (yellow dot)
- ▭ F2E Alignment (orange outline)

Scale: 0 250 500 750 m
GDA 1994 MGA Zone 56

North arrow pointing up with 'N' below it.

F2E Maundia monitoring locations: Northern section
Pacific Highway Upgrade: Frederickton to Eungai



F2E Maundia monitoring locations: Southern section

Pacific Highway Upgrade: Frederickton to Eungai

FIGURE 3

Imagery: (c) LPI 2014-09-18

3. Results

Monitoring was undertaken in December 2017 (summer 1), February 2018 (summer 2) and April 2018 (autumn). Results summarising *Maundia* presence (% cover), recruitment and flowering for each of the sites are presented in Table 3 and Table 4. Field data is provided in Annex A. Photo monitoring results are presented in Annex B.

3.1 Cover extent 2017/2018

The presence of *Maundia* and cover extent recorded at each impact and control site is presented in Table 3 and Table 4. Substantial differences (> 15%) between the cover extent of impact and control sites are highlighted in bold.

Paired impact-control sites

Maundia was recorded on at least one occasion at three of the five paired impact sites and at four of the five paired control sites during the 2017/2018 monitoring period. As in 2016/2017, *Maundia* was not detected at MI06 and MI10 during the 2017/2018 monitoring period.

- MI01 / MC01: **A substantial difference in cover extent was recorded between the two sites in December 2017 (30.0% at control site vs 3.3% at impact site).** While over the three surveys there was not a substantial difference in the average cover extent (15.6% at control site vs 1.6% at impact site), there was a 14.0% greater average cover abundance at the control site.
- MI02 / MC02: **A substantial difference in cover extent was recorded between the two sites in February 2018 (45.0% at control site vs 12.4% at impact site).** While over the three surveys there was not a substantial difference in the average cover extent (30.5% at control site vs 16.3% at impact site), there was a 14.3% greater average cover abundance at the control site.
- MI05 / MC05: **A substantial difference in cover extent was recorded between the two sites in December 2017 (26.2% at control site vs 0.0% at impact site).** While over the three surveys there was not a substantial difference in the average cover extent (12.1% at control site vs 0.05% at impact site), there was a 12.0% greater average cover abundance at the control site.
- MI06 / MC06: A substantial difference in cover extent was not recorded as *Maundia* was not detected at either site.
- MI10 / MC10: *Maundia* was not detected at the impact site however a substantial difference in cover extent was not recorded as average cover extent at the control site was low (4.5%).

Impact-only sites and reference sites

Maundia was recorded at all three reference sites during each of the 2017/2018 monitoring surveys and on at least one occasion at all of the six impact-only sites.

- Reference site 12 is the nearest reference site to impact-only sites MI03E, MI03W and MI04. There was no substantial difference in the average cover extent between MI03E, MI03W and the Reference site during any survey or for all surveys combined. Cover abundance at impact-only site MI04 was substantially higher in December 2017 than at Reference site 12 (35.2% vs 4.8%). This substantial difference however refers to greater cover abundance at an impact site and is therefore not considered in discussions.
- Reference site 14 is the nearest reference site to impact-only sites MI07, MI08 and MI09. There was no substantial difference in the average cover extent between the impact-only sites MI08, MI07 and MI09 and Reference site 14 during any survey or for all surveys combined.

3.2 Recruitment 2017/2018

Maundia recruitment is presented in Table 3 and Table 4. Sites where recruitment was recorded at control sites but absent from paired impact sites or closest reference site are highlighted in bold.

Paired impact-control sites

Recruitment was recorded at the control site but not at the corresponding impact site at one of the five impact-control sites (MI10/MC10). MI06/MC06 was the only paired site where, due to density and water levels, it could be confidently stated that no recruitment was observed at either the control or impact site.

- MI01 / MC01: Recruitment was not observed at the control or impact site, however December 2017 surveys could not determine if recruitment was occurring due to high water levels.
- MI02 / MC02: A number of recruiting individuals were recorded at both the control and impact site but could not be quantified due to high water levels.
- MI05 / MC05: Recruitment could not be determined at the control site due to water depth. Recruitment was observed at the impact site but could not be quantified due to high water levels.
- MI06 / MC06: Recruitment was not recorded at the impact or control site.
- MI10 / MC10: **A number of recruiting individuals were recorded at the control site while no recruitment was recorded at the impact site.** MI10 and MC10 have a distinctly different vegetation structure and site use. Both the MI10 and MC10 recorded high levels of *Persicaria*, however general vegetation density was much higher at MI10. MC10 is exposed to cattle grazing and showed signs of trampling. These differences in land use and vegetation structure may result in varying levels of *Maundia* presence and detection of recruitment. It is therefore not possible to attribute differences directly to the Project.

Impact-only sites and reference sites

Recruitment was observed at Reference sites 11 and 12 but could not be determined at Reference site 14 due to water levels. Recruitment was observed at three of the impact-only sites, could not be determined at two impact-only sites and was not observed at one impact-only site.

- Reference site 12 is the nearest reference site to impact-only sites MI03E, MI03W and MI04. Recruitment was recorded at Reference site 12, MI03E and MI03W but could not be determined at MI04 due to high water levels.
- Reference site 14 is the nearest reference site for impact-only sites MI07, MI08 and MI09. Recruitment was recorded at MI09 but not quantified, was not recorded at MI07 and could not be determined at MI08 or Reference site 14.

It should be noted that the ability to observe recruiting individuals of the species at some of the sites is affected by factors such as water depth and presence of cattle, which may graze recruiting individuals.

3.3 Flowering/Seeding 2017/2018

Maundia flowering/seeding results are presented in Table 3 and Table 4. Substantial differences (> 15%) between the % flowering/seeding at the impact and control/reference sites are highlighted in bold.

Paired impact-control sites

Flowering was recorded at two of the five paired impact sites and at three of the paired control sites.

- MI01 / MC01: Flowering was recorded at both impact and control sites with a greater percentage of flowering individuals at the impact site.
- MI02 / MC02: Flowering was recorded at both impact and control sites at a similarly low level.

- MI05 / MC05: **Flowering was recorded at the control site during December 2017 surveys (25.5%) while no flowering was recorded at the impact site**, however over the three surveys there was not a substantial difference in the average percent flowering individuals. Flowering has been recorded at MI05 on one occasion in 2015/2016, and was not recorded at MC05 until 2016/2017. Flowering at the impact and control site have recorded a similar inconsistency, with records of flowering from only two individual surveys at the control site.
- MI06 / MC06: Flowering was not recorded at the impact or control site.
- MI10 / MC10: Flowering was not recorded at the impact or control site.

Impact-only sites and reference sites

Flowering was not recorded at any reference site, and was recorded at four of the six impact-only monitoring sites.

- Reference site 12 is the nearest reference site to impact-only sites MI03E, MI03W and MI04. Flowering was recorded at MI03W at low levels and at MI04, and was not recorded at MI03E and Reference site 12.
- Reference site 14 is the nearest reference site to impact-only sites MI07, MI08 and MI09. Flowering was recorded at MI08 and MI09 during December 2017 and February 2018 surveys but not at MI07 or Reference site 14.

Table 3: Summary of Maundia presence, recruitment and flowering

Site Name	Design	Maundia triglochinosides flowering and (recruitment) % of Maundia individuals			Maundia triglochinosides cover extent in 100 m ² (%)		
		December 2017	February 2018	April 2018	December 2017	February 2018	April 2018
MI01	Impact	18.9(unk)	0(0)	0(0)	3.33	0.93	0.55
MC01	Control	11.3(unk)	0(0)	0(0)	30.00	9.00	7.84
MI02	Impact	0.7(unk)	1.3(0)	0(Y)	23.40	12.44	12.92
MC02	Control	3.19(unk)	2.2(Y)	0(Y)	26.60	45.04	19.96
MI03E	Impact	0(0)	0(0)	0(Y)	0.00	0.00	0.54
MI03W	Impact	1.5(0)	2.9 (1.0)	0(unk)	2.40	14.48	9.12
MI04	Impact	13.4(unk)	0(0)	0(unk)	35.20	0.00	0.10
MI05	Impact	0(0)	0(0)	0(Y)	0.00	0.00	0.16
MC05	Control	25.5(unk)	0(0)	0(unk)	26.19	4.72	5.42
MI06	impact	0(0)	0(0)	0(0)	0	0	0
MC06	control	0(0)	0(0)	0(0)	0	0	0
MI07	impact	0(0)	0(0)	0(0)	0	0	0.04
MI08	impact	19.8(unk)	5.1(0)	0(0)	5.40	4.20	0.20
MI09	impact	5.2(unk)	1.0(0)	0(Y)	5.33	1.57	0.22
MI10	impact	0(0)	0(0)	0(0)	0	0	0
MC10	control	0 (2.7)	0(unk)	0(Y)	8.00	3.72	1.75

P = individuals present; F = flowering recorded; R = recruitment recorded; N = Maundia not recorded; Y = Yes; unk = unknown

Table 4: Maundia results for reference monitoring sites

Site Name	Design	Maundia triglochinooides flowering and (recruitment) % of Maundia individuals			Maundia triglochinooides cover extent in 100 m ² (%)		
		December 2017	February 2018	April 2018	December 2017	February 2018	April 2018
R11	reference	0 (1.1)	0(unk)	0(Y)	19.00	15.86	11.13
R12	reference	0(unk)	0 (61.0)	0(unk)	4.80	0.29	1.61
R14	reference	0(unk)	0(0)	0(0)	1.60	0.04	0.16

P = individuals present; F = flowering recorded; R = recruitment recorded; N = Maundia not recorded; Y = Yes; unk = unknown

3.4 Successive monitoring event assessment

A summary of previous monitoring events of all sites is provided in Table 5 and results of the successive monitoring event assessments for impact sites are provided in Table 6. Averages were calculated for the three monitoring surveys for each monitoring event. Substantial decreases in cover extent, recruitment and flowering/seeding over successive monitoring events (> 15%) are highlighted in bold.

Table 5: Summary of Maundia results

Year	Average Maundia % cover 100m ²				Average Flowering (%)				Average Recruitment (%)			
	1 [#]	2 [*]	3	4	1	2	3	4	1	2	3	4
MI01	6-25 (3)	2 (3)	1(3)	2 (3)	1 (1)	0	6 (1)	6 (1)	<1 (1)	0	0	0
MC01	6-25 (3)	6 (3)	12 (3)	16 (3)	1 (1)	0	1 (1)	4 (1)	<1 (1)	Y (1)	<1 (1)	0
MI02	6-25 (3)	44 (3)	26 (3)	16 (3)	6 (3)	33 (2)	<1 (1)	<1 (2)	23 (2)	Y (1)	0	Y (1)
MC02	6-25 (3)	34 (3)	10 (3)	31 (3)	1 (1)	15 (3)	<1 (1)	2 (2)	3 (2)	Y (1)	1 (1)	Y (2)
MI03E	1-5 (3)	4 (2)	<1 (1)	<1 (1)	0	9 (1)	0	0	2 (1)	0	2 (1)	Y (1)
MI03 W	1-5 (3)	11 (3)	7 (3)	9 (3)	3 (1)	36 (2)	0	1 (2)	3 (2)	Y (2)	2 (1)	<1 (1)
MI04	0	24 (2)	14 (3)	12 (2)	0	3 (2)	<1 (2)	4 (1)	0	Y	3 (2)	0
MI05	0-5 (1)	<1 (3)	<1 (1)	<1 (1)	0	14 (1)	0	0	0	Y (1)	0	Y (1)
MC05	0-5 (1)	3 (3)	6 (3)	12 (3)	0	0	6 (1)	9 (1)	0	0	6 (2)	0
MI06	1-5 (2)	1 (1)	0	0	3 (2)	Y (1)	0	0	<1 (1)	0	0	0
MC06	0-5 (2)	<1 (1)	<1 (1)	0	1 (1)	17 (1)	0	0	0	Y (1)	0	0
MI07	0	<1 (1)	0	<1 (1)	0	33 (1)	0	0	0	Y (1)	0	0
MI08	0	<1 (2)	<1 (2)	3 (3)	0	28 (1)	12 (1)	8 (2)	0	Y (1)	0	0
MI09	0	2 (3)	3 (3)	2 (3)	0	39 (2)	18 (2)	2 (2)	0	Y (1)	0	Y (1)
MI10	0-5 (1)	<1 (1)	0	0	0	33 (1)	0	0	0	0	0	0
MC10	1-5 (3)	7 (3)	4 (3)	4 (3)	0	0	0	0	3 (1)	Y (1)	7 (2)	<1 (2)
R11	1-5 (3)	21 (3)	10 (3)	15 (3)	0	0	<1 (1)	0	0	0	1 (2)	<1 (2)
R12	26-50 (3)	21 (3)	4 (3)	2 (3)	0	<1 (1)	0	0	<1 (1)	Y (3)	<1 (1)	20 (1)
R14	0-5 (3)	1 (3)	<1 (2)	<1 (3)	0	0	0	0	0	Y (1)	0	0

[#] = cover extent derived from Braun-Blanquet cover abundance scale used in 400m² quadrat methodology. ^{*} = average based on two surveys where 100m² transect data available, but 'n' reflects all three surveys. (n) = number of surveys recorded. Y = recorded but no number or % available. Note that recruitment is only shown for where recruitment was observed. Sites where it could not be determined are shown as 0. Year 1 = 2014/2015; 2 = 2015/2016; 3 = 2016/2017; 4 = 2017/2018.

Table 6: Successive monitoring outcomes

Site	Result	Substantial difference detected
MI01	Maundia has been recorded during the four successive monitoring events without substantial changes in cover extent, flowering/seeding or recruitment. It has consistently been recorded during all surveys.	
MI02	Maundia has been recorded during the four successive monitoring events. Recruitment was high in 2014/2015, undefined in 2015/2016, absent in 2016/2017 and present but undefined in 2017/2018. As recruitment could not be quantitated it is not possible to conclude a substantial difference.	<p>Flowering/seeding recorded a substantial decrease between 2015/2016 and 2016/2017 and remained at a level consistent with 2016/2017 in 2017/2018. The paired control site also recorded a substantial decrease from 2015/2016. Decreased flowering at this site cannot therefore be directly attributed to the Project.</p> <p>Cover extent recorded a substantial decrease between 2015/2016 and 2016/2017 and decreased again in 2017/2018 by 10%. The paired control site also recorded a substantial decrease from 2015/2016, however cover extent increased substantially in 2017/2018 at the control site. It should be noted that cover extent at the impact site still remains within the range observed during the first surveys and has not decreased substantially from the higher extension of this range. Continued monitoring of this site will determine if there is a decreasing trend or if changes are seasonal fluctuations. Recommendations are discussed below.</p>
MI03E	Maundia has been recorded during the four successive monitoring events without substantial changes in cover extent, flowering/seeding or recruitment.	
MI03W	Maundia has been recorded during the four successive monitoring events without substantial changes in cover extent or recruitment.	<p>Flowering/seeding recorded a substantial decrease between 2015/2016 and 2016/2017 and remained at a level consistent with 2016/2017 in 2017/2018. The closest reference site (R12) cannot be used as a comparison as flowering has only been recorded once at very low levels at this site. Higher levels of flowering in general were observed in 2015/2016 for impact and control sites. As such, at this stage decreases from 2015/2016 cannot be directly attributed to the Project. It should be noted that current flowering levels are consistent with the first surveys.</p>
MI04	Maundia has been recorded in all three monitoring events since 2015/2016 without substantial changes in cover extent, flowering/seeding or recruitment.	
MI05	Maundia has been recorded during the four successive monitoring events at a consistently low level without substantial changes in cover extent, flowering/seeding or recruitment.	
MI06	Maundia was only recorded during the 2014/2015 and 2015/2016 surveys at low levels.	While changes cannot be classified as substantial due to the initial low levels, the species has not been observed at this site during the last two monitoring events. Similarly Maundia was not recorded at the paired control site during the 2017/2018 monitoring period and was observed during a single survey at low cover extent during the 2016/2017 surveys. Absence of Maundia from this site cannot therefore be directly attributed to the Project.

Site	Result	Substantial difference detected
MI07	Maundia been recorded during the 2015/2016 and 2017/2018 surveys at low cover extent. The apparent substantial decrease in flowering/seeding in 2016/2017 cannot be considered as a real decrease in flowering/seeding as no individuals were recorded at this site during these surveys.	
MI08	Maundia has been recorded in all three monitoring events since 2015/2016 without substantial changes in cover extent or recruitment.	Flowering/seeding recorded a substantial decrease between 2015/2016 and 2016/2017 and remained at a level consistent with 2016/2017 in 2017/2018. The closest reference site (R14) cannot be used as a comparison as flowering has not been recorded at this site. Higher levels of flowering in general were observed in 2015/2016 for impact and control sites. As such, at this stage decreases from 2015/2016 cannot be directly attributed to the Project. It should be noted that current flowering levels have increased from the first surveys where no flowering was recorded.
MI09	Maundia has been recorded in all three monitoring events since 2015/2016 without substantial changes cover extent or recruitment. Recruitment was recorded for the first time at this site in 2017/2018 surveys.	Flowering/seeding recorded a substantial decrease between 2015/2016 and 2016/2017 and again between 2016/2017 and 2017/2018. The closest reference site (R14) cannot be used as a comparison as flowering has not been recorded at this site. Higher levels of flowering in general were observed in 2015/2016 for impact and control sites. As such, at this stage decreases from 2015/2016 cannot be directly attributed to the Project. Other sites where flowering was observed in 2017/2018 generally experienced an increase in flowering/seeding, although small. It should be noted that current flowering levels have increased from the first surveys where no flowering was recorded. Despite this, continued monitoring of this site will determine if there is a decreasing trend or if changes are seasonal fluctuations. Recommendations are discussed below.
MI10	Maundia was recorded only during the 2014/2015 and 2015/2016 surveys without substantial changes in cover extent or recruitment. The apparent substantial decrease in flowering/seeding in 2016/2017 cannot be considered as a real decrease in flowering/seeding as no individuals were recorded at this site during these surveys.	While changes cannot be classified as substantial due to the initial low levels, the species has not been observed at this site in the last two monitoring events. Maundia continues to be recorded at the paired control site, including recruiting individuals. Continued absence from the impact site with coinciding presence at the paired control site may imply impacts from the Project. Recommendations are discussed below.

4. Discussion

4.1 Performance measures

A summary of the 2017/2018 survey results in relation to the performance indicators is provided in Table 7 and Table 8.

Table 7: Performance indicators of successful mitigation

Performance indicators of success	Discussion
Exclusion fencing with signage identifying these as 'no go' zones (during construction)	This performance indicator is no longer applicable due to the road now being operational.
Sediment control fencing in place (during construction)	This performance indicator is no longer applicable due to the road now being operational.
Flowering and/or seeding is consistent with paired control and/or nearest reference site	<p>This performance indicator has been met by all but one (MI05) of the five paired impact control sites.</p> <p>Flowering was recorded at MI05 during December 2017 surveys (25.5%) while no flowering was recorded at the impact site, however over the three surveys there was not a substantial difference in the average percent flowering individuals. Flowering has been recorded at MI05 on one occasion in 2015/2016, and was not recorded at MC05 until 2016/2017. Flowering at the control site has recorded a similar inconsistency, with records of flowering from only two individual surveys. No consistent declining trend has been observed at this site, as such, at this stage it is not possible to attribute this difference directly to the Project.</p>
Flowering and/or seeding at impact sites is consistent with previous monitoring results	<p>This performance indicator has been met by all but 4 (MI02, MI03W, MI08 and MI09) of the 11 impact sites.</p> <p>MI02, MI03W and MI08 recorded a substantial decrease between 2015/2016 and 2016/2017 and remained at a level consistent with 2016/2017 in 2017/2018. Higher levels of flowering in general were observed in 2015/2016 for impact and control sites. As such, at this stage decreases from 2015/2016 cannot be directly attributed to the Project.</p> <p>MI09 recorded a substantial decrease between 2015/2016 and 2016/2017 and again between 2016/2017 and 2017/2018. Other sites where flowering was observed in 2017/2018 generally experienced an increase in flowering/seeding, although small.</p> <p>The absence of flowering at the nearest reference site removes the ability to compare observed trends, however, it should be noted that current flowering levels have either increased from or remain consistent with the first surveys at these sites.</p> <p>The differences between the percentages of individuals flowering could be attributed to a number of factors, such as differing abiotic conditions across years, and varying annual weather conditions which may impact water flow, depth, turbidity, pH, nutrients, etc., and temperature. Given the species grows in warm conditions, this variable may impact upon the flowering times.</p>

Table 8: Performance indicators of unsuccessful mitigation

Performance Indicators of unsuccessful mitigation	Discussion
Breached exclusion fencing (during construction).	This performance indicator is no longer applicable due to the road now being operational.
No signage in place identifying the sensitive nature of the location as threatened species habitat (during construction).	This performance indicator is no longer applicable due to the road now being operational.
A significant (if statistics are used) or substantial difference (i.e. 15% allowance) between paired monitoring sites with regard to flowering/seeding and overall extent or recruitment that cannot be attributed to environmental factors.	<p>This performance indicator of unsuccessful mitigation has been met for MI01, MI02 and MI05 in relation to cover extent.</p> <p>At MI01, MI02 and MI05, cover extent was substantially higher at the paired control sites during a single survey, and generally higher in the remaining two surveys. While the average cover extent over the three surveys was not substantially lower at any of these sites, differences remain high at approximately 14%. As such, recommendations are discussed below.</p> <p>It is considered that observed differences in recruitment and flowering/seeding between MI10 and MI05 and their paired control sites are likely attributable to environmental factors (as discussed in Section 3.2 and Table 7).</p> <p>This performance indicator of unsuccessful mitigation has not been met in relation to extent/cover abundance for all impact-only sites for all criteria.</p>
A significant (if statistics are used) or substantial difference (15% allowance) between impact monitoring sites over subsequent monitoring events that cannot be attributed to environmental factors.	<p>This performance indicator of unsuccessful mitigation has been met for MI02 and MI10.</p> <p>As discussed in Table 6, MI02 has decreased in cover extent since 2015/2016 while it's paired control site had a comparable increase in cover extent in 2017/2018. Recommendations are discussed below.</p> <p>MI10 cannot be classified as recording substantial decreases due to the initial low levels, however Maundia has not been recorded at the impact site since 2015/2016, while it continues to be recorded at the paired control site. Recommendations are discussed below.</p> <p>It is considered that observed substantial decreases between successive monitoring events at impact-only sites MI03W, MI04, MI08 and MI09 in flowering and cover extent are likely attributable to environmental factors (as discussed in Table 6).</p>

5. Recommendations

5.1 Contingencies

The EMP lists potential problems and contingency measures for various components of the monitoring program. Those that are considered to be relevant to the Maundia monitoring program are listed and discussed in Table 9. Sites where substantial differences are considered as likely attributable to environmental factors or natural variations and fluctuations, as discussed in Table 6, Table 7 and Table 8, have not been considered below.

Table 9: Potential problems and contingency measures proposed in the EMP

Potential Problem	Contingency Measure proposed in EMP	Relevance of contingency measure
Significant difference ($p < 0.05$ level) in flowering/seeding and/or extent of relative cover between control sites (adjacent road corridor) and treatment sites (habitat protection zones within road corridor) or within impact-only monitoring sites.	Review drainage (local hydrological patterns)	This contingency measure addresses only flowering/seeding and extent of cover. At MI01, MI02 and MI05, cover extent was substantially higher at the paired control sites during a single survey, and generally higher in the remaining two surveys. However, considering all three surveys the average cover extent was not substantially lower at the impact sites. Differences remain high however at approximately 14%. This contingency measure is therefore considered relevant for MI01, MI02 and MI05.

5.2 Recommendations

The recommendations provided in Table 10 aim to address proposed contingency measures and to meet performance criteria. As above, sites where substantial differences are considered as likely attributable to environmental factors or natural variations and fluctuations, as discussed in Table 6, Table 7 and Table 8, have not been considered below when identifying sites that should be targeted for the specified recommendations. It should be noted however that due to the proximity of paired impact control sites, and thereby lack of independence, as well of varying land use and management practices at most sites, it is generally not possible to attribute differences in Maundia populations solely to the Project.

Similar findings relating to *Persicaria* dominance at impact sites were discussed in the previous 2016/2017 monitoring report (Niche 2017b). Recommendations made in this report aimed to enhance existing populations by managing the competitive influence of invasive species. The report recommended weed control at the site, specifically hand weeding around Maundia patches, targeting weeds and over abundant native species (such as *Persicaria* spp.).

After considering the recommendation, RMS concluded that *“RMS does not believe that we can effectively undertake hand weeding of the Maundia patches to remove the Persicaria without damaging or impacting on the Maundia. Further, RMS understands that the Persicaria is a native pioneer species that is present upstream of the monitoring locations and would be likely to re-establish should it be removed.”*, and proposed to *“to review the ongoing monitoring before consideration to any actions would be taken.”* This position was also supported by the EPA.

Table 10: Recommendations

Relevant performance indicator or contingency measure	Application	Recommendations
<p>Review drainage (local hydrological patterns)</p> <p>A significant (if statistics are used) or substantial difference (i.e. 15% allowance) between paired monitoring sites with regard to flowering/seeding and overall extent or recruitment that cannot be attributed to environmental factors.</p>	<p>MI01, MI02 and MI05: cover extent was substantially higher at the paired control sites than impact sites during one survey and remained at approximately 14% for all three paired sites when considering the average cover extent for the three surveys.</p> <p>Persicaria was recorded as the dominant species at MI01 and MI02.</p>	<p>Where possible, cattle should be excluded from all sites.</p> <p>If these substantial differences persist after the final monitoring event (2018/2019), consideration should be given to the potential of re-establishing the plant via seed at these sites.</p>
<p>A significant (if statistics are used) or substantial difference (15% allowance) between impact monitoring sites over subsequent monitoring events that cannot be attributed to environmental factors.</p>	<p>MI02: has decreased in cover extent since 2015/2016 while it's paired control site had a comparable increase in cover extent in 2017/2018.</p> <p>MI10: Maundia has not been recorded at the impact site since 2015/2016, while it continues to be recorded at the paired control site.</p>	

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Annex A. 2017/2018 monitoring results

Site		Inspection Date			Maundia present			% Maundia cover average cover in 100 m ²			Water Depth (mm)			% Flowering/ Seeding			Recruitment %			Signs of disturbance			Note		
		Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn
F2E MI01	impact	19/12/2017	21/02/2018	16/04/2018	Y	Y	Y	3.3	0.9	0.6	400	0	350	18.9	0	0	UNK	0	0	Nil	Nil	Nil	Persicaria dominant throughout majority of transect. Water depth = unknown recruitment.	Persicaria dominant.	Persicaria
F2E MC01	control	19/12/2017	21/02/2018	16/04/2018	Y	Y	Y	30.0	9.0	7.8	300	200	250	11.3	0	0	UNK	0	Y	cattle trampling to edge of creek	Cattle	Nil	Main Maundia population was in the centre of the creek (outside of the transect). Water depth = unknown recruitment.		Persicaria
F2E MI02	impact	19/12/2017	23/02/2018	18/04/2018	Y	Y	Y	23.4	12.4	12.9	50	300	200	0.7	1.3	0	UNK	0	Y	Nil	Nil	Nil	Dense growth = recruitment unknown.	Persicaria	Some recruitment evident.

Site		Inspection Date			Maundia present			% Maundia cover average cover in 100 m ²			Water Depth (mm)			% Flowering/ Seeding			Recruitment %			Signs of disturbance			Note		
		Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn
F2E MC02	control	19/12/2017	23/02/2018	18/04/2018	Y	Y	Y	26.6	45.0	19.9	150	400	500	3.2	2.2	0	UNK	Y	Y	Nil	Nil	Nil	Water depth = unknown recruitment.		Water too deep to count recruitment. But it is evident recruitment is occurring.
F2E MI03E	impact	19/12/2017	21/02/2018	16/04/2018	N	N	Y	0	0	0.5	0	0	200	0	0	0	0	0	Y	Cattle tramp ling.	Cattle	Cattle	Very dry.	Very Dry	
F2E MI03 W	impact	20/12/2017	21/02/2018	16/04/2018	Y	Y	Y	2.4	14.5	9.1	0	200	100	1.5	2.9	0	0	1	UNK	Nil	Nil	Nil		Water too deep to count recruitment. But it is evident recruitment is occurring.	
F2E MI04	impact	20/12/2017	21/02/2018	16/04/2018	Y	N	Y	35.2	0	0.1	300	200	300	13.0	0	0	UNK	0	UNK	Nil	Cattle	Cattle	Water depth = unknown recruitment.	Very dry on edges of drainage line. Heavily grazed and disturbed.	Heavily grazed.
F2E MI05	impact	19/12/2017	23/02/2018	18/04/2018	N	N	Y	0	0	0.2	100	200	300	0	0	0	0	0	Y	Nil	Nil	Cattle			







Site		Inspection Date			Maundia present			% Maundia cover average cover in 100 m ²			Water Depth (mm)			% Flowering/ Seeding			Recruitment %			Signs of disturbance			Note								
		Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn						
F2E MC05	control	19/12/2017	23/02/2018	18/04/2018	Y	Y	Y	26.2	4.7	5.4	250	300	300	25.5	0	0	UNK	0	UNK	Nil	Cattle	Nil	Water depth = unknown recruitment.		Water depth too much to count recruitment. But it is evident recruitment is occurring.						
F2E MI06	impact	19/12/2017	22/02/2018	17/04/2018	N	N	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Nil	Cattle	Nil		Dry	Persicaria
F2E MC06	control	19/12/2017	22/02/2018	17/04/2018	N	N	N	0	0	0	0	0	250	0	0	0	0	0	0	Cattle	Cattle	Cattle			Dry	Persicaria					
F2E MI07	impact	19/12/2017	22/02/2018	18/04/2018	N	N	Y	0	0	0.04	100	200	300	0	0	0	0	0	0	Nil	Nil	Nil	Frogmouth (<i>Philydrum lanuginosum</i>) dominant.	Dominated by Frogmouth and Persicaria.	Frogmouth, Persicaria and Baumea dominate.						
F2E MI08	impact	19/12/2017	22/02/2018	16/04/2018	Y	Y	Y	5.4	4.2	0.2	350	400	200	19.8	5.1	0	UNK	0	0	Nil	Nil	Nil	Persicaria dominant throughout majority of transect. Water depth = unknown recruitment.	Persicaria dominant. Lots of Maundia beyond fence line.							







Site		Inspection Date			Maundia present			% Maundia cover average cover in 100 m ²			Water Depth (mm)			% Flowering/ Seeding			Recruitment %			Signs of disturbance			Note		
		Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn
F2E MI09	impact	19/12/2017	22/02/2018	16/04/2018	Y	Y	Y	5.3	1.6	0.2	150	400	200	5.2	1.0	0	UNK	0	Y	Nil	Nil	Nil	Persicaria dominant throughout majority of transect with Maundia growing in open areas. Water depth and dense vegetation = unknown recruitment.	Persicaria dominant.	Persicaria
F2E MI10	impact	19/12/2017	22/02/2018	17/04/2018	N	N	N	0	0	0	0	150	50	0	0	0	0	0	0	Nil	Nil	Nil	Dense vegetation with Persicaria dominant. Open sunny site.	Persicaria dominant.	Persicaria
F2E MC10	control	19/12/2017	22/02/2018	17/04/2018	Y	Y	Y	8.0	3.7	1.8	0	200	150	0	0	0	2.7	UNK	Y	Cattle tramp ling.	Cattle	Cattle	Open ground cover and shaded site.	Persicaria dominant.	Persicaria
R11	reference	20/12/2017	22/02/2018	17/04/2018	Y	Y	Y	19.0	15.9	11.1	0	300	350	0	0	0	1.1	UNK	Y	Nil	Nil	Nil	Very dry.	Water depth = unknown recruitment.	Recruitment evident.







Site		Inspection Date			Maundia present			% Maundia cover average cover in 100 m ²			Water Depth (mm)			% Flowering/ Seeding			Recruitment %			Signs of disturbance			Note		
		Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn	Summer 1	Summer 2	Autumn
R12	reference	20/12/2017	21/02/2017	16/04/2018	Y	Y	Y	4.8	0.3	1.6	300	50	250	0	0	0	UNK	61	UNK	See note	Cattle	Cattle	Water depth = unknown recruitment.. A number of large <i>M. quinquenervia</i> uprooted and fallen into wet area.	Mostly dry. Small plants coming back.	Lots of Maundia present outside transect in deep water.
R14	reference	20/12/2017	21/02/2018	16/04/2018	Y	Y	Y	1.6	0.04	0.2	0	0	300	0	0	0	UNK	0	0	Nil	Nil	Nil	Dense growth = recruitment unknown. Persicaria dominant throughout majority of transect.	Persicaria dominant.	Persicaria

Y = Yes; N = No







Annex B. 2017/2018 Photo Monitoring







Site ID	December 2017	February 2018	April 2018
MI01			
MC01			







Site ID	December 2017	February 2018	April 2018
MI02			
MC02			







Site ID	December 2017	February 2018	April 2018
MI03E			
MI03W			

Site ID	December 2017	February 2018	April 2018
MI04			
MI05			




Site ID	December 2017	February 2018	April 2018
MC05			
MI06			

Site ID	December 2017	February 2018	April 2018
MC06			
MI07			

Site ID	December 2017	February 2018	April 2018
MI08			
MI09			

Site ID	December 2017	February 2018	April 2018
MI10			
MC10			

Site ID	December 2017	February 2018	April 2018
R11			
R12			

Site ID	December 2017	February 2018	April 2018
R14			

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Appendix C Green-thighed Frog Ponds



Green-thighed Frog Monitoring 2017/2018

Habitat Protection and Breeding Ponds

Frederickton to Eungai Pacific Highway Upgrade

Prepared for Roads and Maritime Services

September 2018

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Cover photograph: Green-thighed Frog located at Collombatti Reference Site during 2017 monitoring (Photo: F. Lemckert)

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Executive Summary

Context

This report documents the second round of Green-thighed Frog monitoring undertaken as part of the Frederickton to Eungai Ecological Monitoring Program (EMP, RMS 2016), required for the Frederickton to Eungai (F2E) Pacific Highway Upgrade Project (the Project). The Green-thighed Frog (*Litoria brevipalmata*) was one threatened species identified as requiring mitigation and monitoring throughout the course of the Project's construction and operational period. This report details the second of three monitoring events required at constructed compensatory habitat breeding sites (Green-thighed Frog Breeding Ponds), and the second of two monitoring events at a known and protected breeding site (Habitat Protection – Green-thighed Frog Breeding Sites). The NSW Roads and Maritime Services (Roads and Maritime) is required to manage and monitor the effectiveness of biodiversity mitigation measures implemented as part of the Project. The Habitat Protection – Green-thighed Frog Breeding Sites monitoring occurs at one breeding location (Hills Lane), and Green-thighed Frog Breeding Pond monitoring is to occur at 24 constructed breeding ponds and one area of adjacent habitat (at five sites).

Aims

The aims of this report are to summarise the methods and results of the 2017/2018 monitoring and determine if Green-thighed Frogs are using the purpose-built compensatory breeding habitat and persisting in known breeding habitat, and thus determine whether the Project is meeting the performance indicators for the species. Corrective actions are also to be recommended where required.

Methods

Surveys were undertaken in accordance with the EMP in two stages. Stage 1 surveys focussed on adult frog detection after a sufficient rainfall trigger event, and Stage 2 surveys focussed on tadpole detection (indicating successful breeding). Stage 1 surveys involved a 30 minute nocturnal active search at the Collombatti reference site, at Hills Lane, and at each of the constructed pond sites (24) as well as a peripheral habitat search. Stage 2 surveys involved a 20 minute active search of the ponds and adjacent vegetation and dip-netting of ponds for tadpoles. During Stage 2 surveys, pond depth was recorded, presence of fish and predatory larvae noted, and a photo was taken from a designated reference point.

Key results

At site 3(E&W) excess ponds were constructed on either side of the carriageway due to the original ponds not holding water. From these ponds, five on either side of the carriageway were to be selected for monitoring once their suitability was determined. Of all the constructed ponds, only three ponds on either side of the carriageway have held water into Stage 2 surveys to date and have therefore been identified as suitable for monitoring (3W1, 3W2, 3W3, 3E3, 3E4, 3E5).

Stage 1 surveys were undertaken on the 22 and 23 March 2018, after rainfall that was deemed suitable by the Project Ecologist (24 hour rainfall at sites varied from 70.8-175.2 millimetres; cumulative rainfall over 72 hours varied from 75.8-258.8 millimetres). Stage 2 surveys were undertaken on the 26 and 27 April 2018, 35 days after Stage 1 surveys.

No Green-thighed Frogs or their tadpoles were recorded during Stage 1 or Stage 2 surveys at any of the constructed pond sites, the Hills Lane breeding site or Collombatti reference site. Five of the 20 selected ponds did not retain water for the minimum period specified in the EMP, and additional constructed ponds at Site 3(E&W) were not selected as monitoring ponds to reach the required five ponds on either side of the carriageway as none were found to hold water during Stage 2 surveys.

Conclusions

Performance indicators of success have not been met. Green-thighed Frogs (tadpoles, metamorphs, juveniles or adults) were not detected at the breeding pond sites or Hills Lane breeding site and a number of ponds are not holding water long enough for successful breeding to occur.

Management implications

A number of identified potential problems and contingency measures presented in the EMP (RMS 2016) are considered relevant due to the absence of Green-thighed Frogs from monitoring sites and the constructed ponds not holding water for sufficient period after rain, including the survey of surrounding habitat to determine ongoing presence of the species in the area. Due to these outcomes, it is recommended that Roads and Maritime Services pursue discussions with the EPA to review the adequacy of the mitigation and monitoring program and consider the requirement for corrective actions.

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1. Introduction

1.1 Context

As part of Frederickton to Eungai (F2E) Pacific Highway Upgrade Project (the Project), Roads and Maritime Services (Roads and Maritime) implemented an Ecological Monitoring Program (RMS 2016) (hereafter referred to as the EMP) in accordance with the Minister for Planning's Condition of Approval (MCoA) No. 3.1. The EMP combines the approval conditions provided within the Ministers Conditions of Approval (MCoA) and Statement of Commitments (SoC), and defines the mitigation and offsetting requirements for threatened species and ecological communities impacted by the Project.

The Green-thighed Frog (*Litoria brevipalmata*) was one threatened species identified as requiring mitigation and monitoring throughout the course of the Project's construction and operational periods. Monitoring of this species involves monitoring of both a known breeding site (Habitat Protection – Green-thighed Frog Breeding Sites) and specially constructed breeding ponds (Green-thighed Frog Breeding Ponds).

1.1.1 Legal status

The Green-thighed Frog is listed as vulnerable under the New South Wales *Biodiversity Conservation Act 2016* (BC Act). Monitoring of the species is required under the Project's approval.

1.1.2 Monitoring framework

The EMP states the following regarding monitoring:

- For Habitat Protection – Green-thighed Frog Breeding Sites: *“Monitoring will only be undertaken if construction works extend into the identified known Green-thighed Frog breeding sites”*. This condition was triggered at the Hills Lane breeding site in summer 2015.
- For Green-thighed Frog Breeding Ponds: *“Monitoring will be undertaken on three occasions commencing in 2015 with each event at least 10-12 months apart but ultimately dependant on rainfall.”*

It is noted that the rainfall required to trigger breeding, and therefore survey, did not occur during the specified monitoring period in 2015/2016 (RMS 2017), as such monitoring commenced in summer 2016/2017.

The 2018 monitoring represents the second of two Habitat Protection – Green-thighed Frog Breeding Sites monitoring events and the second of three Green-thighed Frog Breeding Ponds monitoring events. To date, these monitoring events have been undertaken and reported on as follows:

- *Summer (March) 2017*: Niche 2017.
- *Summer (March) 2018*: current report.

This report therefore presents the final results for Habitat Protection – Green-thighed Frog Breeding Sites monitoring. The final Green-thighed Frog Breeding Ponds monitoring event is scheduled to occur after the next suitable rainfall event from spring 2018.

1.1.3 Baseline data

Breeding ponds

The EMP provides the following background data for Green-thighed Frog Breeding Ponds:

“Targeted surveys for the Green-thighed Frog in 2005 are considered the baseline data for this ecological monitoring program (Lewis 2005). These surveys identified Green-thighed Frogs calling in the area of the proposed frog pond locations at:

- *Ch. 22800 where 4-5 males were heard and observed, however, follow up surveys to determine the success of this breeding event found no evidence of tadpoles, metamorphs nor juvenile frogs.*
- *Ch. 26100 where more than a 100 Green-thighed Frogs were recorded with follow up surveys identifying numerous metamorphs and juvenile frogs to confirm a successful breeding event.*
- *Ch. 34000 where male frogs have been recorded during general spotlight surveys and are suspected of breeding nearby (i.e. < 500 m).”*

Breeding sites

In relation to Habitat Protection – Green-thighed Frog Breeding Sites, the EMP refers to a number of suitable breeding sites within and adjacent to the Project. However, monitoring at these sites was to be undertaken only if construction works extended into any of these identified breeding sites. This became relevant for a single site in summer 2015, where back filling of a dam approximately 20-40 meters from the Hills Lane breeding site (Hills Lane drainage line) triggered the need for monitoring of this site. The Hills Lane site was successfully used as a breeding site in 2005 (RMS 2016).

1.1.4 Purpose of this report

This report complies with the monitoring requirements described within the EMP and details the findings obtained from the second of three monitoring events to be completed for the Green-thighed Frog Breeding Ponds and the final monitoring event for Habitat Protection – Green-thighed Frog Breeding Sites.

The aim of this report is to summarise the methods and results of the 2017/2018 monitoring, provide an overall discussion of all monitoring events and determine if performance measures have been met, as per the EMP.

1.2 Performance Measures

Table 1 lists the performance indicators specified in the EMP for the Green-thighed Frog Breeding Ponds (GThF BP) and Habitat Protection – Green-thighed Frog Breeding Sites (HP GThF) monitoring.

Table 1: Performance indicators

	GThF BP	HP GThF
Performance indicators of success		
Continued presence of Green-thighed Frog at Sites 1, 2 and 3 and Hills Lane.	✓	✓
Green-thighed Frogs calling from the edge of the constructed ponds.	✓	
The presence of tadpoles, juveniles or metamorphs during follow up surveys.	✓	✓
Signs of the mitigation being unsuccessful		
Absence of Green-thighed Frogs from the area (GThF BP).	✓	✓
Absence of Green-thighed Frogs from the area that cannot be attributed to environmental factors (HP GThF)		
Ponds not holding water for a sufficient time to enable tadpoles to reach metamorphosis.	✓	
Ponds holding water for too long and representing unsuitable habitat (i.e. permanent versus ephemeral).	✓	

1.3 Monitoring Timing

The EMP specifies that monitoring is to be undertaken on three occasions commencing, at its earliest, in 2015 with each event at least 10-12 months apart but ultimately dependant on rainfall events. One of these monitoring events was to occur during the operational phase of the project (i.e. Year 4/5). Monitoring was only to commence once the vegetation on the edges of the constructed ponds is considered sufficient (>20% groundcover).

The current monitoring took place in March 2018. As per the EMP, the next monitoring event should take place from January 2019.

1.4 Reporting

As per the EMP, annual reporting of monitoring results will include:

- A description of the monitoring methodology employed.
- Results of the monitoring surveys.
- A discussion of the results, including how the results compare against key performance criteria.
- The need for any corrective actions/contingency measures and any general recommendations.

All reports prepared under the EMP will be submitted to the Director General of the NSW Department of Planning and Environment and the NSW Environment Protection Authority (EPA).

1.5 Limitations

The following limitations to the monitoring procedure were encountered:

- A definitive statement as to the fulfilment of performance indicators relating to ponds “*not holding water for a sufficient time*” or “*holding water for too long*” cannot be made for some or all of the ponds, due to surveys requiring Stage 2 surveys to be undertaken 30-50 days after Stage 1 and the requirement for ponds to “*support water for up to 60-80 days*” (Table 3-5 of the EMP). As such, data concerning the presence of water in the ponds after Stage 2 surveys cannot be captured without additional surveys, which are beyond the identified scope.

2. Methods

2.1 Monitoring Sites

Green-thighed Frog Breeding Ponds were established as compensatory habitat within the areas identified in the baseline surveys (RMS 2016). The site locations are shown in Figure 1, with details provided in Table 2. Individual constructed breeding ponds are shown in Figure 2, Figure 3 and Figure 4. The Collombatti site was used as the reference site. It should be noted that the aerial imagery for Site 2 and 3 is from 2014 and therefore the corresponding figures do not show the ponds or their surroundings in their current state.

Table 2: Monitoring sites

Site Name (map ID)	Frog pond sites/breeding sites (EMP)
Collombatti Reference (Ref)	A site near Collombatti School within Tamban State Forest (Easting: 483825 Northing: 6573800) was nominated and retained as the reference site.
1E	Ch. 22800: A total of four ponds were monitored as well as adjacent habitat. Four breeding ponds, as opposed to five, were constructed and monitored due to the availability of natural habitat in the area and to reduce the need for additional clearing. The EMP states: <i>“At this location, an area of retained suitable habitat will be monitored, in addition to the four constructed ponds. This location will be selected during the first monitoring event”</i> . No Green-thighed Frogs have been recorded in adjacent habitat to date, as such the general area will be monitored in future monitoring events and a specific site nominated if and when Green-thighed Frogs are identified.
2E	Ch. 26100: A total of 10 ponds were monitored, five on the eastern side of the carriageway and five on the western side.
2W	
3E	Ch. 34000: A total of 10 ponds were to be monitored, five on the eastern side of the carriageway and five on the western side. To date, only six ponds (three on the eastern side of the carriageway and three on the western side) have been selected for the monitoring program. Excess ponds were constructed on either side of the carriageway due to the original ponds not holding water. From these ponds, five on either side of the carriageway were to be selected for monitoring once their suitability was determined. Of all the constructed ponds, only three ponds on either side of the carriageway have held water into Stage 2 surveys to date and have therefore been identified as suitable for monitoring (3W1, 3W2, 3W3, 3E3, 3E4, 3E5). To identify and select two additional ponds on either side of the carriageway, all additional constructed ponds were also monitored, however no additional ponds were found to be suitable as they did not hold water during Stage 2 surveys. Inspection of all ponds will continue during surveys and should any additional ponds be determined as suitable (based on results) they will be selected as the compensatory breeding ponds to meet the requirement for five ponds on either side of the carriageway.
3W	
Hills Lane	Hills Lane drainage line – triggered by backfilling of adjacent dam.

2.2 Survey Method

The survey method described within the EMP was employed for all surveys (Breeding Ponds and Habitat Protection site) and is provided below.

“Monitoring of the constructed breeding ponds would be undertaken on a rainfall event basis either after:

- *the 24 hr rainfall totals exceed 75 mm, or*
- *a cumulative total of 150 mm over a 72 hour period, or*
- *an alternative rainfall event deemed suitable by the ecologist.*

Rainfall events would be monitored for either one or more of the three weather stations installed by the Contractor and/or the Bureau of Meteorology (BOM) website and specifically the Collombatti location (Station No. 599037). Surveys would be performed using a two stage process outlined below.

a) Stage 1 – Determining Presence and Breeding Activity

Once the rainfall trigger values detailed above occur in the area the reference site would be visited to determine the extent of Green-thighed Frog activity. The constructed ponds and their surrounds would also be surveyed.

The survey would comprise a 30 minute nocturnal active search at each of the breeding pond areas (sites) using a hand held spotlight. Peripheral habitats (i.e. <100 m) would also be surveyed at this time. Upon the completion of Stage 1 surveys the next stage would be implemented.

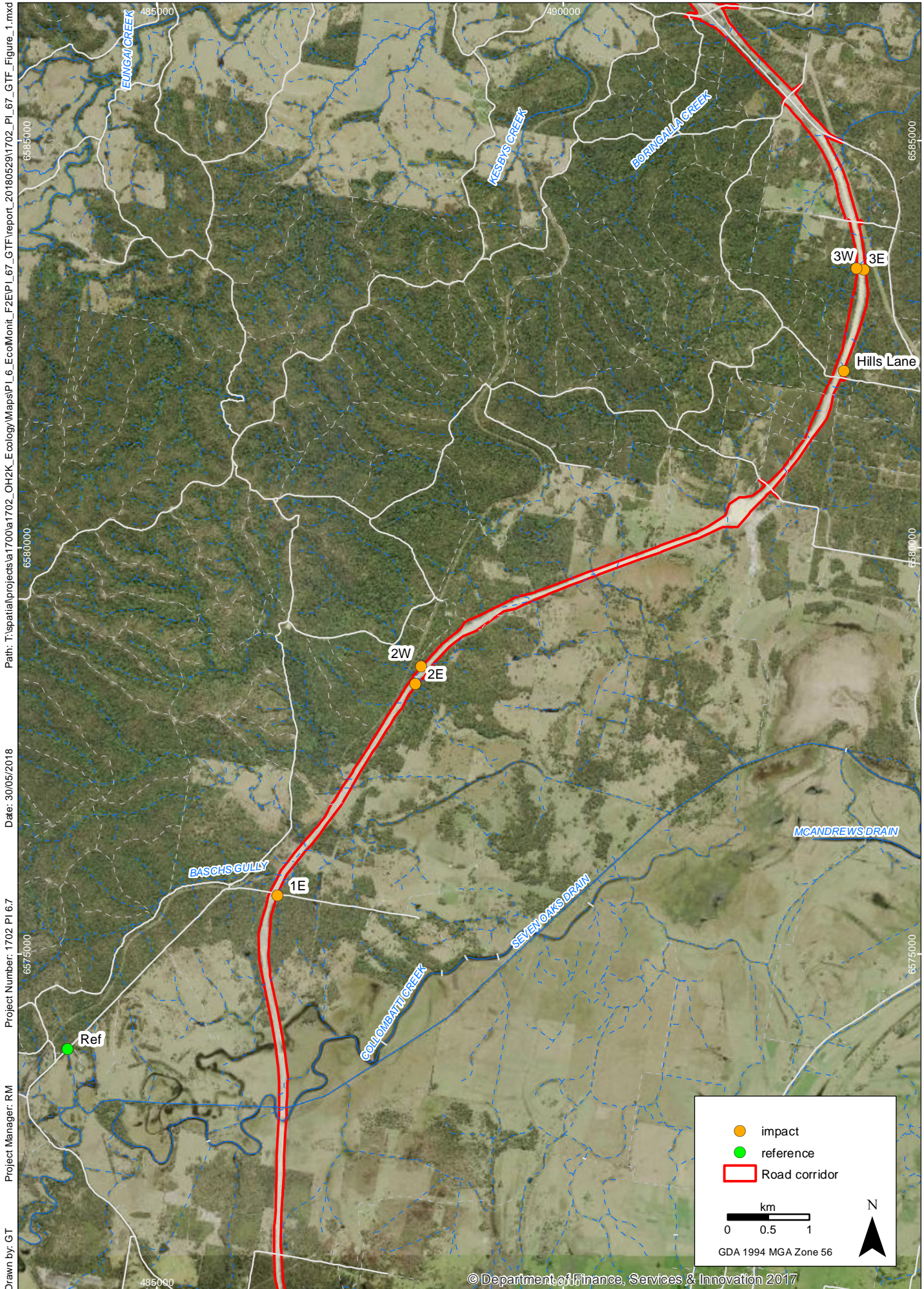
b) Stage 2 – Determining the Success of the Breeding Event

All sites would be subject to follow-up surveys between 30-50 days after the initial census to assess the outcome of the breeding event. This follow up survey will comprise:

- A 20 minute active search for metamorphs and juvenile frogs around the pond edge and vegetation immediately adjacent to the pond (i.e. <10 m).
- Dip-netting of the constructed pond and subsequent tadpole identification. Specific attention will be given toward identifying the presence of fish (both native and exotic) along with predatory invertebrates such as dytiscid beetle adults and larvae.
- The depth of the ponds would be measured from the permanently installed water staff, or alternative method.
- Photo taken from a designated reference point.”

2.3 Analysis

Monitoring results were analysed in accordance with the performance indicators specified within the EMP. In the case of the Green-thighed Frog, performance measures are based on presence/absence results and pond habitat and do not require statistical comparison between survey events.



Green-thighed Frog monitoring sites
Pacific Highway Upgrade Frederickton to Eungai

FIGURE 1

Imagery: (c) LPI 2014-09-18



Path: T:\spatial\projects\1700\1702_OH2K_Ecology\Maps\PI_6_EcolMonit_F2E\PI_67_GTF\report_20180529\1702_PL_67_GTF_Figure_2_Site1.mxd
 Date: 19/09/2018
 Project Number: 1702 PI 6.7
 Project Manager: RM
 Drawn by: GT

Green-thighed Frog Monitoring Site 1E
 Pacific Highway Upgrade Frederickton to Eungai



FIGURE 2
 Imagery: (c) DigitalGlobe 2017-01-31



Path: T:\spatial\projects\1700\1702_OH2K_Ecology\Maps\PI_6_EcolMonit_F2E\PI_67_GTF\report_20180529\1702_PL67_GTF_Figure_3_Site2.mxd
 Date: 19/09/2018
 Project Number: 1702 PI 6.7
 Project Manager: RM
 Drawn by: GT

Source: Esri, DigitalGlobe, GeoEye, CNES/Airbus DS, USDA, USGS, AeroCommunity

Green-thighed Frog Monitoring Site 2E and 2W
 Pacific Highway Upgrade Frederickton to Eungai

FIGURE 3

Imagery: (c) DigitalGlobe 2014-12-16





Path: T:\spatial\projects\1700\1702_OH2K_Ecology\Maps\PI_6_EcolMonit_F2E\PI_L67_GTF\report_20180529\1702_PL67_GTF_Figure_4_Site3.mxd
Date: 19/09/2018
Project Number: 1702 PI 6.7
Project Manager: RM
Drawn by: GT

**Green-thighed Frog Monitoring Site 3E and 3W
Pacific Highway Upgrade Frederickton to Eungai**



FIGURE 4
Imagery: (c) DigitalGlobe 2014-12-16

3. Results

Field data from Stage 1 and Stage 2 monitoring for all sites are provided in Annex 1, and photo monitoring in Annex 2.

3.1 Frog Fence Monitoring

Frog fence monitoring is undertaken as part of the Fauna Underpass and Associated Fauna Fencing Monitoring program for the Project. A number of substantial issues were identified with the neoprene frog fencing. At a number of locations neoprene fences had begun tearing at screw attachment points, joins in the neoprene were not holding (screws coming out or neoprene tearing away) resulting in areas of neoprene fence falling away from the fauna fence completely. These issues will be detailed and discussed within the Fauna Underpass and Associated Fauna Fencing Monitoring report.

Roads and Maritime has subsequently removed the neoprene sheeting and replaced it with vermin-proof mesh, as approved on the Pacific Highway Upgrade between Woolgoolga and Ballina. These frog fence replacement works were completed in November 2018.

3.2 Breeding Ponds Stage 1 – Determining Presence and Breeding Activity

3.2.1 Conditions

Suitable rainfall conditions required to conduct the surveys, as specified within the EMP, did not occur until March 2018. As such, Stage 1 surveys were undertaken on the 22 and 23 March 2018 when the amount of rainfall was deemed suitable by the Project Ecologist. Rainfall at the sites in the previous 24 hours before these surveys ranged from 175 mm to 241 mm (which exceeded the recommended minimum total rainfall within a 24 hour period required to trigger surveys). Air temperatures ranged from 20°C to 21°C.

3.2.2 Nocturnal active searches

No Green-thighed Frogs were heard calling or observed at any pond or at the Collombatti reference site during Stage 1 surveys.

Green-thighed Frog monitoring was undertaken over the same period as part of the Oxley Highway to Kempsey Green-thighed Frog monitoring program (Niche 2018). Green-thighed Frogs were detected on the first night of the Stage 1 surveys at Site 3W of the Kundabung to Kempsey (Ku2K) section of the Oxley Highway to Kempsey Pacific Highway Upgrade. This site was revisited on the second night to ensure continued activity. Green-thighed Frogs were still active at this site on the second survey night.

Nine other frog species were either heard calling or observed at the Collombatti reference site, Site 1E, Site 2(E&W) and Site 3(E&W). Other species identified include the Great Barred Frog (*Mixophyes fasciolatus*), Striped Marsh Frog (*Limnodynastes peronii*), Whirring Tree Frog (*Litoria revelata*), Green Tree Frog (*Litoria caerulea*), Emerald Spotted Tree Frog (*Litoria Peronii*), Tyler's Tree Frog (*Litoria tyleri*), Graceful Tree Frog (*Litoria gracilentia*), Common Froglet (*Crinia signifera*) and Eastern Dwarf Tree Frog (*Litoria fallax*).

3.2.3 Pond depth at Stage 1

Pond depth varied greatly between ponds and the Collombatti reference site due to the volume of rain received and subsequent flooding of some sites. The Collombatti reference site was flooded and water depth was variable with depths greater than 100 centimetres. Site 1E ponds contained 50 to 100 centimetres of water, Site 2(E&W) contained 20 to 50 centimetres of water and Site 3(E&W) recorded depths from 5 to 50 centimetres of water. Table 3 provides the Stage 1 and Stage 2 water levels in the constructed ponds.

3.2.4 Vegetation structure and other observations

Ponds at Sites 2W, 3E and 3W were more exposed (little to no canopy cover) and quite distant from surrounding habitat. While the surrounding habitat at Site 1E was determined to be suitable Green-thighed Frog habitat, the vegetation immediately surrounding the ponds consisted of dense invasive grass species. It is possible that invasive grass species present at many ponds is too dense and possibly not suitable for Green-thighed Frogs, a species that requires leaf litter for foraging (OEH 2018) and a more open low ground vegetation (Hero *et al.* 2004) such as ferns and mat rushes. Photo of each of the sites is provided in Annex 2.

3.3 Breeding Ponds Stage 2 – Determining the Success of the Breeding Event

Stage 2 surveys were undertaken on the 26 and 27 April 2018, 35 days after the Stage 1 surveys.

3.3.1 Active searches and dip-netting

A number of tadpoles were caught at the Collombatti reference site, Site 1E (ponds 1, 2 and 3), Site 2W (ponds 2 and 3), Site 2E (ponds 3 and 4), and Site 3E (ponds 3 and 4). No tadpoles were identified as Green-thighed Frog tadpoles. The tadpoles were identified as either Eastern Dwarf Tree Frog, Striped Marsh Frog or *Crinia* spp. No tadpoles were captured at Hills Lane.

3.3.2 Predatory fish and invertebrates

A number of predatory invertebrates were identified to be present at the Collombatti reference site, Hills Lane breeding site, Site 1E, Site 2E and Site 3E. These included *Gambusia* (*Gambusia holbrooki*), dragonfly nymph, damselfly, beetles, yabbies, Firetail Gudgeon (*Hypseleotris gali*) and beetle larvae. Predator presence is summarised as follows:

- Site 1E: all four constructed ponds had both predatory fish and invertebrates.
- Site 2W: no predators recorded.
- Site 2E: two of five ponds with one predator type.
- Site 3W: no predators detected (ponds dry).
- Site 3E: two ponds of three holding water had at least one predatory invertebrate and no predatory fish.

3.3.3 Pond depth at Stage 2

Table 3 provides the Stage 1 and Stage 2 water levels in the constructed ponds. According to the EMP (Table 3-5) ponds should have a maximum depth of 400 mm and hold water for up to 60-80 days. Stage 2 surveys were undertaken 35 days after Stage 1 surveys.

Water levels during Stage 2 surveys were as follows:

- Collombatti reference site: 30 - 40 centimetres deep.
- Site 1E: all four constructed ponds held water (28 - 30 centimetres deep).
- Site 2E: all five constructed ponds held water (11 - 34 centimetres deep).
- Site 2W: four of the five constructed ponds held water (2 - 26 centimetres deep).
- Site 3E: all three selected constructed ponds held water (20 - 30 centimetres deep). All additional constructed ponds were dry.
- Site 3W: all three selected constructed ponds were dry. All additional constructed ponds were dry.

Minimum water retention period – 60 days

Four ponds were dry (three at Site 3W and one at Site 2W) and one contained only two centimetres of water (Site 2W, therefore considered likely to dry prior to 60 days) at Stage 2 surveys. Stage 2 surveys were undertaken 35 days after Stage 1 surveys. Therefore at least five of the 24 ponds did not retain water for the minimum period required for successful breeding of the Green-thighed Frog. For the remaining ponds that contained water during Stage 2 surveys, survey timing precludes a definitive statement as to whether or not ponds still contained water at 60 or 80 days.

It should be noted that Stage 2 water levels were likely impacted by rainfall immediately prior to surveys. Kempsey Weather Station recorded 20 millimetres of rainfall over 24 hours on the 25 April, the day prior to Stage 2 surveys.

Maximum water retention period

Given that Stage 2 surveys were undertaken 35 days after Stage 1 surveys it is not possible to state the duration of water retention in the ponds. In addition, as water retention is dependent not only on pond permeability but on weather conditions and local rainfall, it is difficult to draw conclusions regarding the likelihood of ponds to dry. Research has shown that an extended hydroperiod is unlikely to impact the breeding of this species, as long as the pond is ephemeral (Lemckert *et al.* 2006, and Lemckert *pers. comm.*). Therefore, water retention within ponds somewhat beyond the preferred hydroperiod is not considered as important to the survival of this species as the retention of water for long enough to allow for metamorphosis.

Table 3: Pond water retention

Site	Site condition	Pond	Stage 1 water depth (cm)	Stage 2 water depth (cm) at 35 days	Minimum water retention (60 to 80 days)
1E	Moderately exposed with surrounding sclerophyll forest.	1	50-100	30	Unknown
		2	50-100	25	Unknown
		3	50-100	30	Unknown
		4	50-100	28	Unknown
		5- adjacent habitat	50-100	0-5	Not applicable
2W	Sunny exposed. Vegetation adjacent to west.	1	20-40	2	Considered unsuccessful
		2	20-40	26	Unknown
		3	20-40	13	Unknown
		4	20-40	0	No
		5	20-40	21	Unknown
2E	Moderately exposed with surrounding shrub growth.	1	50	22	Unknown
		2	50	11	Unknown
		3	50	34	Unknown
		4	50	32	Unknown
		5	50	30	Unknown
3W	Sunny exposed. Vegetation adjacent to west.	1	10-20	0	No
		2	10-20	0	No
		3	10-20	0	No
3E	Sunny exposed. Vegetation adjacent to east.	3	40-50	27	Unknown
		4	40-50	30	Unknown
		5	40-50	20	Unknown

3.4 Breeding Ponds Cumulative Results

Summary results of the two monitoring events conducted to date are provided in Table 4. Green-thighed Frogs have not been detected during either monitoring period at any of the constructed breeding ponds. All ponds at Site 3W (including non-selected constructed ponds) are considered to have shown insufficient water retention in both monitoring periods and two of the 2W ponds have shown insufficient water retention in both monitoring periods. Water retention post-survey cannot be definitively determined due to the fact that the ponds are not re-visited after the Stage 2 surveys (at between 30 and 50 days).

Table 4: Cumulative monitoring results (bold = did not meet minimum water retention period)

Site (pond)	2016/2017			2017/2018		
	# GTF	#GTF Tadpoles	Met minimum water retention period (60 days)? (checked at 43 days)	# GTF	#GTF Tadpoles	Met minimum water retention period (60 days)? (checked at 35 days)
Ref	1	0		0	0	
1E(1)	0	0	Unknown	0	0	Unknown
1E(2)	0	0	Unknown	0	0	Unknown
1E(3)	0	0	No	0	0	Unknown
1E(4)	0	0	No	0	0	Unknown
2W(1)	0	0	No	0	0	No
2W(2)	0	0	Unknown	0	0	Unknown
2W(3)	0	0	Unknown	0	0	Unknown
2W(4)	0	0	No	0	0	No
2W(5)	0	0	No	0	0	Unknown
2E(1)	nm	nm	nm	0	0	Unknown
2E(2)	nm	nm	nm	0	0	Unknown
2E(3)	nm	nm	nm	0	0	Unknown
2E(4)	nm	nm	nm	0	0	Unknown
2E(5)	nm	nm	nm	0	0	Unknown
3W(1)	0	0	No	0	0	No
3W(2)	0	0	No	0	0	No
3W(3)	0	0	No	0	0	No
3E(3)	0	0	No	0	0	Unknown
3E(4)	0	0	Unknown	0	0	Unknown
3E(5)	0	0	Unknown	0	0	Unknown

Unknown = water present during Stage 2 but unknown if retained to 60 days due to survey limitations; No = pond dry at Stage 2 survey ; nm = not monitored as ponds not complete.

3.5 Habitat Protection - Hills Lane Stage 1 – Determining Presence and Breeding Activity

Stage 1 monitoring at Hills Lane was undertaken on the 23 March 2018, at the same time as the Green-thighed Frog breeding pond monitoring. Hills Lane Stage 1 monitoring involved surveying the drainage line (HL1) to the south of the road and a general survey of the habitat further (approximately 30 – 50 metres) into Tamban state Forest (HL2) where areas of suitable habitat were identified by the Project Ecologist.

No Green-thighed Frogs were observed or heard calling from the habitat at Hills Lane. No other frog species were observed or heard calling.

3.6 Habitat Protection - Hills Lane Stage 2 - Determining the Success of the Breeding Event

Stage 2 surveys were undertaken on the 27 April 2018, 35 days after Stage 1 surveys. HL1 was dry during Stage 2 surveys and HL2 held 40 centimetres of water. No tadpoles of any species were captured in HL2, however both predatory fish and invertebrates were recorded in HL2, including Gambusia, Firetail Gudgeon and yabbies.

3.7 Habitat Protection - Hills Lane Cumulative Results

No Green-thighed Frogs have been recorded during either monitoring event at the Hills Lane breeding site. A number of other frog species were heard calling or observed during the 2017 monitoring, including the Whirring Tree Frog calling, Common Froglet, Red-backed Toadlets (*Pseudophryne coriacea*), Striped Marsh Frog and Great Barred Frog, however no other frog species were recorded during the 2018 monitoring. HL1 was dry in both monitoring events and HL2 held approximately 40 centimetres of water in both monitoring events.

4. Discussion

4.1 Performance Measures

A discussion of the 2018 monitoring results in relation to the performance measures detailed in the EMP is provided in Table 5 and Table 6.

Table 5: Performance indicators of success

Performance indicators of success	GThF BP*	HP GThF*
Continued presence of Green-thighed Frog at Sites 1, 2 and 3 and Hills Lane breeding site.	This performance indicator has not been met. Green-thighed Frogs were not observed at any of the sites.	
Green-thighed Frogs calling from the edge of the constructed ponds.	This performance indicator has not been met. Green-thighed Frogs were not heard calling at any of the sites containing constructed ponds.	NA
The presence of tadpoles, juveniles or metamorphs during follow up surveys.	This performance indicator has not been met. Green-thighed Frog tadpoles, juveniles or metamorphs were not observed during follow up surveys.	

* GThF BP = Green-thighed Frog Breeding Ponds; HP GThF = Habitat Protection - Green-thighed Frog Breeding Sites; NA = not applicable

Table 6: Signs of the mitigation being unsuccessful

Performance indicators of unsuccessful mitigation	GThF BP*	HP GThF*
Absence of Green-thighed Frogs from the area.	This indicator of unsuccessful mitigation has been met. Green-thighed frogs were not detected in the area of constructed ponds.	NA
Absence of Green-thighed Frogs from the area that cannot be attributed to environmental factors.	NA	This indicator of unsuccessful mitigation has not been met. While a high rainfall event occurred in December 2017 which may have been sufficient to initiate Green-thighed Frog activity and breeding, Stage 1 surveys were not undertaken at that time as the amount of rainfall did not meet the trigger requirements as set out in the EMP. Given the inherent variability in breeding and temporal distribution of this species it is not possible to conclude that the absence of records is due to the backfilling of an adjacent dam in 2015 as, prior to 2017, monitoring had not been undertaken since 2005.
Ponds not holding water for a sufficient time to enable tadpoles to reach metamorphosis.	This indicator of unsuccessful mitigation has been met for three ponds at Site 3W and two ponds at Site 2W, and all other non-selected constructed ponds at Site 3(E&W). According to the EMP ponds should have a maximum depth of 400 millimetres and hold water for up to 60-80 days. Four ponds were dry and one contained only two centimetres of water (therefore considered likely to dry prior to 60 days) at Stage 2 surveys undertaken 35 days after Stage 1 surveys.	NA

Performance indicators of unsuccessful mitigation	GThF BP*	HP GThF*
Ponds holding water for too long and representing unsuitable habitat (i.e. permanent versus ephemeral).	<p>This performance indicator of unsuccessful mitigation cannot be assessed due to survey limitations.</p> <p>Given that Stage 2 surveys were undertaken 35 days after Stage 1 surveys it is not possible to comment on the permanent versus ephemeral nature of the ponds.</p>	NA

*GThF BP = Green-thighed Frog Breeding Ponds; HP GThF = Habitat Protection - Green-thighed Frog Breeding Sites, NA = not applicable

5. Recommendations

5.1 Contingency Measures

The EMP lists potential problems and contingency measures for various components of the monitoring program. Those that are considered to be relevant to the Green-thighed Frog monitoring program are listed and discussed in Table 7.

Table 7: Contingency Measures

Potential Problem	Contingency Measure proposed in EMP	Discussion of proposed measure
Habitat Protection – Green-thighed Frog Breeding Sites (Hills Lane)		
Lack of communication between construction staff leading to damage or removal of known breeding site	Review the CEMP and site induction procedures	This contingency measure is not considered relevant.
Habitat not used by Green-thighed Frog	Survey adjacent areas to confirm frogs remain in the area	Green-thighed Frogs were not recorded at the Hills Lane site. This contingency measure is considered relevant.
Green-thighed Frog Breeding Ponds		
Ponds not used by Green-thighed frog	Survey adjacent areas to confirm frogs remain in area. Review/modify ponds to improve potential site suitability problems	Green-thighed Frogs were not recorded at the constructed ponds. This contingency measure is considered relevant.
Ponds not holding water long enough to enable breeding to succeed	Review/modify ponds either by placing a semi permeable layer or further excavation	Five of the 20 constructed ponds selected for monitoring were dry during Stage 2 surveys. Additional suitable constructed ponds at Site 3(E&W) have not been identified and selected as all additional ponds were dry during Stage 2 surveys. This contingency measure is considered relevant.
Ponds holding water for too long encouraging competition from non-target frog fauna	Improve drainage	This problem cannot be assessed due to survey limitations. However, research has shown that an extended hydroperiod is unlikely to impact the breeding of this species, as long as the pond is ephemeral. The relevance of this contingency measure cannot be determined.
Exotic fish species recorded in breeding ponds	Modify pond to ensure it dries out	Exotic fish species were detected in constructed ponds at site 1E (all ponds) and 2E (pond 4). This contingency measure is considered relevant.

5.2 Recommendations

5.2.1 Breeding ponds

Green-thighed Frogs have not been recorded at the constructed breeding ponds during monitoring periods where they were recorded at either the Collombatti reference site (2016/2017) or a Ku2K constructed breeding pond (2017/2018). Due to these outcomes, it is recommended that the Roads and Maritime pursue discussions with the EPA to determine appropriate measures for continued monitoring and any corrective actions needed. Table 8 summarises the performance measures that have not been met to date and suggests possible corrective actions.

Table 8: Signs of the mitigation being unsuccessful and corrective actions

Problem encountered	Proposed contingency measure (EMP)	Corrective actions
Absence of Green-thighed Frogs from the area.	Survey adjacent areas to confirm frogs remain in area. Review/modify ponds to improve potential site suitability problems.	Applies to: all sites Consider additional surveys in habitat that is adjacent to monitoring sites and that is deemed suitable (by the Project Ecologist) for Green-thighed Frogs to assist in determining the continued presence and activity of the Green-thighed Frog in the general area. Consider reviewing vegetation structure in and around ponds and undertaking necessary clearing/replanting upon the advice of a Green-thighed Frog specialist.
Ponds not holding water for a sufficient time to enable tadpoles to reach metamorphosis.	The corrective action for this would involve a review and if deemed necessary, modification of the ponds by placing a semi permeable layer or further excavation.	Applies to: Site 2W(1 and 4), all ponds at Site 3W and non-selected ponds at Site 3E Consider laying a semi-permeable layer to improve water retention. Consider increasing the depth of the ponds. Consider increasing pond vegetation to improve shading.

5.2.2 Habitat protection – Hills Lane

Successful breeding of the Green-thighed Frog was recorded in 2005 where metamorphs were identified within the Hills Lane area (RMS 2016). This site was triggered for monitoring due to backfilling of an adjacent dam in summer 2015.

Monitoring of this area undertaken in March 2017 and March 2018 did not record Green-thighed Frog activity and the drainage line adjacent to Hills Lane has been found to be dry during Stage 2 surveys during both monitoring events. Niche 2017 stated that it was possible that the absence of Green-thighed Frogs from this area during the 2017 surveys may have been attributable to environmental factors as the identification of a single non-calling Green-thighed Frog at the Collombatti reference site four days earlier indicates that it is possible that superfluous rainfall during and around the time of the 2017 surveys may have provided opportunity for breeding at other times. In 2018, heavy rainfall commenced on 21 March and continued until 24 March and in the two months prior to these dates rainfall (recorded at Kempsey AP station # 59007) was minimal. A heavy rainfall event (64 millimetres in 24 hours) at the end of December 2017 did not trigger the EMP minimum rainfall (>75 millimetres in 24 hours) but may have been sufficient to initiate a breeding event (Frank Lemckert *pers. comm.*).

Prior to 2017, Green-thighed Frog activity at the site has not been monitored since 2005 (RMS 2016). As such it is not possible to conclude that the lack of records of Green-thighed Frogs from the Hills Lane site is directly due to the backfilling of the adjacent dam that occurred in summer 2015.

To determine the ongoing presence of this species in the Hills Lane area a more detailed assessment is required. As recommended for the constructed breeding ponds, consideration should be given to additional surveys of the site and surrounding habitat as well as a review of the vegetation within the drainage line and adjacent habitat. It is recommended that the Roads and Maritime pursue discussions with the EPA to determine appropriate measures for continued monitoring and any corrective actions needed.

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Annex 1. 2017/2018 Results

Table 9: Stage 1 Results

Site	Date	Time	GTF Observed	GTF Calling	Other species	Rainfall mm (24hrs)	Air Temp	Humidity	Wind	Cloud Cover %	Water Depth (cm)
Reference	23/03/2018	7:22:00 PM	0	0	Whirring Tree Frog, Striped Marsh Frog, Great Barred Frog, Green tree Frog, Clicking Froglet, Emerald-spotted Tree Frog	241	21	82	0	80	> 100
Hills Lane	23/03/2018	11:00:00 PM	0	0		175	20	82	0	100	40-80
1	23/03/2018	8:20:00 PM	0	0	Eastern Sedge Frog, Clicking Froglet, Tyler's Tree Frog, Graceful Tree Frog, <i>Uperoleia</i> sp.	241	20	80	0	30	50-100
2W	22/03/2018	11:30:00 PM	0	0	Striped Marsh Frog, Common Froglet, Whirring Tree frog, Great Barred Frog, Graceful Tree frog,	175	21	80	1	100	20-40
2E	23/03/2018	12:00:00 AM	0	0	Whirring Tree Frog, Great Barred Frog, Common Froglet	175	20	80	0	100	50
3W	22/03/2018	12:00:00 AM	0	0	Common Froglet, Graceful Tree Frog	175	21	80	0	100	10-30
3E	23/03/2018	10:00:00 PM	0	0	Whirring Tree Frog, Striped Marsh Frog, Common Froglet, Eastern Dwarf Tree Frog	175	20	80	0	100	5-50
















Table 10: Stage 2 Results

Site	Pond	Water Depth (cm)	Site Photo	Pond Photo	No. GTF (juv)	No. of tadpoles caught	Tadpoles identified	Presence of Fish	Predatory Invertebrates
Reference	Collombatti	30-40	2293		0	50	Striped Marsh Frog, Dainty Green Tree Frog & Whirring Tree Frog	Yes - Gambusia	Beetle larvae
Hills Lane	HL1 (beside road)	0	2236		0	0		Nil	Nil
	HL2 (Tambar State Forest)	40	2237		0	0		Yes- Gambusia and Firetail Gudgeon	Yabbies
1	1	30	2295	2294	0	1	Striped Marsh Frog	Gambusia	Water Beetle
	2	25		2296	0	1	Striped Marsh Frog	Gambusia and Firetail Gudgeon	Dragonfly nymph. Yabbies
	3	30		2297	0	2	Striped Marsh Frog, small unknown	Firetail Gudgeon	Yabbies
	4	28	2299	2298	0	0		Gambusia	Yabbies
	Adjacent habitat	0		2331	0	0		Nil	Nil
	Pond in adjacent habitat	5		2330	0	0		Nil	Nil
	Adjacent habitat across road	2			0	0		Nil	Nil
2W	1	2	2303	2304	0	0		Nil	Nil

2W	2	26		2305	0	30+	Eastern Dwarf Tree Frog, unknown small species.	Nil	Nil
2W	3	13		2306	0	30-40	Unknown species with strong pattern.	Nil	Nil
2W	4	0		2307	0	0		Nil	Nil
2W	5	21	2317	2308	0	0		Nil	Nil
2E	1	22	2309	2310	0	0		Nil	Nil
2E	2	11		2311	0	0		Nil	Nil
2E	3	34		2312	0	10	<i>Crinia</i> sp.	Nil	Beetle
2E	4	32		2313	0	5	Small brown tadpole	Gambusia	Nil
2E	5	30	2315	2314	0	0		Nil	Nil
3W	1	0	2319	2318	0	0		Nil	Nil
3W	2	0		2320	0	0		Nil	Nil
3W	3	0	2322	2321	0	0		Nil	Nil
3W	7 Ponds further south	All dry 0	2335		0	0		Nil	Nil
3E	Ponds further south	0	2334, 2329	2328	0	0		Nil	Nil
3E	3	27	2323	2324	0	1	Unk species with strong pattern.	Nil	Dragonfly nymph.
3E	4	30		2325	0	4	Small unknown species - heavily patterned. Larger unknown species.	Nil	Spiders, Damselfly
3E	5	20	2327	2326	0	0		Nil	Nil

Annex 2. Photo Monitoring

Table 11: Individual pond photo monitoring

Site	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5
1E 2017					
1E 2018					
2W 2017					

<p>2W 2018</p>					
<p>2E 2018</p>					
<p>3W 2017</p>				<p>Suitable pond not available</p>	<p>Suitable pond not available</p>



















<p>3W 2018</p>				<p>Suitable pond not available</p>	<p>Suitable pond not available</p>
<p>3E 2017</p>	<p>Suitable pond not available</p>	<p>Suitable pond not available</p>			
<p>3E 2018</p>	<p>Suitable pond not available</p>	<p>Suitable pond not available</p>			

Table 12: Site Photo Monitoring

Site ID	2017	2018
Collombatti Reference		
Site 1		
Site 2W		
Site 2E	NA	

<p>Site 3W</p>		
<p>Site 3(1-2)E</p>		
<p>Site 3(3-5)E</p>		
<p>Hills Lane (HL2)</p>		

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Appendix D Aerial Crossing Structures



Aerial Crossing Monitoring 2018

Frederickton to Eungai Pacific Highway Upgrade

Prepared for Roads and Maritime Services

February 2019

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Cover photograph: Common Brushtail Possum Site 3 (left), Yellow-bellied Glider Site 2 eastern glider pole (middle), Sugar Glider Site 3 (right).

Executive summary

Context

This report documents the 2018 monitoring period, the second of three monitoring cycles for the aerial crossing structures, as required by the Frederickton to Eungai (F2E) Ecological Monitoring Program (EMP, RMS 2016). The NSW Roads and Maritime Services (Roads and Maritime) is required to manage and monitor the effectiveness of biodiversity mitigation measures implemented as part of the Project.

Aims

The aim of this report is to summarise the methods and results of the autumn and spring 2018 monitoring and determine if performance measures have been met, as per the EMP.

Methods

In accordance with the EMP, each of the three aerial crossing zones was monitored in autumn and spring of 2018. Monitoring involved the use of automated cameras for a period of 60 consecutive days and arboreal tree trapping (20 traps at each zone) was undertaken in residual habitat adjacent to each crossing zone (10 traps either side of the carriageway) over four consecutive nights in autumn and spring.

Key results

- Remote cameras detected three glider species using the aerial crossings; the Feathertail Glider, Sugar Glider and the threatened Yellow-bellied Glider.
- Gliders were detected on the median glider poles at two sites, indicating complete crossings at Sites 2 and 3.
- Arboreal mammals including the Sugar Glider, Feathertail Glider and Brushtail Possum were recorded on all three canopy rope crossings.
- Complete crossings were not detected on canopy rope crossings.
- Two species of native fauna were captured during arboreal tree trapping, the Common Brushtail Possum and Brown Antechinus. Two Common Brushtail Possums were PIT tagged however there were no recaptures of tagged individuals.
- There were no records of road kill glider species from the 2017/2018 road kill monitoring results.

Conclusions

Glider poles: As gliders have been recorded using both eastern and western poles and the median poles at all sites on at least one occasion it is considered that indicators of success in relation to successful complete crossings of the glider poles by glider species have been met, despite the absence of recapture data and quick succession records. Neither sign of unsuccessful mitigation has been met for the glider crossings as gliders have been detected on all median poles and gliders have not been recorded as road kill.

Rope bridges: While arboreal fauna have been recorded on the canopy rope bridges at all sites, successful complete crossings have not been confirmed using remote cameras or recaptures during arboreal trapping. As such, indicators of success have not been met for canopy rope bridges. However, the majority of fauna detected using the canopy rope bridges were glider species. As gliders may arrive and depart from the rope bridge at an undefined point, they may do so without triggering the second camera.

Management implications

Recommendations have been made in relation to contingency measures provided within the EMP to address unsuccessful performance indicators. Notably, consideration should be given to downloading photographic data on a more regular basis in an effort to capture additional crossings that may occur outside of the 60 day monitoring period, and a review of the vegetation status immediately adjacent to the crossing poles should be considered, with the aim of determining if additional lead/lure ropes from neighbouring trees to the rope ladder canopy bridges would improve fauna access to the rope ladder, notably for small scansorial species.

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1. Introduction

1.1 Context

As part of the Frederickton to Eungai (F2E) Pacific Highway Upgrade Project (the Project), Roads and Maritime Services (Roads and Maritime) have implemented an Ecological Monitoring Program in accordance with the Minister for Planning’s Condition of Approval (MCoA) No. 3.1. This Ecological Monitoring Program (RMS 2016) (hereafter referred to as the EMP) combines the approval conditions provided within the Ministers Conditions of Approval (MCoA) and Statement of Commitments (SoC), and defines the mitigation and offsetting requirements for threatened species and ecological communities impacted by the Project.

Aerial crossings have been installed to reduce the impacts on fauna, facilitate movement and maintain connectivity for existing glider/arboreal mammal populations (RMS 2016). These structures are to be monitored to assess their effectiveness.

1.1.1 Monitoring framework

The EMP states the following regarding monitoring:

“It is proposed that monitoring of the glider crossings be undertaken in order to provide long term insights into the mitigation effectiveness once the carriageway becomes operational. With this in mind, monitoring would commence 6 months after the structures have been installed and focus on a 4 week sampling period in autumn and spring in 2017, 2018, and 2019, after which the need for further monitoring would be reviewed in consultation with EPA”.

To date, these monitoring events have been undertaken and reported on as follows:

- *Autumn and spring 2017: Aerial Crossing Monitoring 2017 (Niche 2018a)*
- *Autumn and spring 2018: Aerial Crossing Monitoring 2018 (current report).*

The 2018 monitoring therefore represents the second of three monitoring cycles required by the EMP for aerial crossing monitoring. The final monitoring period (2019) is scheduled to commence in autumn 2019 and will consist of two monitoring events (autumn 2019 and spring 2019), after which the need for ongoing monitoring will be discussed based on the outcomes of all monitoring events.

1.1.2 Baseline data

The EMP provides the following background information:

“Table A3 provides results of surveys in the vicinity of the three nominated aerial crossing locations. Yellow-bellied Glider has been recorded at or near each of the three crossing locations as have Brush-tailed Phascogale and other common arboreal fauna including Common Brushtail Possum, Sugar Gliders and Feathertail Glider”.

Table A3 is provided in the original EMP (Lewis 2013) and presents the results of systematic surveys for the Kempsey to Eungai Environmental Assessment (Lewis 2005).

1.1.3 Purpose of this report

This report complies with the monitoring requirements described within the approved EMP and details the findings of the second monitoring event.

The aims of this report are to summarise the methods and results of the autumn and spring 2018 monitoring and determine if performance measures have been met, as per the EMP.

1.2 Performance Measures

The EMP specifies the performance indicators for the aerial crossing structures as follows:

Indicators of success for the glider poles would include one or more of the following:

- *Evidence of use by any glider species using the median pole.*
- *Photographic evidence of a glider using both the eastern and western poles.*
- *One or more gliders with left ear tag/notch occurring on the western side of the carriageway and fauna with right ear tag/notch occurring on the eastern side of the carriageway.*

Signs of the glider poles being unsuccessful will be based on the:

- *Absence of gliders being recorded using the median pole or other evidence of complete crossings.*
- *Unacceptable levels of road strike (presence of deceased individuals during each sampling period for either year). For example, recording one or more gliders as road strike in both monitoring seasons would be considered as unsuccessful and require contingency measures.*

Indicators of success for the rope canopy bridges would include on or more of the following:

- *Photographic evidence of any arboreal species using both sides of the rope ladder to indicate a successful passage.*
- *One or more arboreal species with left ear tag/notch occurring on the western side of the carriageway and arboreal fauna with right ear tag/notch occurring on the eastern side of the carriageway.*

Signs of the canopy rope bridges being unsuccessful will be based on the:

- *No photographic evidence of arboreal fauna successfully crossing the rope bridge or other evidence of complete crossings (i.e. ear tags, notches).*
- *Unacceptable levels of road strike (presence of deceased individuals during each sampling period for either year). For example, recording one or more gliders as road strike in both the winter and spring would be considered as unsuccessful and require contingency measures.*

Note, PIT tagging of captured animals was used in place of ear notching as an alternative (and ethically more sound) approach to identifying individual animals during the mark-recapture component of the monitoring. This change in methodology was undertaken in consultation with Roads and Maritime and the NSW Environment Protection Authority (EPA).

1.3 Monitoring Timing

As per the EMP, monitoring will be undertaken in autumn and spring of 2017, 2018 and 2019.

1.4 Reporting

As per the EMP, annual reporting of monitoring results is to include:

- A description of the monitoring methodology employed
- Results, including field data, of the monitoring surveys
- A discussion of the results, including how the results compare against key performance criteria
- General recommendations including the need for any corrective actions/contingency measures. .

All reports prepared under the EMP will be submitted to the Director General of the NSW Department of Planning and Environment and the NSW Environment Protection Authority (EPA).

1.5 Limitations

The following limitations to the monitoring procedure were encountered:

- The camera detection system is designed to maximise the likelihood that any animal using the structures is photographed, i.e. the cameras are fitted with motion detectors triggered to take photographs as animals pass by and the glider poles also have collars to force the animals through a single gap where the camera is trained. However, the highly mobile nature of gliders may result in their arrival on the structures at a variety of locations, all of which cannot be captured by the cameras. As a result complete passage across the structure/road may not always be captured. This limitation applies to both glider poles and rope bridges.

2. Survey Methods

2.1 Survey Sites

Three aerial crossing zones (hereafter Sites 1- 3) are specified in the EMP. Site 1 and 2 each have a single canopy rope bridge and a set of glider poles consisting of a pole on each opposing road verge and a single median pole. Site 3 has a single canopy rope bridge and a single glider pole crossing, consisting of two median poles and one road verge pole (east), due to existing suitable trees to glide from/to on the opposing road verge. The location of each crossing structure is provided in Figure 1.

2.2 Survey Method

2.2.1 Remote cameras

Automated cameras were installed at the top of each crossing structure pole. A single camera was installed on each glider pole and a single camera was installed at each end of the canopy rope bridge. Customised surveillance systems were installed at glider crossings and canopy rope bridges using BuckEye Cam X7D Covert IR wireless surveillance cameras (minimum response time 200 milliseconds) and standard antennae. Cameras were mounted on a customised adjustable camera mount or strut. Power is provided via a solar panel and extension power cable connected to a battery housing near ground level, which is mounted on each pole. Each glider pole was fitted with a collar to direct animals toward the camera in order to capture their image. Rope bridges were fitted with an external dual active infra-red sensor to trigger cameras. All cameras were calibrated for short focus and reduced infrared output to maximise species identification. These devices were specifically designed by Faunatech Pty Ltd for these crossing structures. Images were downloaded wirelessly to ground level via X-Manager software installed on a laptop.

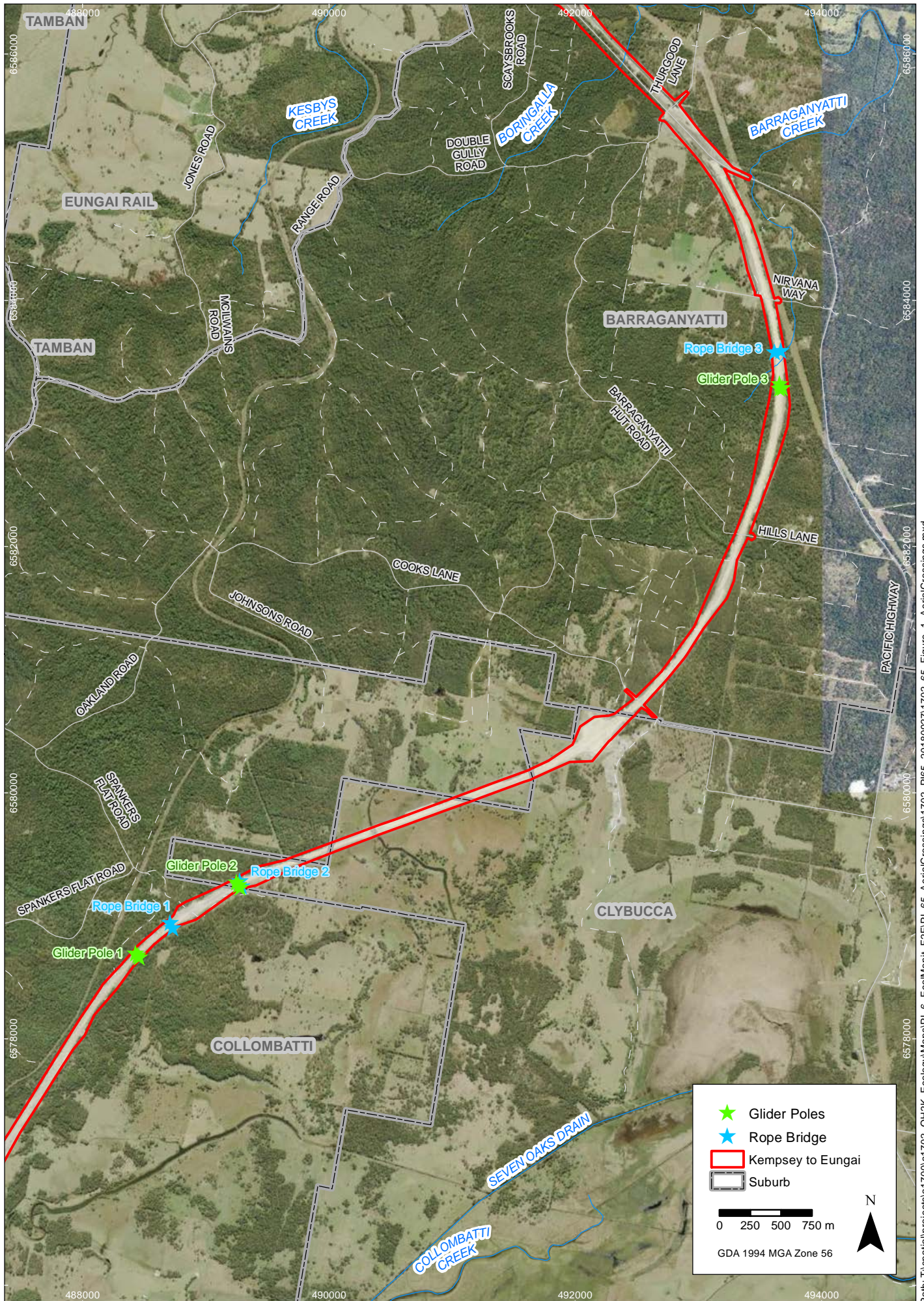
2.2.2 Arboreal trapping

Trapping was undertaken in residual habitat adjacent to the crossing zones over four nights. A total of 20 traps were deployed at each crossing zone; 10 traps were placed on either side of the carriageway and grouped around the crossing structure poles (i.e. the 10 traps were distributed between the canopy rope bridges and glider pole crossings where these structures were not immediately adjacent to each other). Figure 2 to Figure 4 show the trap locations. A range of arboreal trap types were used including pipe, Elliott and cage traps (Table 1). Details recorded of captured individuals included species, weight, gestation and sex where possible. Larger species that were captured (i.e. any arboreal marsupial greater than 100 grams in weight) were implanted with a passive integrated transponder (PIT) microchip to allow for individual identification. As mentioned previously, this was used in place of ear notching to allow identification of individual animals. Traps were baited with a mixture of rolled oats and peanut butter and positioned on brackets two metres above the ground. The host tree was sprayed with a mixture of honey water above and below the trap as an additional attractant. The traps were left operating over four consecutive nights. Traps were checked within two hours of sunrise each morning, re-baited and re-sprayed with honey water.

Table 1: Trapping effort 2018

Trap type	Site 1		Site 2		Site 3	
	Autumn	Spring	Autumn	Spring	Autumn	Spring
Elliott B	7	6	6	6	6	6
Cage	4	4	4	4	4	4
Pipe	9	10	10	10	10	10

Drawn by: RJ Project Manager: CMcE Project Number: 1702 6.5 Date: 28/09/2018



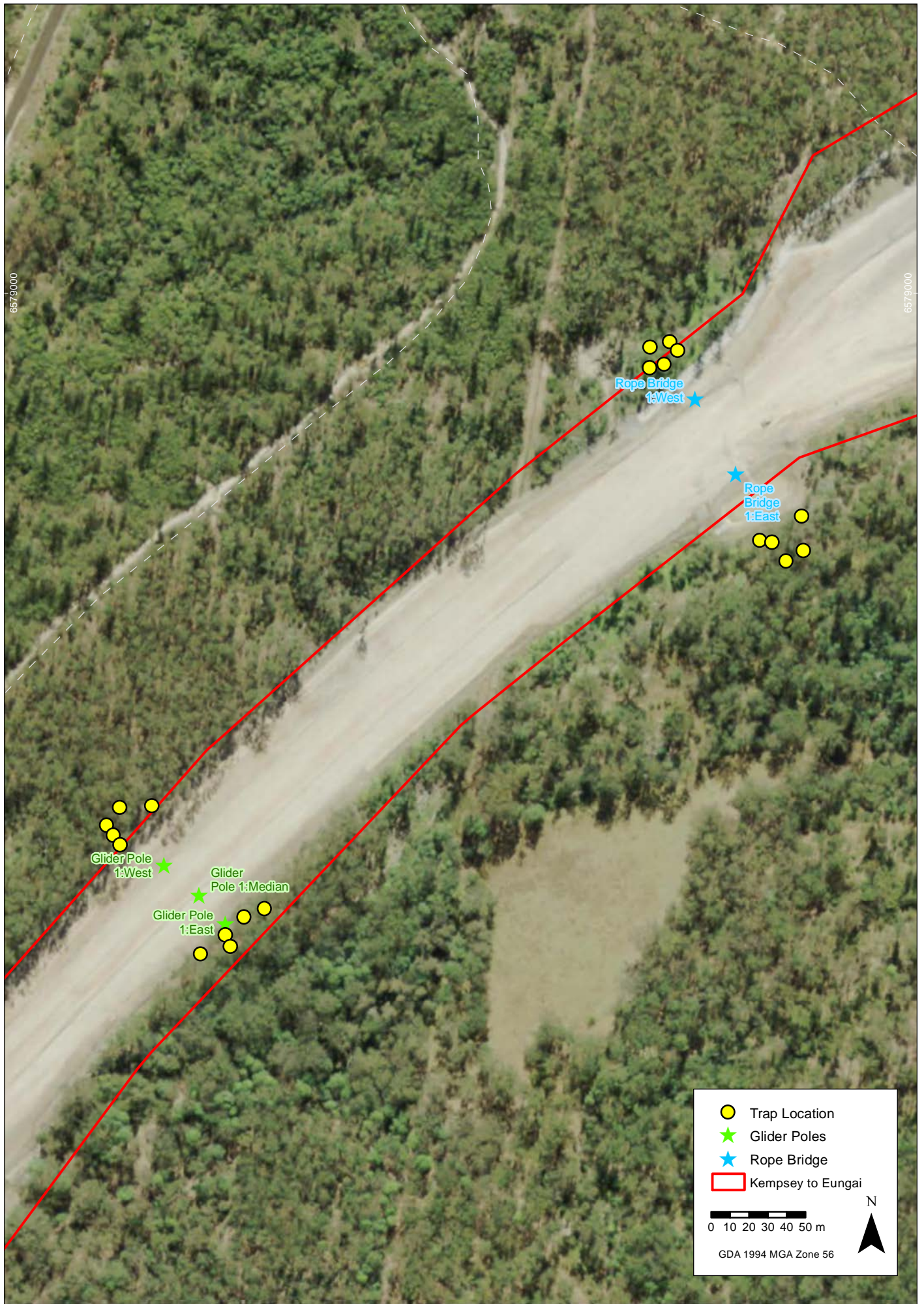
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Location of Aerial Crossings
Frederickton to Eungai Pacific Highway Upgrade

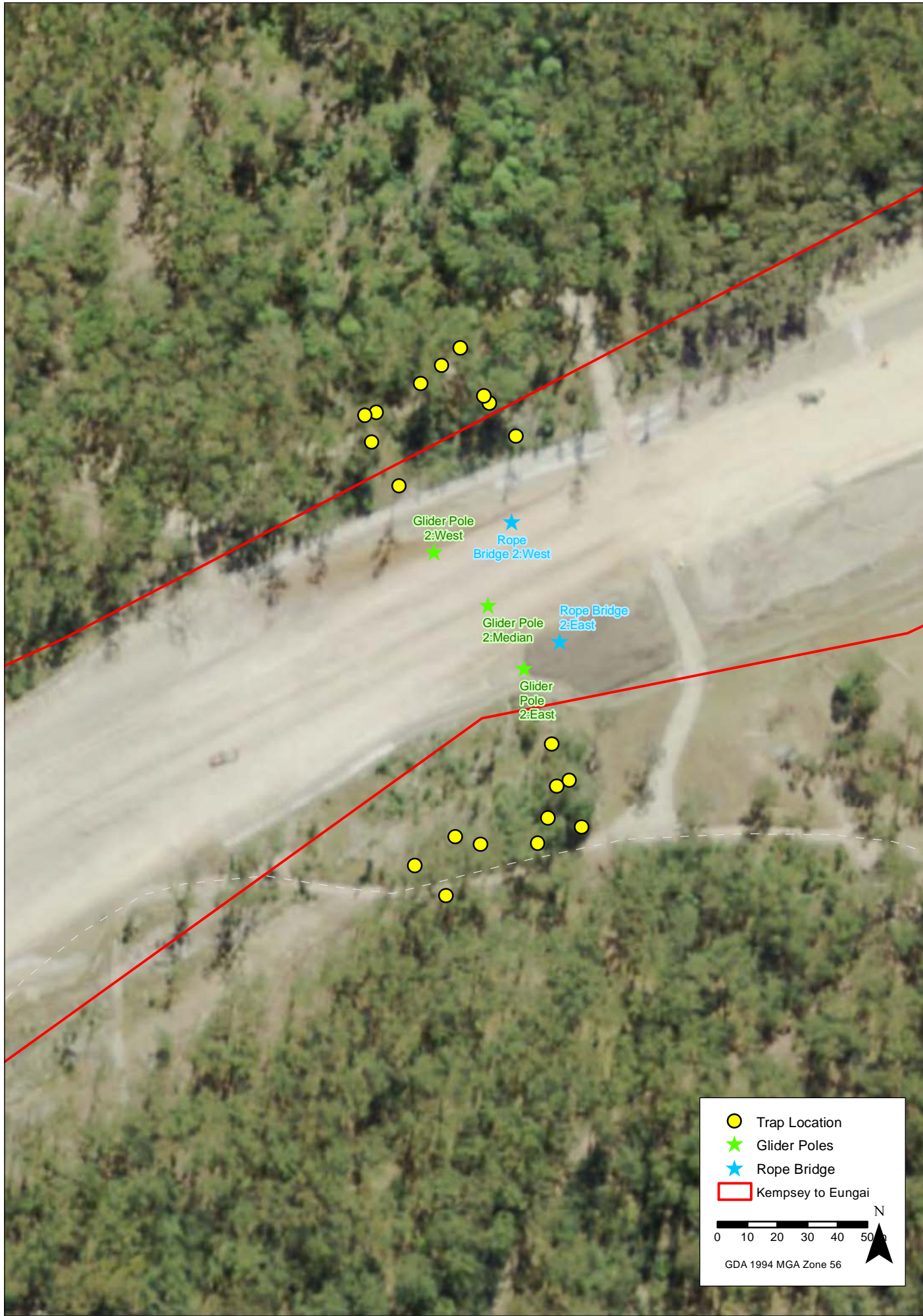
FIGURE 1





Imagery: (c) LPI 2014-09-18

Drawn by: MH Project Manager: CMcE Project Number: 1702 6.5 Date: 2/20/2019



Path: T:\spatial\projects\1700\1702_OH2K_Ecology\Maps\PI_6_EcolMonit_F2E\PI_65_AerialCrossings\1702_P165_20180927\1702_P165_Figures_234_TrappingZones_123.mxd



-  Trap Location
-  Glider Poles
-  Rope Bridge
-  Kempsey to Eungai

0 10 20 30 40 50 m

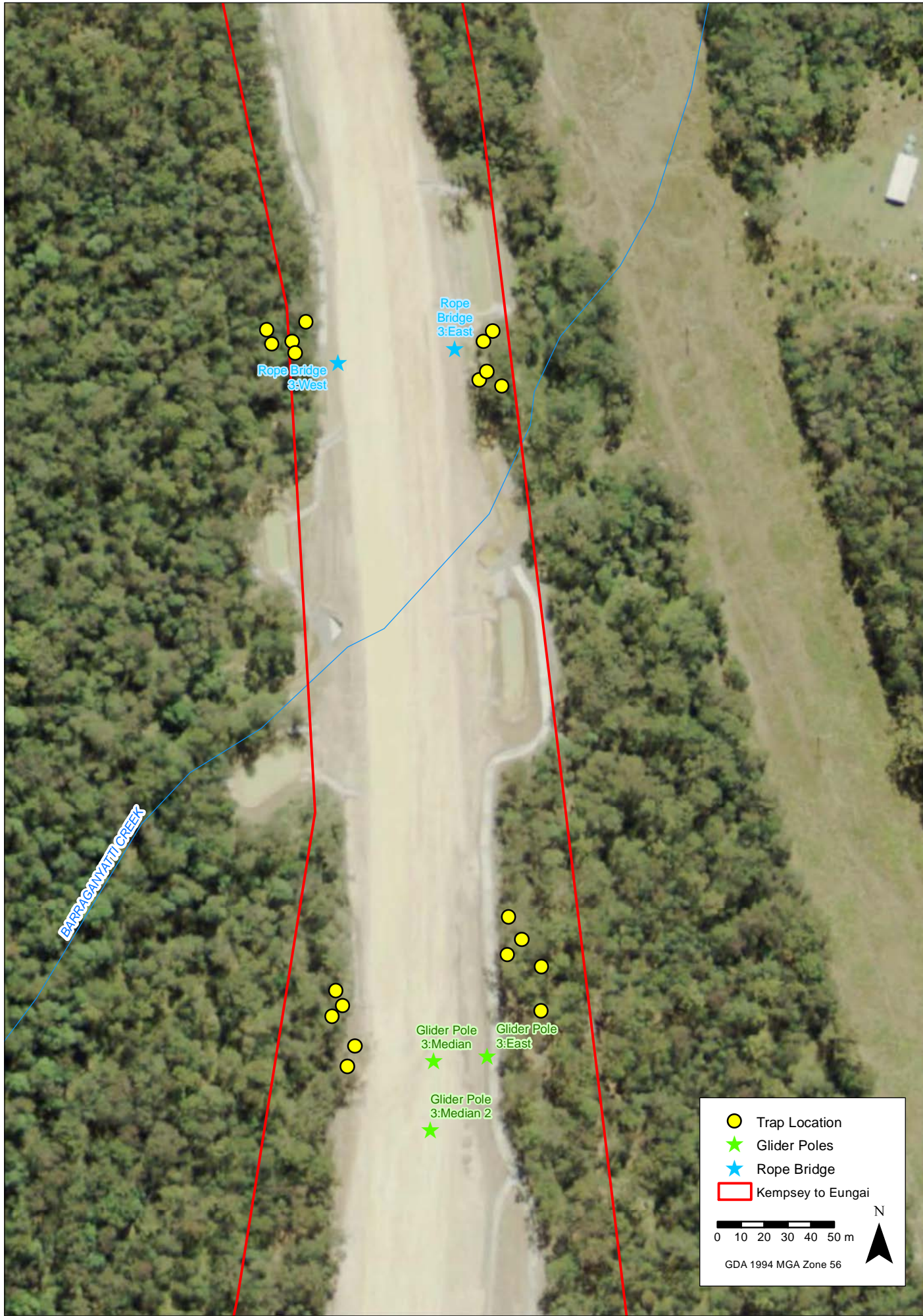
GDA 1994 MGA Zone 56

N

Site 2 trap location
Frederickton to Eungai Pacific Highway Upgrade

FIGURE 3

Imagery: (c) LPI 2014-09-18



3. Results

Detailed survey results for the 2018 autumn and spring monitoring are presented in Annex 1 and Annex 2.

3.1 Remote Cameras

Combined results from autumn and spring for the glider crossings and canopy rope bridges are presented in Table 2 and Table 3 respectively. A summary of results for each site is provided in Table 4, Table 5 and Table 6.

The sixty day monitoring periods were 8 March - 7 May 2018 (autumn) and 13 September – 12 November 2018 (spring). However, as data downloading did not occur immediately at the end of these periods, additional data was available. Fauna records obtained after the nominated 60 day survey period were included in the results as they are considered as value adding data. Median pole 2 at Site 3 glider crossing was not functioning at the commencement of the spring survey period. Photos are therefore not available for this pole in spring 2018.

3.1.1 Glider crossings

A successful crossing is considered to have occurred if an individual animal is detected using the median pole. Photographic data was also analysed for the detection of the same species in rapid succession on both the western and eastern road verge poles at Sites 1 and 2 as an indication of a successful crossing.

In some cases, it was not possible to definitively distinguish between the threatened Squirrel Glider (*Petaurus norfolcensis*) and the Sugar Glider (*Petaurus breviceps*) due to partial or blurred images. Glider images where a Squirrel Glider identification was considered possible but not definite, are referred to as Sugar/Squirrel Glider records. Sugar Gliders and Sugar/Squirrel Gliders were recorded at all three sites, but were noted as using the median glider poles at Site 2 (eight occasions) and Site 3 (three occasions). The Feathertail Glider (*Acrobates pygmaeus*) was observed frequently using the road verge poles at all sites but and was detected on the median poles at Site 2 and 3 only. The threatened Yellow-bellied Glider (*Petaurus australis*) was detected on the eastern pole at Site 2. The results of the glider pole use by various glider species is summarised below.

Site 1

- Glider species were not detected using the median pole.
- Glider species were detected using the east and west road verge poles.
- There were no quick succession records on the east and west road verge poles.

Site 2

- Glider species were detected using the median pole.
- Glider species were detected using the east and west road verge poles.
- There were no quick succession records on the east and west road verge poles.
- The threatened Yellow-bellied Glider was detected on the eastern road verge pole.

Site 3

- Glider species were detected using only median pole 1.
- Median pole 2 camera was not functioning during the spring survey period.
- Glider species were detected using the eastern verge pole (no western pole).

Table 2: Fauna use of glider crossings during autumn and spring 2018.

Species	Site 1			Site 2			Site 3		
	Eastern	Median	Western	Eastern	Median	Western	Eastern	Median	Median2
Feathertail Glider			✓ (12)		✓ (4)	✓ (10)	✓ (36)	✓ (20)	
Sugar Glider	✓ (1)		✓ (2)	✓ (1)	✓ (3)				
Sugar/Squirrel Glider	✓ (1)				✓ (5)	✓ (5)	✓ (1)	✓ (3)	
Yellow-bellied Glider				✓ (1)					
Unknown mammal					✓ (1)				

(n) = number of separate occasion the species was detected.

3.1.2 Canopy rope bridges

As for the glider crossings, photographic data was analysed for the detection of the same species in rapid succession at both the western and eastern ends of the crossing as an indication of a successful crossing.

Three arboreal mammal species, the Sugar Glider, Feathertail Glider and Brushtail Possum (*Trichorurus* spp.), were detected using the canopy rope bridges. The Feathertail Glider frequented rope bridges on the western side at all three sites and the eastern side at Site 3. Photographic time stamps did not indicate a complete crossing at any site. As gliders may arrive and depart from the rope bridge at an undefined point, they may do so without triggering the second camera. The results of the canopy rope bridge use by arboreal species is summarised below.

Site 1

- No arboreal species were detected at **both** eastern and western ends of the rope bridge.
- There were no quick succession records at the eastern and western ends of the rope bridge.
- Only Feathertail Gliders were detected at the western end.

Site 2

- No arboreal species were detected at **both** eastern and western ends of the rope bridge.
- There were no quick succession records at the eastern and western ends of the rope bridge.
- Sugar and Feathertail Gliders were detected at the western end.

Site 3

- Feathertail Gliders were detected at **both** eastern and western ends of the rope bridge.
- There were no quick succession records at the eastern and western ends of the rope bridge.
- Sugar Gliders and Brushtail Possums were detected at the eastern end.

Table 3: Fauna use of rope canopy bridges during autumn and spring 2018.

Species	Site 1		Site 2		Site 3	
	Eastern	Western	Eastern	Western	Eastern	Western
Feathertail Glider		✓ (27)		✓ (29)	✓ (15)	✓ (13)
Sugar Glider				✓ (1)	✓ (2)	
Brush-tail Possum					✓ (2)	
Australian Magpie (<i>Gymnorhina tibicen</i>)			✓ (1)	✓ (1)		
<i>Corvus</i> spp.	✓ (7)	✓ (1)		✓ (1)		
Laughing Kookaburra (<i>Dacelo novaeguineae</i>)				✓ (5)		

(n) = number of separate occasions the species was detected.

3.1.3 Site summary

Table 4, Table 5 and Table 6 provide a summary of the records from each site for autumn and spring 2018. Sugar and Feathertail Gliders were recorded in both autumn and spring surveys at all sites, while Brush-tail Possums were recorded during autumn only and the Yellow-bellied Glider during spring. Detection frequency between the canopy rope bridges and glider crossings was variable across all sites.

Table 4: Site 1 remote camera records 2018

Camera	Autumn	Spring	Detection frequency (mammals)
GP1 East	Sugar/Squirrel Glider (1)	Feathertail Glider (1) Sugar Glider (1)	3
GP1 Med	No animals	No animals	0
GP1 West	Sugar Glider (2) Feathertail Glider (2)	Feathertail Glider (9)	15
RB1 East	<i>Corvus</i> spp. (6)	<i>Corvus</i> sp. (1)	0
RB1 West	No animals	<i>Corvus</i> sp. (1) Feathertail Glider (32)	27

Table 5: Site 2 remote camera records 2018

Camera	Autumn	Spring	Detection frequency (mammals)
GP2 East	No animals	Yellow-bellied Glider (1) Sugar Glider (1)	2
GP2 Med	Sugar/Squirrel Glider (5) Feathertail Glider (4) Unknown Mammal (1)	Sugar Glider (3)	13
GP2 West	Sugar/Squirrel Glider (4) Feathertail Glider (4)	Feathertail Glider (6) Sugar/Squirrel glider (1)	15
RB2 East	Magpie (1)	No animals	0
RB2 West	<i>Corvus</i> spp. (Ravens) (1) Magpie (1) Sugar Glider (1)	Small bird (1) Kookaburra (4) Feathertail Glider (29)	30

Table 6: Site 3 remote camera records 2018

Camera	Autumn	Spring	Detection frequency (mammals)
GP3 East	Feathertail Glider (24) Sugar/ Squirrel Glider (1)	Feathertail Glider (10)	34
GP3 Med	Feathertail Glider (17) Sugar/ Squirrel Glider (3)	Feathertail Glider (3)	23
GP3 Med2	No fauna	Camera malfunction	0
RB3 East	Brushtail Possum (2)	Feathertail Glider (15) Sugar Glider (2)	19
RB3 West	No fauna	Feathertail Glider (13)	13

3.2 Arboreal Trapping

Arboreal trapping survey periods were as follows:

- *Autumn 2018*: 19 – 23 March
- *Spring 2018*: 17 – 21 September.

Two species were captured in arboreal traps during autumn and spring monitoring, including the Common Brushtail Possum (*Trichosurus vulpecula*) and Brown Antechinus (*Antechinus stuartii*).

Four Common Brushtail Possums were captured at four separate sites: Site 1 (RB1) east, Site 2 west, Site 3 (RB3) east and (GP3) west. The individuals captured at RB1 and RB3 were implanted with PIT tags. There were no recaptures to indicate successful road crossings by any of these individuals. Trapping results are provided in Annex 2.

3.3 Road Kill

Road kill monitoring results are presented in the Frederickton to Eungai Fauna Underpass and Associated Fauna Fencing Monitoring report 2017/2018 (Niche 2018b). While road strike monitoring was not part of aerial crossings monitoring, the EMP requires specific reporting on the presence of road strike gliders at or in vicinity of aerial crossings. Data presented within Niche 2018b did not show any records of glider species from the 2017/2018 road kill results.

3.4 Cumulative Analysis

3.4.1 Glider poles

To date, the outcome of the glider pole use by various glider species is provided in Table 7 and is summarised as follows:

Site 1

- A Sugar Glider species has been detected using the median pole on one occasion.
- Glider species have been detected using the east and west road verge poles.
- There have been no quick succession records on the east and west road verge poles.

Site 2

- Glider species have been detected using the median pole.
- Glider species have been detected using the east and west road verge poles.
- There has been a single occurrence of quick succession records on the east and west road verge poles in 2017 by a Feathertail Glider (Niche 2018a).
- The threatened Yellow-bellied Glider and Brush-tailed Phascogale (*Phascogale tapoatafa*) have been recorded on the eastern pole.

Site 3

- Glider species have been detected using both median poles, however median pole 2 has a much lower detection frequency and no fauna were recorded in 2018.
- Glider species have been detected using the eastern verge pole (no western pole).

Site 3 median pole 2 has a lower detection frequency than median pole 1 and did not record use in autumn 2018 and was not functioning in spring 2018. This is noteworthy considering the relatively higher frequency with which the adjacent median pole and road verge pole have been used. The efficacy of Site 3 median pole 2 should be again considered in 2019 and consideration given to its location/distance from adjacent vegetation.

Table 7: Cumulative glider pole records

Species	Site 1			Site 2			Site 3		
	Eastern	Median	Western	Eastern	Median	Western	Eastern	Median	Median2
Feathertail Glider	✓ (4)		✓ (20)	✓ (7)	✓ (7)	✓ (18)	✓ (57)	✓ (21)	✓ (5)
Sugar Glider	✓ (1)	✓ (1)	✓ (4)	✓ (2)	✓ (4)	✓ (1)			
Sugar/Squirrel Glider	✓ (1)				✓ (5)	✓ (5)	✓ (1)	✓ (3)	
Yellow-bellied Glider			✓ (1)	✓ (1)					
Unknown mammal			✓ (1)	✓ (2)	✓ (1)			✓ (1)	
Brush-tailed Phascogale				✓ (1)					

3.4.2 Canopy rope bridges

To date, the outcome of the canopy rope bridge use by arboreal species is provided in Table 8 and is summarised as follows:

Site 1

- No arboreal species have been detected at **both** the eastern and western ends of the rope bridge.
- There have been no quick succession records at the eastern and western ends of the rope bridge.
- Only Feathertail Gliders have been detected at the western end.

Site 2

- No arboreal species have been detected at **both** the eastern and western ends of the rope bridge.
- There have been no quick succession records at the eastern and western ends of the rope bridge.
- Sugar and Feathertail Gliders have been detected at the western end.

Site 3

- Sugar and Feathertail Gliders have been detected at **both** the eastern and western ends of the rope bridge.
- There have been no quick succession records at the eastern and western ends of the rope bridge.
- Brushtail Possums have been detected at the eastern end.

Table 8: Cumulative canopy rope bridge records

Species	Site 1		Site 2		Site 3	
	Eastern	Western	Eastern	Western	Eastern	Western
Feathertail Glider		✓ (27)		✓ (29)	✓ (17)	✓ (17)
Sugar Glider				✓ (1)	✓ (2)	✓ (2)
Brushtail Possum					✓ (2)	
Australian Magpie			✓ (1)	✓ (1)		
<i>Corvus</i> spp.	✓ (55)	✓ (18)	✓ (17)	✓ (54)		
Laughing Kookaburra				✓ (6)		
Small Bird				✓ (1)		

3.5 Comparison with Baseline Data

Baseline surveys in adjacent bushland detected a number of arboreal and scansorial mammal species near some or all aerial crossing locations, including: Brush-tailed Phascogale, Yellow-bellied Glider, Sugar Glider, Greater Glider (*Petauroides volans*), Feathertail Glider, Common Ringtail Possum (*Pseudocheirus peregrinus*), Common Brushtail Possum, Mountain Brushtail Possum (*Trichosurus cunninghami*), Bush Rat (*Rattus fuscipes*), and Brown Antechinus.

Of these 10 species, four (the Yellow-bellied Glider, Sugar Glider, Feathertail Glider and Brushtail Possum) have been observed using the aerial crossing structures and another two (the Brown Antechinus and Brush-tailed Phascogale) have been recorded in the vicinity of the crossings. Three of the four glider species previously recorded (with the exception of the Greater Glider) have been detected on the glider crossings and canopy rope bridges.

4. Discussion

4.1 Performance Measures

A summary of the autumn and spring 2018 survey results and the cumulative results in relation to the performance indicators is provided in Table 9 to Table 12.

Table 9: Indicators of success for the glider poles

Indicators of success	Discussion
Evidence of use by any glider species using the median pole.	This performance indicator of success has been met for all sites. The median glider poles at Sites 2 and 3 (one pole) were used by at least one glider species in 2017 and 2018. The median pole at Site 1 has a single record of use that occurred in 2017.
Photographic evidence of a glider using both the eastern and western poles.	This performance indicator of success has been met at Site 2. While gliders have been detected on the eastern and western poles at Sites 1 and 2 and on the eastern pole at Site 3 in 2017 and 2018, photographic evidence showing use of both poles in a complete crossing is limited to a single occurrence at Site 2 in 2017 by a Feathertail Glider (Niche 2018a).
One or more gliders with left ear tag/notch occurring on the western side of the carriageway and fauna with right ear tag/notch occurring on the eastern side of the carriageway.	This performance indicator of success has not been met. Implantation of PIT microchips was implemented (in consultation with RMS and the EPA) as an alternative method to ear notching to identify individual animals. There have been no captures of individually marked animals on both sides of the road.

Table 10: Signs of the glider poles being unsuccessful

Signs of the glider poles being unsuccessful	Discussion
Absence of gliders being recorded using the median pole or other evidence of complete crossings.	This sign of unsuccessful mitigation has not been met. The median glider poles at Sites 2 and 3 (one pole) were used by at least one glider species in 2017 and 2018. The median pole at Site 1 has a single record of use that occurred in 2017.
Unacceptable levels of road strike (presence of deceased individuals during each sampling period for either year). For example, recording one or more gliders as road strike in both monitoring seasons would be considered as unsuccessful and require contingency measures.	This sign of unsuccessful mitigation has not been met. There have been no records of road kill glider species from the road kill monitoring results to date.

Table 11: Indicators of success for the canopy rope bridges

Indicators of success	Discussion
Photographic evidence of any arboreal species using both sides of the rope ladder to indicate a successful passage.	This performance indicator of success has not been met. No individual has been recorded using both sides of a crossing in rapid succession.
One or more arboreal species with left ear tag/notch occurring on the western side of the carriageway and arboreal fauna with right ear tag/notch occurring on the eastern side of the carriageway.	This performance indicator of success has not been met. Implantation of PIT microchips was implemented (in consultation with RMS and the EPA) as an alternative method to ear notching to identify individual animals. There were no captures of individually marked animals on both sides of the road.

Table 12: Signs of the rope bridges being unsuccessful

Signs of the rope bridges being unsuccessful	Discussion
No photographic evidence of arboreal fauna successfully crossing the rope bridge or other evidence of complete crossings (i.e. ear tags, notches).	<p>This sign of unsuccessful mitigation has been met. No individual has been recorded using both sides of a crossing in rapid succession.</p>
Unacceptable levels of road strike (presence of deceased individuals during each sampling period for either year). For example, recording one or more gliders as road strike in both the winter and spring would be considered as unsuccessful and require contingency measures.	<p>This sign of unsuccessful mitigation has not been met. There have been no records of road kill glider species from the road kill monitoring results to date.</p>

5. Recommendations

5.1 Contingency Measures

The EMP lists potential problems and contingency measures for various components of the monitoring program. Those that are considered to be relevant to the aerial crossing monitoring program are listed and discussed in Table 13.

Table 13: Contingency measures

Potential problem	Contingency measure proposed in EMP	Discussion of proposed measure
No fauna recorded using the poles or rope ladder canopy bridges	<ul style="list-style-type: none"> Review other monitoring data. Review planting schedules/status of vegetation bordering the poles and/or rope ladder canopy bridges. 	<p>A range of fauna have been detected on the crossing structures.</p> <p>Use of the median pole of glider crossings is considered to represent a successful crossing, despite the absence of recapture data and quick succession records. These contingency measures are therefore not considered relevant for glider pole crossings.</p>
No evidence or marked/tagged gliders crossing the carriageway.	<ul style="list-style-type: none"> Review monitoring program and make necessary adjustments. Consider placing lead/lure ropes from neighbouring trees to the poles and/or rope ladder canopy bridges. 	<p>Successful crossings of canopy rope bridges have not been confirmed. However, the majority of fauna detected using the canopy rope bridges are glider species. As gliders may arrive and depart from the rope bridge at an undefined point, they may do so without triggering the second camera.</p> <p>The absence of scansorial fauna and few records of non-gliding arboreal mammals is however noted.</p> <p>These contingency measures are therefore considered relevant for canopy rope bridges.</p>
Unacceptable levels of road strike for gliders (>1 during each monitoring event for Year 1, Year 2, Year 3)	<ul style="list-style-type: none"> Review current information of glider pole plane angles. Consider design adjustment that could improve the usability of the poles and/or rope ladder canopy bridges. Review the extent of vegetation in the median. 	<p>These contingency measures are not considered relevant.</p> <p>There have been no road kill records of glider species.</p>

5.2 Recommendations

In relation to the relevant contingency measures noted above (Table 13), and performance indicators that have not been met, a number of recommendations have been made. These are detailed in Table 14 below.

Table 14: Recommendations

Problem identified during 2018 monitoring	Discussion/Recommendation
Successful crossings of canopy rope bridges have not been confirmed.	<ul style="list-style-type: none"> As the cameras have been installed and function continually throughout the year, consideration should be given to downloading photographic data on a more regular basis in an effort to capture additional crossings by fauna that may occur outside of the 60 day monitoring period. As provided for within the contingency measures, a review of the vegetation status immediately adjacent to the crossing poles should be considered, with the aim of determining if additional lead/lure ropes from neighbouring trees to the rope ladder canopy bridges would improve fauna access to the rope ladder, notably for small scansorial species.
Recaptures of tagged fauna have not been made on either side of the road, therefore there is no evidence of tagged fauna crossing the carriageway.	<ul style="list-style-type: none"> Due to low capture rate of fauna combined with the limited trapping effort, it is considered that this means of identifying successful crossings is unlikely to result in positive outcomes. It is likely that a substantial increase in trapping effort would be required to obtain the necessary micro chipping numbers to provide results based on mark-recapture surveys. It is recommended that the success of these mitigation measures be determined by successful crossings established by a combination of either photographic means and/or tagging, and that the absence of recaptures alone should not be considered as a sign of unsuccessful mitigation.
Camera malfunction	<ul style="list-style-type: none"> Site 3 Median pole 2 camera is no longer functioning. If possible, steps should be taken to troubleshoot and resolve this issue with the supplier/technician.

6. References

Lewis, B.D. (2005). Kempsey to Eungai Pacific Highway Upgrade: Fauna Survey. Report prepared by Lewis Ecological Services for Parsons Brinckerhoff-Sydney.

Lewis, B.D. (2013). Ecological Monitoring Report: Frederickton to Eungai Upgrade. Report prepared for Roads and Maritime Services by Lewis Ecological Surveys.

Niche (2018a). Aerial Crossing Monitoring 2017. Prepared for NSW Roads and Maritime Services.

Niche (2018b). Fauna Underpasses and Associated Fauna Fence Monitoring Report 2017/2018. Prepared for NSW Roads and Maritime Services.

RMS (2016). Frederickton to Eungai Pacific Highway Upgrade Ecological Monitoring Program. Roads and Maritime Update to report prepared by Lewis Ecological Surveys, May 2016.

Annex 1 – Remote camera results

Table 15: Remote camera records - autumn and spring 2018

Season	Site	Pole	Camera	Date	Time	Species	Direction facing
Autumn	1	GP1 East	1	14/05/2018	2:50:08	Sugar/Squirrel Glider	Upwards
Autumn	1	GP1 West	3	28/03/2018	4:16:59	Feathertail Glider	Upwards
Autumn	1	GP1 West	3	11/04/2018	21:34:40	Feathertail Glider	Downwards
Autumn	1	GP1 West	3	14/04/2018	23:49:19	Sugar Glider	Upwards
Autumn	1	GP1 West	3	10/05/2018	4:24:15	Feathertail Glider	Upwards
Autumn	1	GP1 West	3	15/05/2018	0:22:35	Sugar Glider	Upwards
Autumn	1	RB1 East	4	07/04/2018	6:10:03	<i>Corvus</i> sp.	n/a
Autumn	1	RB1 East	4	07/04/2018	7:31:36	<i>Corvus</i> sp.	n/a
Autumn	1	RB1 East	4	08/04/2018	7:31:41	<i>Corvus</i> sp.	n/a
Autumn	1	RB1 East	4	21/04/2018	6:52:59	<i>Corvus</i> sp.	n/a
Autumn	1	RB1 East	4	22/04/2018	7:36:10	<i>Corvus</i> sp.	n/a
Autumn	1	RB1 East	4	23/04/2018	6:25:53	<i>Corvus</i> sp.	n/a
Autumn	2	RB2 East	6	12/05/2018	8:50:17	Australian Magpie	n/a
Autumn	2	RB2 West	7	19/03/2018	18:53:46	<i>Corvus</i> sp.	n/a
Autumn	2	RB2 West	7	23/04/2018	1:17:12	Sugar Glider	East
Autumn	2	RB2 West	7	12/05/2018	15:38:03	Australian Magpie	West
Autumn	2	GP2 Mid	9	06/04/2018	21:37:51	Unknown	Upwards
Autumn	2	GP2 Mid	9	13/04/2018	20:45:24	Feathertail Glider	Upwards
Autumn	2	GP2 Mid	9	13/04/2018	20:45:38	Feathertail Glider	Downwards
Autumn	2	GP2 Mid	9	18/04/2018	0:57:10	Sugar or Squirrel Glider	Upwards
Autumn	2	GP2 Mid	9	26/04/2018	2:18:39	Sugar or Squirrel Glider	Upwards
Autumn	2	GP2 Mid	9	29/04/2018	21:39:48	Sugar or Squirrel Glider	Upwards
Autumn	2	GP2 Mid	9	01/05/2018	3:05:17	Sugar or Squirrel Glider	Upwards
Autumn	2	GP2 Mid	9	13/05/2018	23:29:23	Sugar or Squirrel Glider	Upwards
Autumn	2	GP2 Mid	9	15/05/2018	22:25:54	Feathertail Glider	Upwards
Autumn	2	GP2 Mid	9	17/05/2018	20:52:45	Feathertail Glider	Upwards
Autumn	2	GP2 West	10	24/04/2018	1:13:42	Sugar/Squirrel Glider	Upwards
Autumn	2	GP2 West	10	11/04/2018	23:43:00	Sugar/Squirrel Glider	Upwards
Autumn	2	GP2 West	10	13/04/2018	5:18:36	Feathertail Glider	Upwards
Autumn	2	GP2 West	10	16/04/2018	3:18:38	Sugar/Squirrel Glider	Upwards
Autumn	2	GP2 West	10	16/04/2018	3:24:56	Feathertail Glider	Downwards
Autumn	2	GP2 West	10	26/04/2018	3:20:36	Sugar/Squirrel Glider	Upwards
Autumn	2	GP2 West	10	13/05/2018	2:44:55	Feathertail Glider	Upwards
Autumn	2	GP2 West	10	14/05/2018	23:53:39	Feathertail Glider	Upwards
Autumn	3	GP3 East	11	10/03/2018	23:33:43	Feathertail Glider	Upwards
Autumn	3	GP3 East	11	12/03/2018	2:48:19	Feathertail Glider	Upwards
Autumn	3	GP3 East	11	12/03/2018	4:41:58	Feathertail Glider	Upwards
Autumn	3	GP3 East	11	13/03/2018	3:38:31	Feathertail Glider	Upwards
Autumn	3	GP3 East	11	13/03/2018	4:08:33	Feathertail Glider	Upwards
Autumn	3	GP3 East	11	13/03/2018	4:12:51	Feathertail Glider	Upwards
Autumn	3	GP3 East	11	13/03/2018	4:42:36	Feathertail Glider	Upwards

Season	Site	Pole	Camera	Date	Time	Species	Direction facing
Autumn	3	GP3 East	11	14/03/2018	0:42:24	Sugar/Squirrel Glider	Upwards
Autumn	3	GP3 East	11	14/03/2018	4:25:19	Feathertail Glider	Upwards
Autumn	3	GP3 East	11	14/03/2018	4:36:30	Feathertail Glider	Upwards
Autumn	3	GP3 East	11	21/03/2018	5:04:05	Feathertail Glider	Upwards
Autumn	3	GP3 East	11	16/04/2018	22:59:28	Feathertail Glider	Upwards
Autumn	3	GP3 East	11	19/04/2018	0:37:05	Feathertail Glider	Upwards
Autumn	3	GP3 East	11	19/04/2018	22:00:34	Feathertail Glider	Upwards
Autumn	3	GP3 East	11	19/04/2018	22:33:14	Feathertail Glider	Upwards
Autumn	3	GP3 East	11	20/04/2018	3:02:16	Feathertail Glider	Upwards
Autumn	3	GP3 East	11	20/04/2018	4:37:23	Feathertail Glider	Upwards
Autumn	3	GP3 East	11	21/04/2018	23:40:36	Feathertail Glider	Upwards
Autumn	3	GP3 East	11	23/04/2018	4:52:08	Feathertail Glider	Upwards
Autumn	3	GP3 East	11	24/04/2018	4:14:26	Feathertail Glider	Upwards
Autumn	3	GP3 East	11	25/04/2018	4:31:56	Feathertail Glider	Upwards
Autumn	3	GP3 East	11	26/04/2018	0:58:40	Feathertail Glider	Upwards
Autumn	3	GP3 East	11	26/04/2018	2:22:29	Feathertail Glider	Upwards
Autumn	3	GP3 East	11	26/04/2018	4:21:50	Feathertail Glider	Downwards
Autumn	3	GP3 East	11	19/04/2018	5:20:13	Feathertail Glider	Upwards
Autumn	3	GP3 Mid	12	11/03/2018	3:07:34	Feathertail Glider	Downwards
Autumn	3	GP3 Mid	12	13/03/2018	4:20:11	Feathertail Glider	Upwards
Autumn	3	GP3 Mid	12	13/03/2018	4:41:24	Feathertail Glider	Upwards
Autumn	3	GP3 Mid	12	14/03/2018	4:52:33	Feathertail Glider	Downwards
Autumn	3	GP3 Mid	12	15/03/2018	4:44:25	Feathertail Glider	Upwards
Autumn	3	GP3 Mid	12	17/03/2018	4:27:01	Feathertail Glider	Upwards
Autumn	3	GP3 Mid	12	17/03/2018	23:14:17	Feathertail Glider	Upwards
Autumn	3	GP3 Mid	12	17/03/2018	23:14:32	Feathertail Glider	Upwards
Autumn	3	GP3 Mid	12	19/03/2018	4:14:03	Feathertail Glider	Upwards
Autumn	3	GP3 Mid	12	20/03/2018	21:06:22	Feathertail Glider	Upwards
Autumn	3	GP3 Mid	12	19/04/2018	4:06:04	Sugar/Squirrel Glider	Upwards
Autumn	3	GP3 Mid	12	19/04/2018	22:32:35	Feathertail Glider	Upwards
Autumn	3	GP3 Mid	12	19/04/2018	22:45:13	Feathertail Glider	Upwards
Autumn	3	GP3 Mid	12	22/04/2018	2:35:55	Feathertail Glider	Upwards
Autumn	3	GP3 Mid	12	25/04/2018	4:31:13	Feathertail Glider	Upwards
Autumn	3	GP3 Mid	12	26/04/2018	4:36:12	Sugar/Squirrel Glider	Upwards
Autumn	3	GP3 Mid	12	27/04/2018	4:06:46	Feathertail Glider	Upwards
Autumn	3	GP3 Mid	12	28/04/2018	4:40:39	Feathertail Glider	Upwards
Autumn	3	GP3 Mid	12	29/04/2018	4:51:57	Sugar / Squirrel	Upwards
Autumn	3	GP3 Mid	12	29/04/2018	5:19:26	Feathertail Glider	Upwards
Autumn	3	RB3 East	14	15/03/2018	1:12:33	Brushtail Possum	West
Autumn	3	RB3 East	14	17/03/2018	3:51:57	Common Brushtail Possum	East
Spring	1	GP1 East	1	15/08/2018	2:59:48	Sugar Glider	Unk
Spring	1	GP1 West	3	19/05/2018	23:27:05	Feathertail Glider	Unk
Spring	1	GP1 West	3	14/09/2018	1:23:32	Feathertail Glider	Unk

Season	Site	Pole	Camera	Date	Time	Species	Direction facing
Spring	1	GP1 West	3	19/09/2018	2:02:39	Feathertail Glider	Unk
Spring	1	GP1 West	3	28/09/2018	4:25:41	Feathertail Glider	Unk
Spring	1	GP1 West	3	28/09/2018	20:05:44	Feathertail Glider	Unk
Spring	1	GP1 West	3	10/10/2018	2:47:19	Feathertail Glider	Unk
Spring	1	GP1 West	3	27/10/2018	21:12:02	Feathertail Glider	Unk
Spring	1	GP1 West	3	11/11/2018	21:22:14	Feathertail Glider	Unk
Spring	1	GP1 West	3	04/12/2018	0:10:27	Feathertail Glider	East
Spring	1	RB1 East	4	30/10/2018	5:31:20	<i>Corvus</i> sp.	n/a
Spring	1	RB1 West	5	21/09/2018	6:59:52	<i>Corvus</i> sp.	n/a
Spring	1	RB1 West	5	09/11/2018	2:26:40	Feathertail Glider	West
Spring	1	RB1 West	5	09/11/2018	2:26:43	Feathertail Glider	East
Spring	1	RB1 West	5	10/11/2018	1:52:32	Feathertail Glider	West
Spring	1	RB1 West	5	10/11/2018	1:56:19	Feathertail Glider	East
Spring	1	RB1 West	5	11/11/2018	21:46:56	Feathertail Glider	East
Spring	1	RB1 West	5	11/11/2018	21:47:41	Feathertail Glider	West
Spring	1	RB1 West	5	11/11/2018	21:47:48	Feathertail Glider	West
Spring	1	RB1 West	5	12/11/2018	0:13:49	Feathertail Glider	West
Spring	1	RB1 West	5	12/11/2018	2:09:48	Feathertail Glider	West
Spring	1	RB1 West	5	12/11/2018	2:09:54	Feathertail Glider	West
Spring	1	RB1 West	5	03/11/2018	2:12:58	Feathertail Glider	East
Spring	1	RB1 West	5	23/11/2018	2:03:36	Feathertail Glider	West
Spring	1	RB1 West	5	23/11/2018	2:03:57	Feathertail Glider	West
Spring	1	RB1 West	5	23/11/2018	2:08:24	Feathertail Glider	West
Spring	1	RB1 West	5	23/11/2018	2:08:28	Feathertail Glider	East
Spring	1	RB1 West	5	23/11/2018	2:08:55	Feathertail Glider	East
Spring	1	RB1 West	5	23/11/2018	2:08:59	Feathertail Glider	West
Spring	1	RB1 West	5	23/11/2018	3:08:59	Feathertail Glider	East
Spring	1	RB1 West	5	23/11/2018	3:10:34	Feathertail Glider	West
Spring	1	RB1 West	5	26/11/2018	2:48:21	Feathertail Glider	East
Spring	1	RB1 West	5	26/11/2018	20:55:08	Feathertail Glider	East
Spring	1	RB1 West	5	29/11/2018	22:11:30	Feathertail Glider	East
Spring	1	RB1 West	5	29/11/2018	22:11:33	Feathertail Glider	West
Spring	1	RB1 West	5	01/12/2018	0:42:00	Feathertail Glider	East
Spring	1	RB1 West	5	02/12/2018	2:37:49	Feathertail Glider	West
Spring	1	RB1 West	5	04/12/2018	3:17:02	Feathertail Glider	West
Spring	1	RB1 West	5	04/12/2018	3:17:03	Feathertail Glider	West
Spring	2	RB2 West	7	15/09/2018	8:51:57	Small Bird	n/a
Spring	2	RB2 West	7	14/10/2018	6:58:08	Laughing Kookaburra	n/a
Spring	2	RB2 West	7	18/10/2018	5:40:03	Laughing Kookaburra	n/a
Spring	2	RB2 West	7	19/10/2018	4:52:05	Laughing Kookaburra	n/a
Spring	2	RB2 West	7	04/11/2018	1:34:01	Feathertail Glider	West
Spring	2	RB2 West	7	04/11/2018	3:00:09	Feathertail Glider	West
Spring	2	RB2 West	7	06/11/2018	0:25:00	Feathertail Glider	West

Season	Site	Pole	Camera	Date	Time	Species	Direction facing
Spring	2	RB2 West	7	06/11/2018	0:26:41	Feathertail Glider	West
Spring	2	RB2 West	7	17/11/2018	23:17:23	Feathertail Glider	East
Spring	2	RB2 West	7	20/11/2018	4:43:22	Laughing Kookaburra	n/a
Spring	2	RB2 West	7	24/11/2018	0:40:51	Feathertail Glider	East
Spring	2	RB2 West	7	24/11/2018	0:44:15	Feathertail Glider	West
Spring	2	RB2 West	7	24/11/2018	0:44:21	Feathertail Glider	West
Spring	2	RB2 West	7	24/11/2018	21:05:02	Feathertail Glider	West
Spring	2	RB2 West	7	24/11/2018	21:05:04	Feathertail Glider	West
Spring	2	RB2 West	7	27/11/2018	20:11:49	Feathertail Glider	West
Spring	2	RB2 West	7	27/11/2018	20:11:51	Feathertail Glider	West
Spring	2	RB2 West	7	27/11/2018	20:14:11	Feathertail Glider	West
Spring	2	RB2 West	7	29/11/2018	22:41:29	Feathertail Glider	East
Spring	2	RB2 West	7	01/12/2018	1:09:56	Feathertail Glider	East
Spring	2	RB2 West	7	03/12/2018	20:54:36	Feathertail Glider	East
Spring	2	RB2 West	7	03/12/2018	20:54:40	Feathertail Glider	East
Spring	2	RB2 West	7	03/12/2018	20:55:11	Feathertail Glider	West
Spring	2	RB2 West	7	03/12/2018	22:27:22	Feathertail Glider	East
Spring	2	RB2 West	7	03/12/2018	22:36:31	Feathertail Glider	West
Spring	2	RB2 West	7	03/12/2018	22:36:43	Feathertail Glider	East
Spring	2	RB2 West	7	03/12/2018	22:36:56	Feathertail Glider	East
Spring	2	RB2 West	7	03/12/2018	22:36:57	Feathertail Glider	East
Spring	2	RB2 West	7	03/12/2018	22:36:59	Feathertail Glider	West
Spring	2	RB2 West	7	03/12/2018	22:37:00	Feathertail Glider	West
Spring	2	RB2 West	7	03/12/2018	22:37:02	Feathertail Glider	West
Spring	2	RB2 West	7	03/12/2018	22:54:22	Feathertail Glider	West
Spring	2	RB2 West	7	04/12/2018	1:24:48	Feathertail Glider	West
Spring	2	RB2 West	7	05/12/2018	2:12:42	Feathertail Glider	East
Spring	2	GP2 East	8	19/09/2018	3:04:22	Yellow-bellied Glider	East
Spring	2	GP2 East	8	13/11/2018	22:52:19	Sugar Glider	Unk
Spring	2	GP2 Mid	9	19/05/2018	0:54:05	Sugar Glider	Unk
Spring	2	GP2 Mid	9	22/05/2018	2:31:54	Sugar Glider	Unk
Spring	2	GP2 Mid	9	25/05/2018	23:59:27	Sugar Glider	Unk
Spring	2	GP2 West	10	22/06/2018	4:45:37	Sugar/Squirrel Glider	Unk
Spring	2	GP2 West	10	29/10/2018	23:30:08	Feathertail Glider	Unk
Spring	2	GP2 West	10	04/11/2018	22:07:41	Feathertail Glider	Unk
Spring	2	GP2 West	10	05/11/2018	19:40:56	Feathertail Glider	Unk
Spring	2	GP2 West	10	07/11/2018	1:09:30	Feathertail Glider	Unk
Spring	2	GP2 West	10	11/11/2018	0:48:25	Feathertail Glider	Unk
Spring	2	GP2 West	10	11/11/2018	23:00:16	Feathertail Glider	Unk
Spring	3	GP3 East	11	13/09/2018	21:06:27	Feathertail Glider	Unk
Spring	3	GP3 East	11	14/09/2018	4:26:29	Feathertail Glider	Unk
Spring	3	GP3 East	11	15/09/2018	1:01:45	Feathertail Glider	Unk
Spring	3	GP3 East	11	16/09/2018	0:00:14	Feathertail Glider	Unk

Season	Site	Pole	Camera	Date	Time	Species	Direction facing
Spring	3	GP3 East	11	16/09/2018	1:56:33	Feathertail Glider	Unk
Spring	3	GP3 East	11	25/09/2018	0:46:36	Feathertail Glider	Unk
Spring	3	GP3 East	11	30/09/2018	22:07:23	Feathertail Glider	Unk
Spring	3	GP3 East	11	03/10/2018	21:00:09	Feathertail Glider	Unk
Spring	3	GP3 East	11	07/10/2018	0:57:19	Feathertail Glider	Unk
Spring	3	GP3 East	11	11/12/2018	3:57:28	Feathertail Glider	Unk
Spring	3	GP3 East	11	12/12/2018	3:20:10	Feathertail Glider	Unk
Spring	3	GP3 East	11	12/12/2018	4:32:56	Feathertail Glider	Unk
Spring	3	GP3 Mid	12	15/09/2018	1:01:11	Feathertail Glider	Unk
Spring	3	GP3 Mid	12	03/11/2018	0:36:31	Feathertail Glider	Unk
Spring	3	GP3 Mid	12	03/11/2018	21:03:14	Feathertail Glider	Unk
Spring	3	RB3 East	14	10/07/2018	1:25:48	Feathertail Glider	West
Spring	3	RB3 East	14	14/10/2018	23:17:03	Feathertail Glider	East
Spring	3	RB3 East	14	16/10/2018	0:21:20	Feathertail Glider	West
Spring	3	RB3 East	14	10/11/2018	23:19:21	Feathertail Glider	West
Spring	3	RB3 East	14	17/11/2018	2:13:19	Sugar Glider	West
Spring	3	RB3 East	14	17/11/2018	2:13:27	Sugar Glider	West
Spring	3	RB3 East	14	26/11/2018	1:05:53	Bird	East
Spring	3	RB3 East	14	30/11/2018	23:37:12	Feathertail Glider	West
Spring	3	RB3 East	14	06/12/2018	23:59:21	Feathertail Glider	Unk
Spring	3	RB3 East	14	08/12/2018	0:11:48	Feathertail Glider	Unk
Spring	3	RB3 East	14	08/12/2018	0:12:15	Feathertail Glider	West
Spring	3	RB3 East	14	08/12/2018	0:31:34	Feathertail Glider	East
Spring	3	RB3 East	14	08/12/2018	1:18:31	Feathertail Glider	West
Spring	3	RB3 East	14	08/12/2018	1:18:43	Feathertail Glider	East
Spring	3	RB3 East	14	08/12/2018	1:18:46	Feathertail Glider	East
Spring	3	RB3 East	14	08/12/2018	1:18:48	Feathertail Glider	East
Spring	3	RB3 East	14	08/12/2018	1:18:51	Feathertail Glider	East
Spring	3	RB3 East	14	08/12/2018	2:21:29	Feathertail Glider	East
Spring	3	RB3 West	15	10/11/2018	1:36:09	Feathertail Glider	West
Spring	3	RB3 West	15	19/11/2018	1:51:32	Feathertail Glider	East
Spring	3	RB3 West	15	19/11/2018	1:51:36	Feathertail Glider	West
Spring	3	RB3 West	15	03/12/2018	1:38:44	Feathertail Glider	East
Spring	3	RB3 West	15	03/12/2018	1:39:44	Feathertail Glider	Unk
Spring	3	RB3 West	15	03/12/2018	1:39:49	Feathertail Glider	West
Spring	3	RB3 West	15	06/12/2018	23:58:42	Feathertail Glider	West
Spring	3	RB3 West	15	08/12/2018	0:15:30	Feathertail Glider	West
Spring	3	RB3 West	15	08/12/2018	0:15:34	Feathertail Glider	West
Spring	3	RB3 West	15	08/12/2018	0:15:47	Feathertail Glider	East
Spring	3	RB3 West	15	08/12/2018	0:16:04	Feathertail Glider	West
Spring	3	RB3 West	15	08/12/2018	0:16:05	Feathertail Glider	West
Spring	3	RB3 West	15	08/12/2018	0:31:14	Feathertail Glider	East

Annex 2 – Arboreal trapping results

Table 16: Arboreal trapping results – autumn and spring 2018.

Date	Survey	Site	Side of carriageway	Trap type	Species	Recapture (Y/N)	Sex	Weight	Breeding condition	Microchip ID
20/03/2018	Autumn	GP3	East	Cage	Common Brushtail Possum	N	Unk	Unk	adult	not tagged
20/03/2018	Autumn	RB1	East	Cage	Common Brushtail Possum	N	F	Unk	adult	0007D25806
21/03/2018	Autumn	RB3	West	Cage	Common Brushtail Possum	N	M	>500g	adult	0007A0B966
21/03/2018	Autumn	RB1	East	Pipe	<i>Antechinus</i> sp.	n/a	Unk	Unk	Unk	n/a
22/03/2018	Autumn	RB1	East	Pipe	<i>Antechinus</i> sp.	n/a	Unk	Unk	Unk	n/a
19/09/2018	Spring	Site 2	West	Cage	Common Brushtail Possum	N	F	Unk	With young	not tagged
20/09/2018	Spring	RB1	East	Elliott	Brown Antechinus	n/a	Unk	Unk	adult	n/a

Unk = unknown

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Appendix E Fauna Underpasses and Fencing (incl Road Kill)



Fauna Underpass and Associated Fauna Fence Monitoring 2017/2018

Frederickton to Eungai Pacific Highway Upgrade

Prepared for Roads and Maritime Services

November 2018

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Cover photograph: Common Brushtail Possum (underpass 12 autumn 2018), Lace Monitor (underpass 7 summer 2018).

Executive summary

Context

This report documents the findings of the 2017/2018 monitoring period which includes the second of three monitoring periods for underpasses and associated fauna fences and the third of four monitoring periods for road kill, as specified in the Frederickton to Eungai (F2E) Ecological Monitoring Program (EMP, RMS 2016) and required by the Frederickton to Eungai (F2E) Pacific Highway Upgrade Project (the Project). The NSW Roads and Maritime Services (Roads and Maritime) is required to manage and monitor the effectiveness of biodiversity mitigation measures implemented as part of the Project.

Aims

The aims of this report are to summarise the methods and results of the summer and autumn 2017/2018 monitoring and determine if performance measures have been met, as per the EMP.

Methods

Seven fauna underpass structures were surveyed in accordance with the monitoring method specified in the EMP, specifically:

- Two remote cameras were placed within each underpass and set to record for 60 consecutive days
- 10 hair tube traps were placed in and around each underpass for 15 consecutive nights
- Walked surveys of the fence line were conducted for a distance of 250 metres north and south of each underpass and on both sides of the carriageway
- Four weekly road kill surveys were carried out along the entire length of the Project in summer and autumn.

Key results

Representatives from all six fauna groups identified in the EMP as fauna potentially impacted by the road, and that may benefit from/use the underpasses, were recorded using at least one underpass during 2017/2018 monitoring. To date, macropods, reptiles and small ground-dwelling mammals have been recorded using all underpasses on at least one occasion. Possums have been detected using five of the seven underpasses, Echidnas have been detected using four of the seven underpasses and frogs have only been detected using underpass 12 to date.

The key target species, the Brush-tailed Phascogale, has been recorded at underpass 7 and 12. All seven underpasses have recorded fauna with low dispersal abilities and non-native predators have been detected at all underpasses over the two monitoring periods conducted to date.

The weekly road kill rate decreased from the 2016/2017 monitoring period, as did the number of road kill records within 500 metres of the underpasses. One macropod was recorded as road kill within 500 metres of underpass 7 and a Dainty Green Tree Frog road kill event (including numerous individuals of the species) occurred within 500 metres of underpass 12, where frog fence is installed. Two Striped Marsh Frog road kill events occurred within three months after heavy rain at the same location (approximately 2.5 kilometres north of underpass 12) in an unfenced area.

Conclusions

Three of the five performance indicators of success for the underpasses and associated fauna fence have been met including:

- Use by a range of nominated indicator species,
- Use by fauna with low dispersal ability
- No breaches in the fauna fence by target species
- Low rate of fauna strike.

While the Dainty Green Tree Frog road kill event is considered to represent a breach in the frog fence, the success of the frog fence, as stated in the EMP, “*will be based on the absence of Green-thighed Frog fence breaches/road strike*”, a condition that has been met. The remaining performance indicator of success regarding the use of underpasses by key target species has not been met at some underpasses. Use by the key target species (Brush-tailed Phascogale) to date has been met at two underpasses (7 and 12) during monitoring and a deceased individual was recorded in underpass 10 in May 2017. Continued monitoring, as per the EMP, will add to the number of records at each underpass.

Management implications

A number of recommendations have been made in order to assist the program in meeting its performance measures. Recommendations include:

- Addressing all fauna fence maintenance issues
- Targeted frog surveys at underpasses
- Extension of the remote camera monitoring period to increase the likelihood of detecting target species and nominated fauna groups
- Inspection of the entire fauna fence in the vicinity of underpass 6 for potential breaches/maintenance issues.

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1. Introduction

1.1 Context

As part of the Frederickton to Eungai (F2E) Pacific Highway Upgrade Project (the Project), Roads and Maritime Services (Roads and Maritime) have implemented an Ecological Monitoring Program in accordance with the Minister for Planning's Condition of Approval (MCoA) No. 3.1. This Ecological Monitoring Program (hereafter referred to as the EMP) (RMS 2016) combines the approval conditions provided within the Ministers Conditions of Approval (MCoA) and Statement of Commitments (SoC), and defines the mitigation and offsetting requirements for threatened species and ecological communities impacted by the Project.

1.1.1 Monitoring framework

The EMP states the following regarding monitoring:

"It is proposed that monitoring of the fauna underpasses and associated fauna fencing be undertaken in order to provide long term insights into the mitigation effectiveness once revegetation and landscaping efforts have developed sufficient cover. Monitoring would commence when the upgrade becomes operational and be undertaken for 4 weeks during early summer 2016, late autumn and early summer in 2017 and 2018 as well as during late autumn 2019. After the conclusion of this monitoring the need for further monitoring would be reviewed in consultation with EPA".

In addition, the EMP specifies that monitoring of road kill fauna was to occur within two months of the road opening, with additional road kill surveys undertaken as part of the underpass and associated fauna fence monitoring. As the specified timing for underpass and fauna fence monitoring did not align with the road opening, a road kill survey was undertaken for the first 21 days of the Project being opened to the public, as specified in the original EMP (Lewis 2013).

To date, these monitoring events have been undertaken and reported on as follows:

- *Road opening 21 day road kill monitoring*: Niche 2016
- *Fauna Underpass and Associated Fauna Fence Monitoring 2016/2017*: Niche 2018
- *Fauna Underpass and Associated Fauna Fence Monitoring 2017/2018*: current report.

The 2017/2018 monitoring therefore represents the second of three monitoring periods for underpasses and associated fauna fences and the third of four monitoring periods for road kill. The final monitoring period (2018/2019) is scheduled to commence in summer 2018 and will consist of two monitoring events (early summer 2018 and late autumn 2019).

1.1.2 Baseline data

The EMP provides the following background information for the baseline data:

"The baseline data has been obtained from systematic surveys undertaken as part of the Environmental Assessment for the Kempsey to Eungai Project (Lewis 2005; Parson Brinkerhoff 2006)."

The baseline data was used to class fauna recorded at or near (less than one kilometre) underpass locations and determine which fauna underpasses were to be monitored as part of the EMP. Seven of the thirteen fauna underpasses were identified as most suitable for monitoring and the fauna groups/species recorded at these locations are shown in Table 1.

Construction monitoring of road kill was not undertaken, as such baseline road kill data is not available.

Table 1: Fauna classes previously recorded at/near monitored underpass locations (extracted from Table 3-4 of EMP)

Monitoring Species/Group	Underpass						
	6	7	10	12	13B	14	15
Frogs	√	√	√	√	√	√	√
Reptiles	√	√	√	√	√	√	√
Small Ground Dwelling Mammals (Antechinus, Rodents, Bandicoots)	√		√	√	√	√	√
Echidna	√		√	√	√	√	√
Possums	√	√	√	√	√	√	√
Macropods (Swamp Wallaby, Red-necked Wallaby, Eastern Grey Kangaroo)	√	√	√	√	√	√	√
Brush-tailed Phascogale*	√		√	√	√	√	√

√ = present, * = key target species.

1.1.3 Purpose of this report

This report complies with the monitoring requirements described within the EMP and details the findings of the second monitoring event for underpasses and associated fauna fences and the third road kill monitoring event.

The aims of this report are to summarise the methods and results of the summer 2017 and autumn 2018 monitoring and determine if performance measures have been met, as per the EMP.

1.2 Performance Measures

The EMP specifies the performance indicators for the underpasses and associated fauna fences, as below.

Indicators of success for the fauna underpass and associated fencing monitoring includes:

- Use of fauna underpass by a range of the nominated indicator species
- Use of the fauna underpass by key target species
- Use by fauna with low dispersal abilities
- Low rate of fauna road strike
- No breaches in the fauna fence.

The EMP specifies that the “degree of success of each underpass will be determined by the complete passage of one or more individuals from a range of the six fauna groups previously recorded in that area” (Table 1).

The EMP also specifies that “the degree of success of the floppy top fauna fencing will be determined by the absence of specific road struck fauna including Echidna, Koala, Possums (Common Brushtail, Common Ringtail) and macropods (Swamp Wallaby, Red-necked Wallaby, Eastern Grey Kangaroo) on the highway carriageway in the immediate vicinity (i.e. <500 m) of the fauna underpasses. Where phascogale fencing has been installed, the degree of success will be based on the absence of road killed Brush-tailed Phascogale and other scansorial fauna (i.e. Antechinus). Similarly, for frog fencing, its success will be based on the absence of Green-thighed Frog fence breaches/road strike.”

1.3 Monitoring Timing

As per Lewis 2013, a 21-day road kill survey was undertaken once the road opened to traffic in 2016 (17 May 2016 to 7 June 2016 inclusive). Underpass and fauna fence monitoring (including four weekly road kill surveys) was undertaken early in the summer of 2016/2017 and 2017/2018, and late autumn of 2017 and 2018. The final year of fauna underpass, fauna fence and associated road kill surveys will subsequently be undertaken early in the summer of 2018/2019, and in late autumn in 2019.

1.4 Reporting

As per the EMP, annual reporting of monitoring results is to include:

- A description of the monitoring methodology employed
- Results, including field data, of the monitoring surveys
- A discussion of the results, including how the results compare against key performance criteria
- The need for any corrective actions/contingency measures and any general recommendations.

All reports prepared under the EMP will be submitted to the Director General of the NSW Department of Planning and Environment and the NSW Environment Protection Authority (EPA).

1.5 Limitations

The following limitations to the monitoring program were encountered:

- Due to their small size and cryptic nature, frogs and smaller reptiles are difficult to detect within the underpasses using the current survey methodology and thus if present, may have gone undetected.
- Identification and detection of road kill was limited to what can be observed whilst travelling at 80km/hr as it was not considered safe to stop on the operational highway. As such:
 - Some road kill fauna were identified to the vertebrate group level only.
 - Some records were classified as 'unknown' as road kill fauna could not be identified as a result of extensive collision damage.
 - It is possible that small fauna such as frogs, snakes, small mammals and birds have been undercounted as small-sized road kill fauna have the potential to be partially or wholly removed by scavenger animals, resulting in impossible identification from the vehicle.
- Safety issues prevent the removal of road kill following each survey and therefore road kill may have been recorded multiple times over the four weekly surveys resulting in double-counting and numerous 'unknown' records as the condition of the animal deteriorates.

2. Methodology

2.1 Survey Sites

The location of the seven monitored underpasses are shown in Figure 1 and are described, including targeted species, in Table 2.

Table 2: Monitored underpasses and targeted species (taken from Table 3-3 of the EMP)

Underpass	Type	Targeted species	Fauna fence
6	Combined drainage and fauna underpass	Brush-tailed Phascogale*	Standard and Phascogale fence
7	Fauna underpass	General species	Standard fauna fence
10	Twin Bridges over Seven Hills Road	Brush-tailed Phascogale*, Common Planigale, Green-thighed Frog	Standard, Phascogale and frog fence
12	Combined drainage and fauna underpass	Brush-tailed Phascogale*, Green-thighed Frog	Standard, Phascogale and frog fence
13B	Combined drainage and fauna underpass	Brush-tailed Phascogale*, Green-thighed Frog	Standard, Phascogale and frog fence
14	Combined drainage and fauna underpass	Brush-tailed Phascogale*, Green-thighed Frog	Standard, Phascogale and frog fence
15	Combined drainage and fauna underpass	Brush-tailed Phascogale*	Standard and Phascogale fence

* = key target species.

2.2 Survey Methods

2.2.1 Remote cameras

Two automated cameras were installed in each underpass and left operational for a minimum of 60 consecutive days. At each underpass, one camera was directed along the installed fauna furniture and one just above ground level. This maximised the chance of detecting small, medium and large fauna traveling via the ground or using fauna furniture.

2.2.2 Hair tubes and opportunistic searches

Ten hair tubes were deployed at each underpass and left for 14 consecutive nights. The hair tubes were attached to fauna furniture at different heights within the underpasses and placed in habitat adjacent to each underpass. Each hair tube was baited with a mixture of oats and peanut butter. Hair samples were sent to Barbara Triggs ('Dead Finish') for analysis, and were identified to species level where possible. Opportunistic searches for scats and tracks were undertaken within each underpass during camera and hair tube deployment and retrieval.

2.2.3 Fauna fences

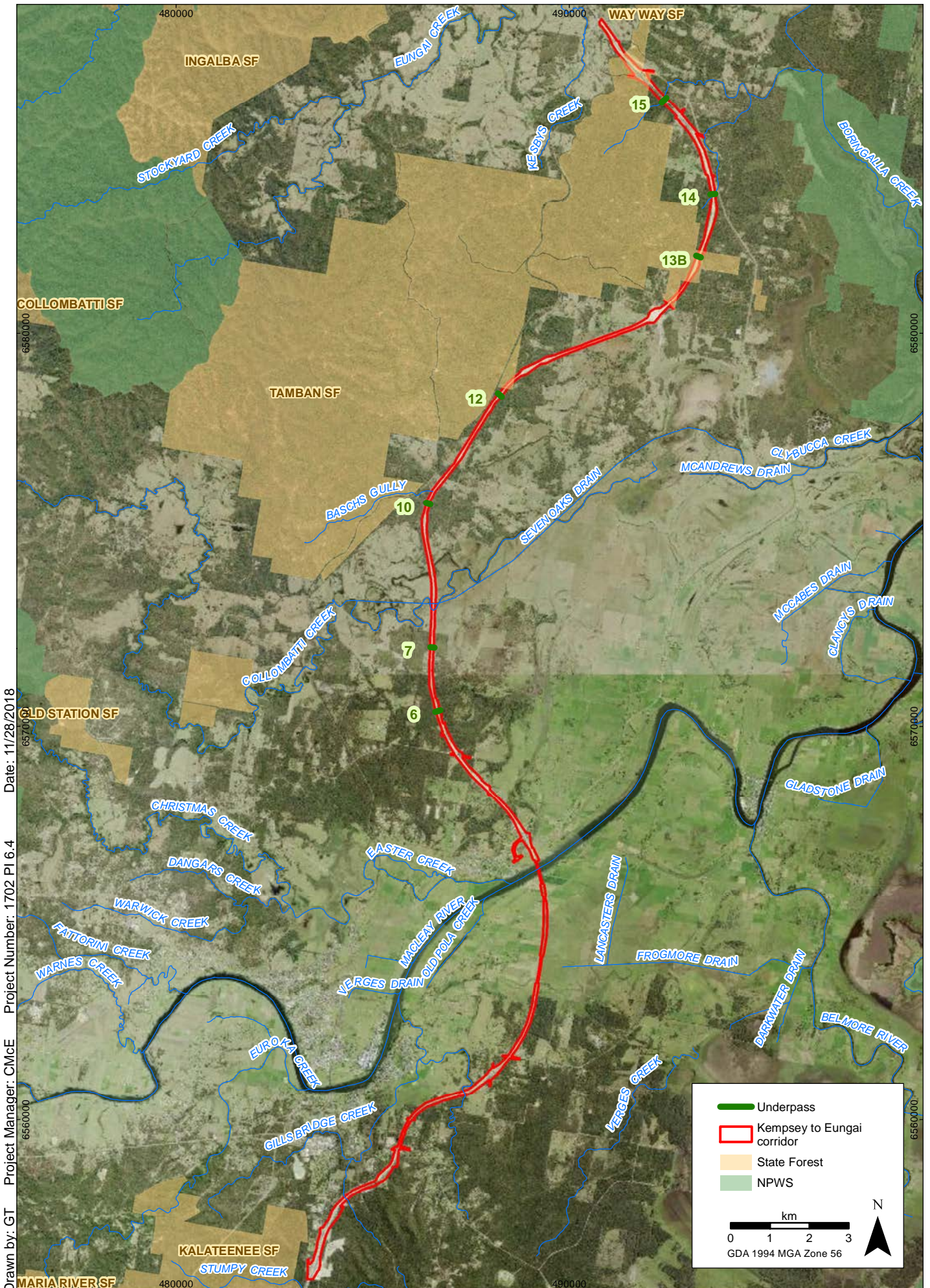
Monitoring of the fauna fences involved surveying the fence line on foot for 250 metres north and south of the underpass and on both sides of the carriageway. Breaches, damage and maintenance issues, such as impinging vegetation growth, were noted and their location recorded.

2.2.4 Road kill

Road kill surveys of the entire Project were undertaken once a week for four weeks during the summer and autumn monitoring events. These surveys involved observations made from a vehicle travelling at approximately 80 km/h. Road kill fauna observed on the road and within three metres of the road verge were recorded by the passenger. Due to the safety issues associated with the operational highway, it was not possible to stop the vehicle to closer inspect or remove road kill. Road kill records were grouped into general fauna groups for analysis.

2.3 Analysis

Weekly road kill rates were calculated to compare changes in rates of road kill between years. An analysis of the number of road kill events (excluding bird records) that occurred within or outside of fenced sections of the Project was undertaken by calculating a *road kill per kilometre* rate.



Frederickton to Eungai - Underpass locations
Pacific Highway Upgrade - Frederickton to Eungai

FIGURE 1

3. Results

3.1 2017/2018 Underpass Monitoring Results

Camera details and field data are provided in Annex 1. Results of the different survey methods have been combined to provide an overall assessment of the use of the monitored underpasses. While specific surveys to determine “complete passage” of individuals have not been specified in the EMP, it is considered that animals captured on remote cameras within the underpass are using the underpass to complete successful crossings.

3.1.1 Monitoring periods

The 2017/2018 monitoring periods were as follows:

- *Summer 2017/2018*: 5 December 2017 – 21 February 2018.
- *Autumn 2018*: 15 March 2018 – 29 May 2018.

Hair tube, fauna fence and road kill surveys were undertaken in the first four weeks of the monitoring period. Due to survey timing, cameras were left operating beyond the minimum 60 days. Species recorded outside of the 60 day monitoring period have been included in the assessment of underpass use by fauna groups as value adding data.

It should be noted that a number of issues were encountered with the cameras during the 2017/2018 surveys. A camera was stolen from underpass 10 and several of the cameras at ground level at sites 6, 7, 14 and 15 malfunctioned due to flooding. Data that could be retrieved from malfunctioning cameras was included in the assessment.

3.1.2 Camera fauna record summary

Table 3 provides a summary of the fauna records for the monitored underpasses. Cameras captured a total of 876 fauna records (excluding cattle) over the two monitoring periods. A proportion (22.5%) of records were unidentified, which were mostly partial and unclear images. Of those records that were identified, 51.1% were identified as native fauna.

Table 3: 2017/2018 camera fauna record summary

Underpass	# records*	# unidentified	# natives	# non native	# introduced predator	% native [^]	% introduced predator [^]
6	234	82	35	117	4	23.0	2.6
7	197	48	66	83	2	44.3	1.3
10	27	0	12	15	14	44.4	51.9
12	187	30	126	31	2	80.3	1.3
13B	88	20	28	40	7	41.2	10.3
14	77	9	45	23	0	66.2	0.0
15	66	8	35	23	0	60.3	0.0
TOTAL	876	197	347	332	29	51.1	4.3

* = cattle records have been excluded from the total record count as underpass 10 is used as a cattle movement route;

[^] = percentages represent proportion of the identified records.

3.1.3 Use of underpasses by different fauna species

Fauna groups

Representatives of all six fauna groups (Table 1) were recorded using at least one underpass during the 2017/2018 monitoring period (Table 4). The most common native species detected using underpasses included the Water Dragon (*Intellagama lesueurii*) (83 occasions, in all underpasses except underpass 10), Lace Monitor (*Varanus varius*) (62 occasions, detected in all underpasses except underpass 10 and 15) and Brushtail Possum (*Trichosurus* spp.) (46 occasions in underpasses 6, 7 and 12). While frogs were previously recorded in the vicinity of all monitored underpasses (Table 3-4 of the EMP), only a single frog was recorded during the 2017/2018 surveys in underpass 12. This lack of detection could be attributed to the survey methods. Hair tubes, remote cameras and limited opportunistic surveys are generally not very effective at detecting small, and often cryptic, amphibian species.

Table 4: 2017/2018 fauna groups recorded at the underpasses

Monitoring Species/Group	6	7	10	12	13B	14	15
Frogs				✓			
Reptiles	✓	✓	✓	✓	✓	✓	✓
Small Ground Dwelling Mammals	✓	✓ ^	✓	✓	✓	✓	✓
Echidna		✓ ^	✓		✓		
Possums	✓	✓		✓			
Macropods	✓	✓		✓	✓		
Records (# detected/# relevant)	4/6	3/4	3/6	5/6	4/6	2/6	2/6

✓ = recorded, ^ = not previously recorded in the vicinity and therefore not considered a relevant fauna group, as per the EMP.

Targeted species

The EMP also identifies targeted species for each underpass (Table 2). Table 5 presents the records for these targeted species for each underpass and provides an assessment of the number of targeted groups/species detected out of the number of targeted groups/species that were nominated in the EMP as relevant for each underpass. Targeted species have only been recorded at two of the seven underpasses: three of the four relevant fauna groups (reptiles, possums and macropods) at underpass 7 and one Brush-tailed Phascogale at underpass 12. Targeted species for the other underpasses include the Brush-tailed Phascogale and the Green-thighed Frog. As mentioned previously, the likelihood of detecting frog species, including the Green-thighed Frog, using current survey methods is low.

Table 5: 2017/2018 targeted species

Underpass	Targeted species (as per Table 3-3 in the EMP)	Targeted fauna recorded	Records (# detected / # nominated)
6	Brush-tailed Phascogale*	No	0/1
7	General species	Three of the four indicator groups (reptiles, possums, macropods) plus ground dwelling mammals and the Echidna.	3/4
10	Brush-tailed Phascogale*, Common Planigale, Green-thighed Frog	No	0/3
12	Brush-tailed Phascogale*, Green-thighed Frog	Brush-tailed Phascogale*	1/2
13B	Brush-tailed Phascogale*, Green-thighed Frog	No	0/2
14	Brush-tailed Phascogale*, Green-thighed Frog	No	0/2
15	Brush-tailed Phascogale*	No	0/1

* = key target species.

Use of underpasses by non-native predators

Non-native predators including cats, dogs and foxes, were detected at five of the seven monitored underpasses (underpass 6, 7, 10, 12 and 13B). Table 6 shows the non-native predators recorded for each underpass and the percentage of all identified fauna records that were non-native predators. Dogs were the most commonly recorded non-native predator and underpass 10 (Seven Hills Road) had the highest visitation rate by non-native predators.

Table 6: 2017/2018 non-native predator records

Non-native predator	6	7	10	12	13B	14	15
Cat (<i>Felis catus</i>)		✓	✓				
Dog (<i>Canis lupus</i>)	✓		✓	✓	✓		
Fox (<i>Vulpes vulpes</i>)					✓		
% of records	2.6	1.3	51.9	1.3	10.3	0	0

✓ = recorded

3.1.4 Use of underpasses by key target species

The key target species nominated in the EMP, the Brush-tailed Phascogale, was recorded at one underpass (underpass 12) during the autumn surveys on three occasions. Records were as follows:

- 23H16 11/05/2018 on the fauna furniture facing west
- 06H45 20/05/2018 on the fauna furniture facing east
- 05H16 22/05/2018 on the fauna furniture facing east

The final two records fell outside the 60-day monitoring period.

3.1.5 Use of underpasses by fauna with low dispersal abilities

Fauna with low dispersal ability was not defined within the EMP. As such fauna with low dispersal ability has been assumed to include animals whose dispersal ability is generally limited by their size, i.e. this would include smaller terrestrial fauna species, which have a reduced ability to disperse compared to larger, more mobile species. Fauna with low dispersal abilities has been interpreted as including individuals from four fauna groups (as per Niche 2017b): frogs, reptiles, small ground dwelling mammals and the Echidna. This definition was determined in consultation with RMS.

As shown in Table 4, reptiles and small ground dwelling mammals were recorded using all underpasses, the Echidna was recorded using three underpasses (7, 10 and 13B) and frogs were only recorded using underpass 12.

3.2 Cumulative Use of Underpasses

Combined results from the 2016/2017 and 2017/2018 monitoring events are presented in Table 7 and Table 8.

3.2.1 Cumulative use of underpasses by a range of species

Fauna groups

Representatives of all six fauna groups (Table 1) have been recorded using at least one underpass during the 2016/2017 and 2017/2018 monitoring (Table 7). Macropods, reptiles and small ground dwelling mammals have been recorded using all underpasses on at least one occasion. Possums have been detected using five of the seven underpasses. The Echidna has been detected using four of the seven underpasses and frogs have only been detected using underpass 12 to date.

Table 7: Cumulative use of underpasses

Monitoring Species/Group	6	7	10	12	13B	14	15
Frogs				✓			
Reptiles	✓	✓	✓	✓	✓	✓	✓
Small Ground Dwelling Mammals	✓	✓ ^	✓	✓	✓	✓	✓
Echidna		✓ ^	✓		✓	✓	
Possums	✓	✓	✓	✓		✓	
Macropods	✓	✓	✓	✓	✓	✓	✓
Records (# detected/# relevant)	4/6	3/4	5/6	5/6	4/6	5/6	3/6

✓ = recorded, ^ = not previously recorded in the vicinity and therefore not considered a relevant fauna group, as per the EMP.

Targeted species

Table 8 presents the records for the targeted species for each underpass recorded during the 2016/2017 and 2017/2018 monitoring periods. Targeted species have only been recorded at three of the seven underpasses (7, 10 and 12). The Brush-tailed Phascogale has been recorded at three different underpasses (7,10 and 12), while the Green-thighed Frog has not been detected at any of the underpasses.

Table 8: Cumulative use by targeted species

Underpass	Targeted species (as per Table 3-3 in the EMP)	Targeted fauna recorded in 2016/2017 and 2017/2018	# detected / # nominated
6	Brush-tailed Phascogale*	No	0/1
7	General species	Three of the four relevant fauna groups (reptiles, possums and macropods) and Brush-tailed Phascogale*	3/4
10	Brush-tailed Phascogale*, Common Planigale, Green-thighed Frog	Brush-tailed Phascogale*#	1/3
12	Brush-tailed Phascogale*, Green-thighed Frog	Brush-tailed Phascogale*	1/2
13B	Brush-tailed Phascogale*, Green-thighed Frog	No	0/2
14	Brush-tailed Phascogale*, Green-thighed Frog	No	0/2
15	Brush-tailed Phascogale	No	0/1

= deceased individual recorded during other Niche monitoring surveys (Niche 2017a), * = key target species.

Use of underpasses by non-native predators

To date, cats, dogs and foxes have been detected at all of the seven monitored underpasses when considering the 2016/2017 and 2017/2018 monitoring periods. Table 9 shows the non-native predators recorded using each underpass. At least two of the three different non-native predators have been recorded at each underpass, and all three have been recorded at underpass 7.

Table 9: Cumulative use of underpasses by non-native predators

Non-native predator	6	7	10	12	13B	14	15
Cat (<i>Felis catus</i>)	✓	✓	✓	✓			✓
Dog (<i>Canis lupus</i>)	✓	✓	✓	✓	✓	✓	
Fox (<i>Vulpes vulpes</i>)		✓			✓	✓	✓

3.2.2 Cumulative use of underpasses by key target species

The key target species nominated in the EMP, the Brush-tailed Phascogale, has been recorded at two underpasses: on five and one occasion in underpass 7 during the autumn and summer 2016/2017 monitoring periods respectively, and on three occasions in underpass 12 during the autumn 2017/2018 monitoring period. An incidental record during Brush-tailed Phascogale monitoring surveys undertaken by Niche in May 2017 also noted a deceased male Brush-tailed Phascogale in underpass 10 (Niche 2017a).

3.2.3 Cumulative use of underpasses by fauna with low dispersal abilities

As mentioned above, fauna with low dispersal abilities has been interpreted as including individuals from four fauna groups (as per Niche 2017b): frogs, reptiles, small ground dwelling mammals and the Echidna.

To date, as per Table 7, reptiles and small ground dwelling mammals have been recorded using all underpasses, while the Echidna has been recorded using four underpasses (7, 10, 13B and 14) and frogs have been recorded using underpass 12 only.

3.3 Fauna Fence Inspections

Fauna fence inspection results are provided in Annex 2.

3.3.1 Maintenance

A number of maintenance issues were identified during the 2017/2018 monitoring (Table 21). Maintenance is required in relation to vegetation encroachments, gaps underneath the fence caused by environmental factors i.e. water or erosion, platting or netting lifting and damage to the frog fence where it has either been burned or has fallen down.

Of particular note, a number of substantial issues were identified with the neoprene frog fence. At a number of locations neoprene fences had begun tearing at screw attachment points, joins in the neoprene were not holding (screws coming out or neoprene tearing away), resulting in areas of neoprene fence falling away from the fauna fence completely. In addition, a large section of the neoprene fence at underpass 14 (north east) has been completely destroyed by fire.

Roads and Maritime has subsequently removed the neoprene sheeting and replaced it with vermin-proof mesh, as approved on the Pacific Highway Upgrade between Woolgoolga and Ballina. These frog fence replacement works were completed in November 2018.

3.3.2 Fence breaches

No fence breaches were recorded during 2017/2018 fence monitoring. While no fauna was recorded on the highway-side of the fauna fence during fence inspections, undertaking maintenance to address identified gaps and ensure secure fastening of the base netting should prevent any breaches from occurring. However during road kill surveys a frog road kill event was recorded in the vicinity of underpass 12, where frog fence is installed. This road kill event is discussed in detail below.

3.4 Road Kill 2017/2018

Road kill results are provided in Annex 3. A total of 13,600 metres (51.3%) of the 26,520 metres of the Project is fenced with a minimum of standard fauna fence (data provided by RMS).

3.4.1 Total alignment

Fauna categories for analysis were defined as follows:

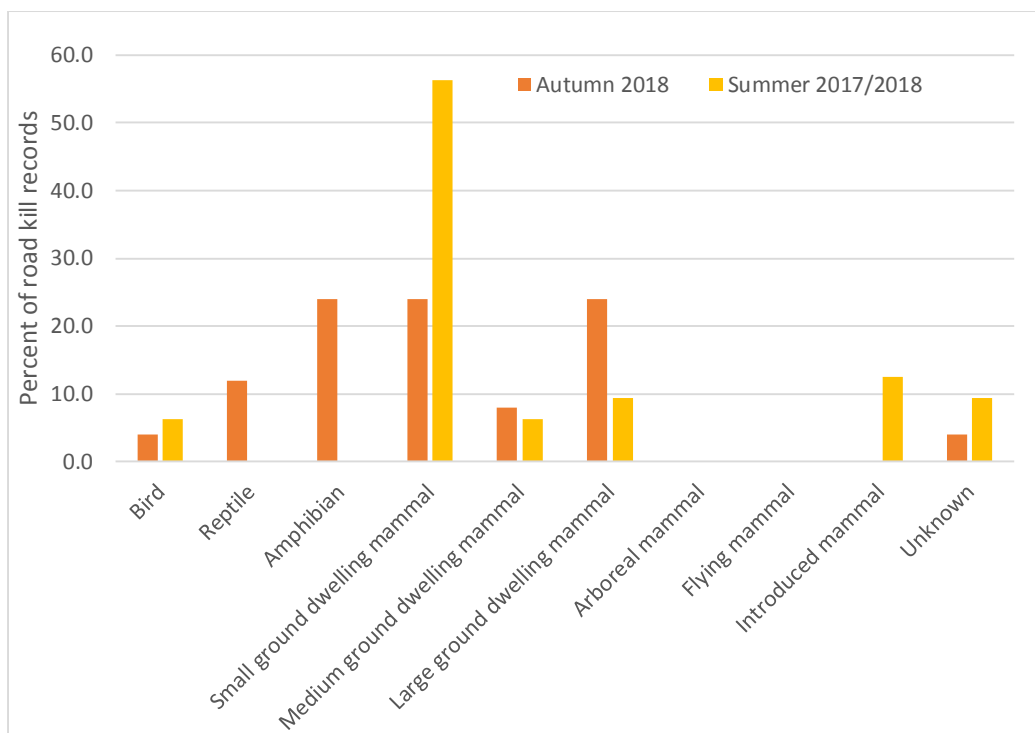
- Arboreal mammals
- Flying mammals (i.e. bats)
- Introduced mammals
- Small ground dwelling mammals
- Medium ground dwelling mammals
- Large ground dwelling mammals
- Amphibians
- Reptiles
- Birds
- Unknown

There were a total of 32 and 25 road kill records in summer 2017/2018 and autumn 2018, respectively. The percentage of road kill records for each category for the current monitoring period is presented in Graph 1. Small ground dwelling mammals (42% of road kill, n = 24), large ground dwelling mammals (Kangaroos and Wallabies) (16% of road kill, n = 9), and amphibians (11%, n = 6) were the most commonly recorded fauna groups.

It should be noted that amphibian road kill recorded in autumn 2018, carried out after a period of heavy rain, included large numbers of frogs. Road kill surveys undertaken on 22 March 2018 recorded a large number of frog road kills in two particular locations (Figure 2a). Species that could be identified were Dainty Green Tree Frogs (*Litoria gracilentia*), a Green Tree Frog (*Litoria caerulea*), and Striped Marsh Frogs (*Limnodynastes peronii*). A particular concentration of road kill Striped Marsh Frogs was observed adjacent to Johnson's Creek where there is no frog fence. The Dainty Green Tree Frog road kill event (including numerous individuals) occurred in the vicinity of underpass 12, where Green-thighed Frog ponds have been constructed and frog fence installed.

Figure 2 shows the distribution of road kill records. Not considering birds, there are a number of areas where road kill appears to be concentrated; notably in unfenced areas between underpass 12 and 13B and south of underpass 6. Within fenced areas, the majority of records occurred in the vicinity of underpass 6.

An analysis of the number of road kill events (excluding the three bird records) that occurred either within or outside of fenced sections of the Project (considering those road kill observations made at the edge of a fenced area to be outside), found that 24 (44%) records were within and 30 (56%) records were outside fenced areas. Considering these data with regard to fencing along the highway, calculation of a *road kill per kilometre* rate (excluding birds) found the rate of road kill in unfenced areas (12.92 kilometres; 2.3 records/kilometre) to be slightly higher than the rate in fenced areas (13.60 kilometres; 1.8 records/kilometre).



Graph 1: 2017/2018 road kill records

3.4.2 Fauna fence (within 500 metres of underpasses)

As per the EMP, success of the fauna fence is to be determined by *“the absence of specific road struck fauna including Echidna, Koala, Possums (Common Brushtail, Common Ringtail) and macropods (Swamp Wallaby, Red-necked Wallaby, Eastern Grey Kangaroo) on the highway carriageway in the immediate vicinity (i.e. <500 m) of the fauna underpasses. Where phascogale fencing has been installed, the degree of success will be based on the absence of road killed Brush-tailed Phascogale and other scansorial fauna (i.e. Antechinus). Similarly, for frog fencing, its success will be based on the absence of Green-thighed Frog fence breaches/road strike.”*

Road kill records within 500 metres of the underpasses are provided in Table 10 and presented in Figure 3. Excluding birds, there were a total of 11 road kill records that occurred within 500 metres of an underpass, mostly in the vicinity of underpass 6. The amphibian record in the vicinity of underpass 12 represents the Dainty Green Tree Frog road kill event which included over 20 individuals. There were no road kill records within 500 metres of underpasses 13B, 14 and 15.

Results of road kill in relation to fauna-specific fences are as follows:

- Standard floppy top fence: There were no road kill records of Echidnas, Possums or Koalas within 500 metres of the underpasses. Only one macropod was recorded as road kill within 500 metres of underpass 7.
- Phascogale fence: No Brush-tailed Phascogales were recorded as road kill during the current surveys.

- Frog fence: A road kill event was recorded within 500 metres of underpass 12 and where frog fence has been installed. As mentioned above, the species was identified as the Dainty Green Tree Frog.

Table 10: Road kill recorded within approximately 500 metres of an underpass

Underpass	Date	Side of carriageway (E/W)	Animal Group	Species
6	01/12/2017	E	Small Mammal	Unknown
6	01/12/2017	E	Bird	Pigeon
6	07/12/2017	E	Unknown	Unknown
6	14/12/2017	E	Small Mammal	Rodent
6	21/12/2017	E	Small Mammal	Unknown
6	21/12/2017	E	Small Mammal	Unknown
6	22/03/2018	E	Reptile	Diamond Python
7	01/12/2017	W	Small Mammal	Unknown
7	21/12/2017	W	Introduced	Rabbit
7	22/03/2018	E	Macropod	Kangaroo
10	21/12/2017	W	Small Mammal	Unknown
12*	22/03/2018	W	Amphibian	Dainty Green Tree Frogs

* = large number of Dainty Green Tree Frogs

3.4.3 Comparison with previous monitoring

Entire alignment

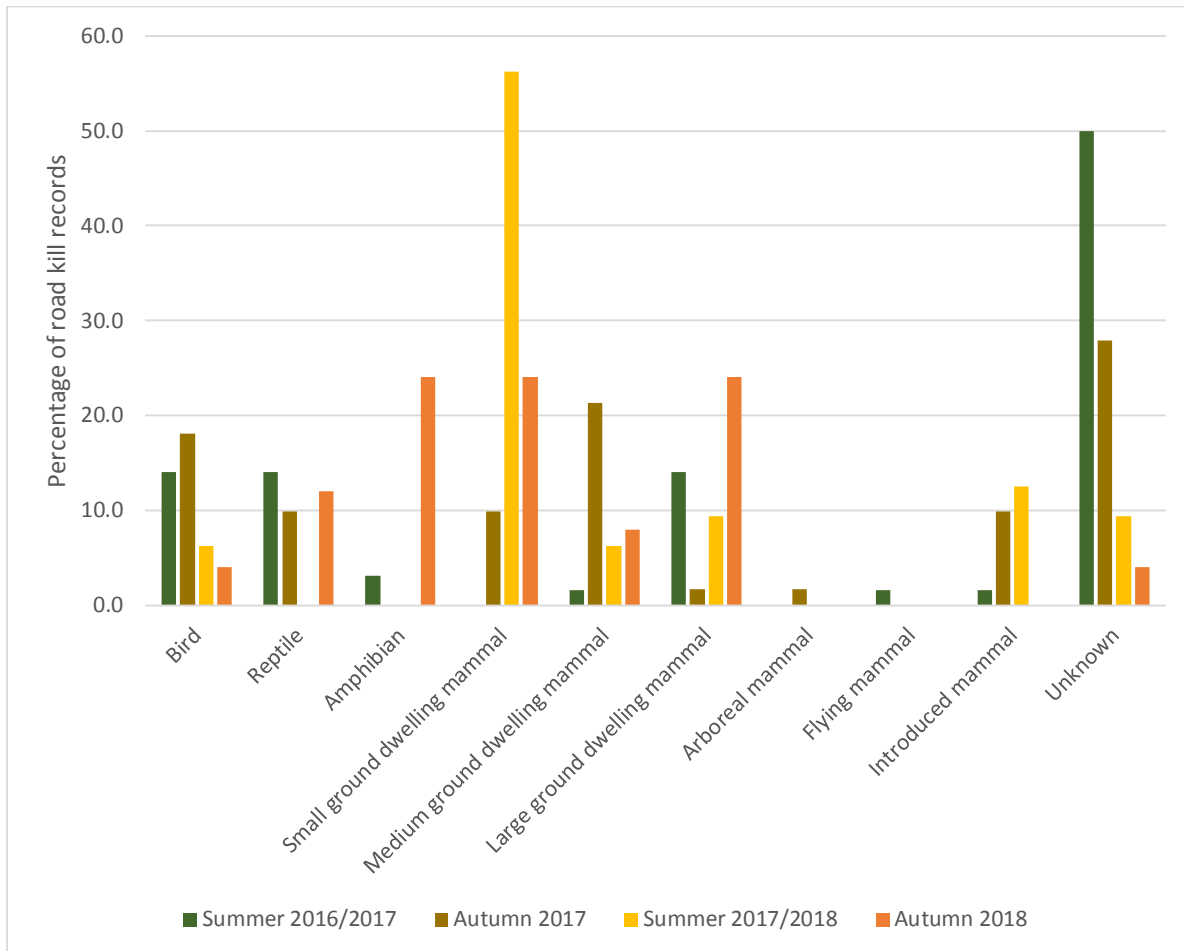
As baseline data is not available for this Project, rates of road kill cannot be defined as low or high in comparison to the pre-existing environment. Instead, road kill records from the road opening survey (Niche 2017c) were used as an indicator of road kill levels in the area at that time. It is important to note that road kill rates are expected to be higher immediately after road opening and that these rates have been used only as a means for comparison, as opposed to as an indicator of ‘usual’ levels.

Figure 4 shows 2016/2017 and 2017/2018 road kill records. Table 11 shows the weekly road kill rate over the various monitoring periods. The data indicate an overall decline in the number of road kill for 2017/2018 compared to previous monitoring events and an apparent decline between the two operational monitoring periods. Graph 2 shows the percentage of road kill records for each fauna group for the 2016/2017 and 2017/2018 monitoring periods. Areas where records were grouped in the 2016/2017 monitoring period (south of underpass 6 and 10) have a reduced number of records in the current monitoring period.

Niche 2018 reported a large number of road kill Striped Marsh Frogs after a rainfall event in January 2018 (incidental record). Autumn 2018 surveys recorded a similar road kill event of Striped Marsh Frogs (Figure 2a) at the same location within three months.

Table 11: Weekly road kill rates for all monitoring events

	21 day survey	2016/2017	2017/2018
Summer		16.0 (n = 64)	8.0 (n = 32)
Autumn		15.3 (n = 61)	6.3 (n = 25)
Total	31.8 (n = 95)	15.6 (n = 125)	7.1 (n = 57)



Graph 2: Comparison of 2016/2017 and 2017/2018 road kill records

Fauna fence (within 500 metres of an underpass)

The total number of road kill within 500 metres of an underpass for all monitoring events is shown in Table 12. The total number of road kill within 500 metres of an underpass decreased in 2017/2018 from the previous monitoring events, however a similar number of records occurred within 500 metres of underpass 6 in both monitoring events.

Results of road kill in relation to fauna-specific fences are as follows:

- Standard floppy top fence: To date there have been no road kill records of Echidnas or Koalas within 500 metres of the underpasses. While in 2016/2017 four macropods (recorded at underpass 6 and 10) and one possum (recorded at underpass 14) were recorded as road kill within 500 metres of underpasses, only one macropod was recorded as road kill within 500

metres of an underpass in 2017/2018 (underpass 7). Macropods and possums have been detected using these underpasses.

- Phascogale fence: To date no Brush-tailed Phascogales have been recorded as road kill.
- Frog fence: No amphibian road kill events were recorded within 500 metres of an underpass during 2016/2017 surveys, however, a Dainty Green Tree Frog road kill event was recorded in March 2018 within 500 metres of underpass 12, where frog fence has been installed. The single amphibian record from underpass surveys occurred in underpass 12.

Table 12: Road kill records within 500 metres of an underpass for all monitoring events

	6	7	10	12	13B	14	15
2016/2017	5	6	5	4		5	
2017/2018	6	3	1	1*			

* = large number of Dainty Green Tree Frogs

4. Discussion

4.1 Performance Measures

A summary of the summer 2017/2018 and autumn 2018 survey results in relation to the performance indicators is provided in Table 13.

Table 13: Performance indicators of success.

Performance indicators of success	Discussion
Use of fauna underpasses by a range of the nominated indicator species.	<p>This performance indicator of success has been met.</p> <p>Each underpass has shown use by a range of the nominated fauna groups, with at least two (maximum five) of the six fauna groups being recorded at each underpass in the current monitoring period and at least three (maximum five) of the six fauna groups being recorded at each underpass when considering both monitoring periods. A single frog has been recorded using one underpass to date. Three fauna groups, reptiles, small ground dwelling mammals and macropods, have been recorded using all underpasses.</p> <p>Use of the underpass is assumed to imply complete passage.</p>
Use of the fauna underpass by key target species.	<p>This performance indicator of success has been met at underpass 7 and 12.</p> <p>The key target species nominated in the EMP, the Brush-tailed Phascogale, has been recorded at two underpasses, underpass 7 (where it was not nominated as a targeted species) and 12, during the 2016/2017 and 2017/2018 monitoring periods respectively. An incidental record during Brush-tailed Phascogale monitoring surveys undertaken by Niche in May 2017 also noted a deceased male Brush-tailed Phascogale in underpass 10 (Niche 2017a).</p> <p>Other targeted species, the Common Planigale and Green-thighed Frog, have not been recorded using the underpasses. The likelihood of detecting frog species using current survey methods is low.</p>
Use by fauna with low dispersal ability.	<p>Four fauna classes fall into this category, including frogs, reptiles, small ground dwelling mammals and the echidna.</p> <p>This performance indicator of success has been met.</p> <p>Frogs have been recorded using one underpass, however survey methods do not favour their detection. The Echidna has been recorded using three of the underpasses to date and reptiles and small ground dwelling mammals have been recorded at all underpasses.</p>
Low rate of fauna road strike.	<p>This performance indicator of success has been met.</p> <p>There was a reduction in the weekly road kill rate between both summer and autumn 2016/2017 and 2017/2018 surveys.</p> <p>The rate of road kill per metre in unfenced areas (12,920 metres; 0.0023 records/metre) was slightly higher than that in fenced areas (13,600 metres; 0.0018 records/metre).</p>
No breaches in the fauna fence.	<p>This performance indicator of success has been met.</p> <p>No fauna was recorded on the highway side of the fauna fencing during fence inspections. However, the Dainty Tree Frog road kill event occurred where frog fence has been installed and in the vicinity of constructed Green-thighed Frog ponds. While no Green-thighed Frogs have been identified as road kill, it should be noted that inspecting all road kill individuals would pose a safety issue and was not therefore possible. Breaches of the neoprene frog fence in this location are considered to have occurred. However, as the EMP states that the success of the frog fencing is to be determined by the absence specifically of Green-thighed Frog road strike, this performance indicator of success has been met. As discussed in section 3.3.1, the neoprene fencing has been replaced with vermin-proof mesh. .</p>
Additional determinants of success specified the EMP	
Absence of specific road kill fauna within 500 metres of underpasses.	<p>This performance indicator of success has been met for one (phascogale fence) of the three fauna fence types.</p> <p>One macropod road kill occurred within 500 metres of underpass 7 in 2017/2018. Four macropods and one possum occurred within 500 metres of underpass 6, 10 and 14 in 2016/2017.</p>

5. Recommendations

5.1 Contingency Measures

The EMP lists potential problems and contingency measures for various components of the monitoring program. Those that are related to the underpass monitoring program are listed and discussed in Table 14.

Table 14: Contingency measures

Potential Problem	Contingency Measure proposed in EMP	Discussion of proposed measure
Low usage rates of native fauna	<ul style="list-style-type: none"> Review/modify habitat structure adjoining the underpass 	<p>All underpasses have shown use by a range of the nominated fauna groups, with at least three of the six fauna groups being recorded at each underpass.</p> <p>This contingency measure is not considered relevant.</p>
A range of indicator species groups not using the underpass structure	<ul style="list-style-type: none"> Review/modify underpass fauna furniture or ground cover attributes adjoining the underpass. Consider additional monitoring Consult with EPA 	<p>Not all fauna groups and target species have been detected at all underpasses during the current monitoring event or to date. Frogs have been recorded at a single underpass (12) and the key target species has been recorded at two underpasses (7 and 12).</p> <p>These contingency measures are considered relevant.</p>
High visitation/usage rates by exotic predators	<ul style="list-style-type: none"> Review/modify design. Seek advice from LHPA concerning control methods. 	<p>While “High visitation/usage rates” was not defined in the EMP, high usage rates has been considered as where visitation by exotic predators equates to greater than 25% of visitations to the underpass or as visitations by exotic predators on more than 25% of the days monitored. This is based on previous underpass monitoring outcomes (Sandpiper Ecological 2015, Sandpiper Ecological 2017) and in consultation with North Coast Local Land Services (Biosecurity Manager).</p> <p>Exotic predators were recorded using five underpasses in 2017/2018. The highest use by exotic predators was recorded at underpass 10 (51.9% of records including cats and dogs), the only underpass that did not record exotic predators in the 2016/2017 monitoring period.</p> <p>This contingency measure is currently considered relevant for underpass 10, and was relevant for underpass 7 after the 2016/2017 monitoring period.</p>
Unacceptable rates of road strike in the vicinity of the underpasses (<250m) [sic]	<ul style="list-style-type: none"> Review/modify fauna exclusion fencing design, location or extent depending on road struck species. 	<p>Road kill within 500 metres of underpasses was analysed, as per the EMP text. The total number of records within 500 metres of an underpass decreased in 2017/2018, however a similar number of records occurred within 500 metres of underpass 6 in both monitoring events.</p> <p>This contingency measure is considered relevant for underpass 6.</p>
Road strike of species which the fence is designed to exclude	<ul style="list-style-type: none"> Inspect fence for breaches and inform maintenance as necessary. Review fence design. 	<p>Only one Macropod was recorded as road kill within 500 metres of underpass 7, however a Dainty Green Tree Frog road kill event occurred where frog fence had been installed to exclude Green-thighed Frogs from the highway.</p> <p>These contingency measures are considered relevant for frog fence.</p>

5.2 Recommendations

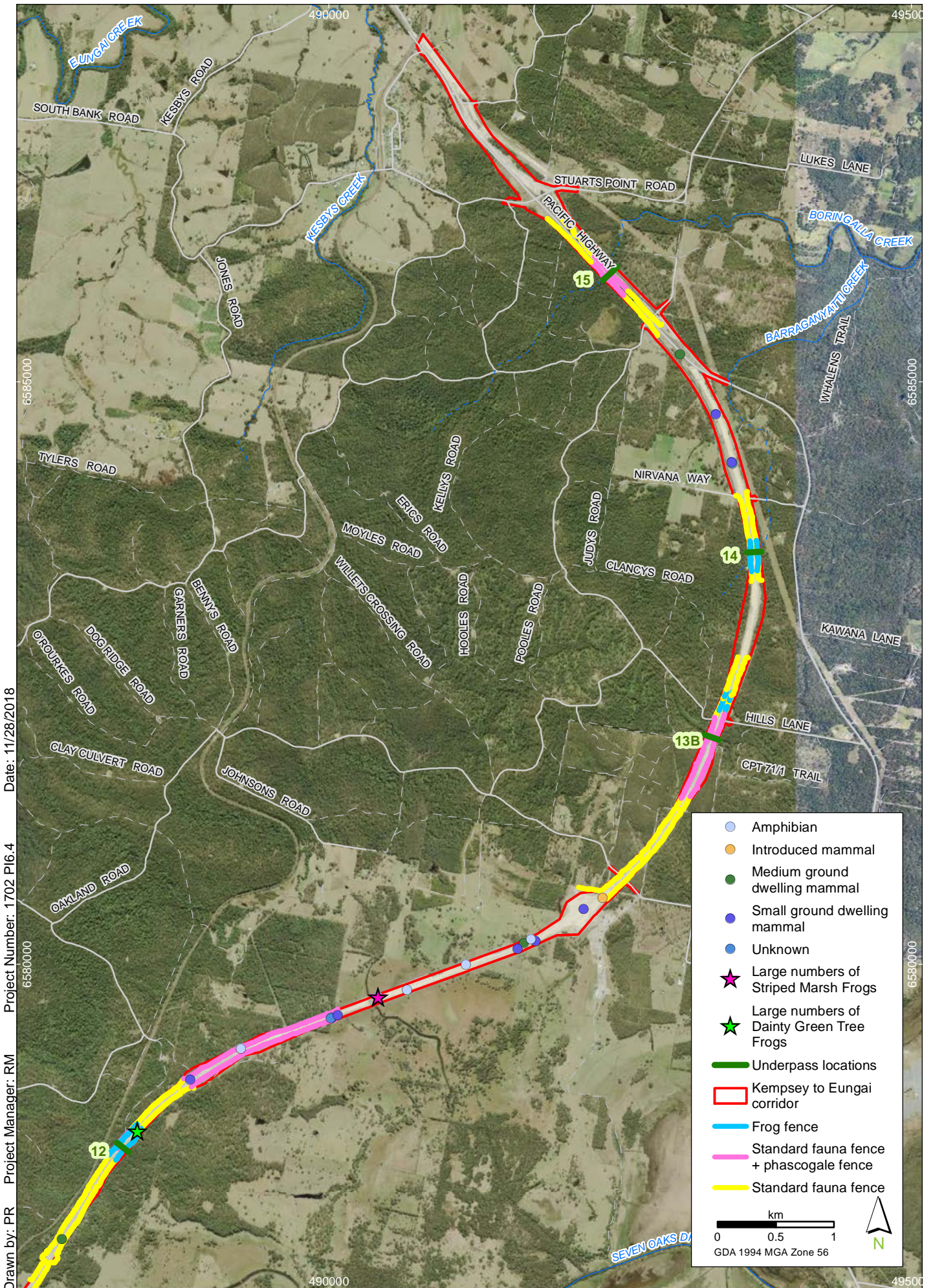
The recommendations provided in Table 15 aim to address proposed contingency measures and to meet performance criteria.

Table 15: Recommendations

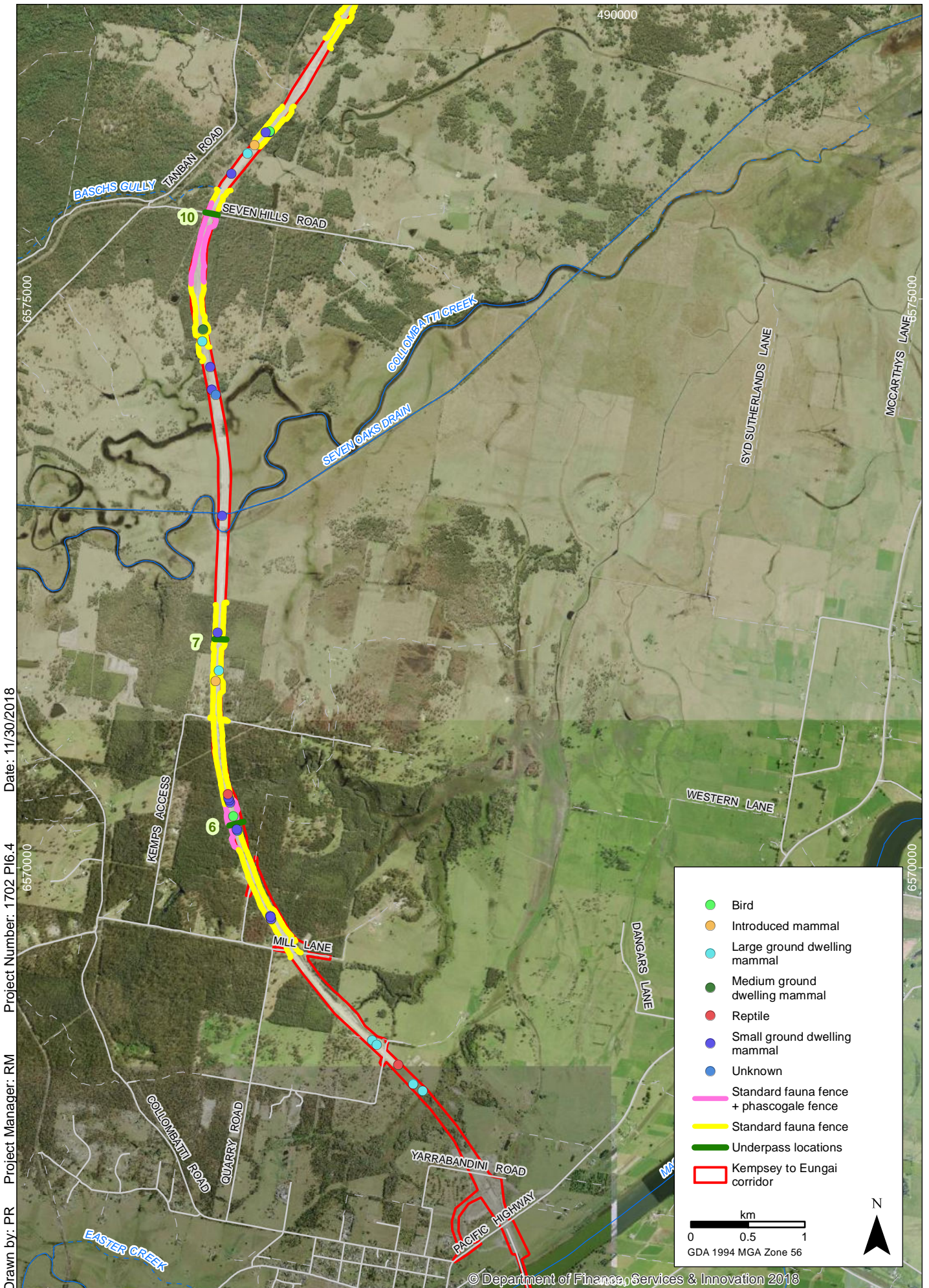
Problem identified	Discussion/Recommendations and actions
Fauna fence general maintenance	<ul style="list-style-type: none"> All identified maintenance issues (Table 21) should be addressed.
Absence of use of the fauna underpasses by key target species	<ul style="list-style-type: none"> Continue monitoring as per the EMP as this will add to the number of records at each underpass. The data pool of fauna detected using underpasses has increased since the 2016/2017 monitoring and will increase as more information is acquired in subsequent surveys.
Absence of some fauna groups from select underpasses.	<ul style="list-style-type: none"> Consider increasing remote camera monitoring periods to increase detection opportunity.
Lack of evidence of use by frog species.	<ul style="list-style-type: none"> The likelihood of detecting the Green-thighed Frog and other amphibians using current survey methods is low. Consider undertaking targeted frog surveys/dip netting for tadpoles during/following suitable weather conditions (underpass 10 does not contain a wet area).
Road kill records of specific fauna within 500 metres of underpasses.	<ul style="list-style-type: none"> Continue monitoring as per the EMP. As per recommendations in Niche 2018, consideration should be given to the inspection of the complete length of the fauna fence in the vicinity of underpass 6, with maintenance undertaken where necessary, due to a similar level of road kill between the two monitoring periods where fauna fence is in place. Dainty Green Tree Frog road kill event: the neoprene frog fence has been replaced with vermin-proof mesh throughout the entire Project. The success of this fence type will be determined with ongoing monitoring.
High visitation/usage rates by exotic predators	<ul style="list-style-type: none"> As per recommendations in Niche 2018, in collaboration with Local Land Services, baiting for introduced predators at underpass 7 commenced in October 2018. Consideration should be given to extending this baiting program to underpass 10 where predators represented approximately 50% of records.

6. References

- Lewis, B.D. (2005). Kempsey to Eungai Pacific Highway Upgrade: Fauna Survey. Report prepared by Lewis Ecological Surveys for Parsons Brinckerhoff-Sydney.
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- Niche (2016). Frederickton to Eungai Pacific Highway Upgrade Road kill Monitoring 2016. Prepared for Roads and Maritime Services, Port Macquarie, NSW.
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- Niche (2017b). Kempsey Bypass: Fauna Mitigation Monitoring Results 2016-2017. Prepared for Roads and Maritime Services, Port Macquarie, NSW.
- Niche (2017c). Road Kill Monitoring 2016. Road opening - Frederickton to Eungai Pacific Highway Upgrade. Prepared for Roads and Maritime Services, Port Macquarie, NSW.
- Niche (2018). Fauna Underpass and Associated Fauna Fence Monitoring 2016/2017. Frederickton to Eungai Pacific Highway Upgrade. Prepared for Roads and Maritime Services, Port Macquarie, NSW.
- Parsons Brinckerhoff. (2006). Kempsey to Eungai: Upgrading the Pacific Highway Project Application Report Supporting Information Ecological Assessment. Report prepared for Roads and Traffic Authority NSW.
- RMS (2016). Frederickton to Eungai Pacific Highway Upgrade Ecological Monitoring Program. Roads and Maritime Update to report prepared by Lewis Ecological Surveys, May 2016.
- Sandpiper Ecological (2015). Pacific Highway Upgrade: Glenugie. Operation phase fauna crossing structure monitoring program. Report prepared for NSW Roads and Maritime Services.
- Sandpiper Ecological (2017). Pacific Highway Upgrade: Sapphire to Woolgoolga. Operation phase fauna crossing monitoring program – year 1. Report prepared for NSW Roads and Maritime Services.

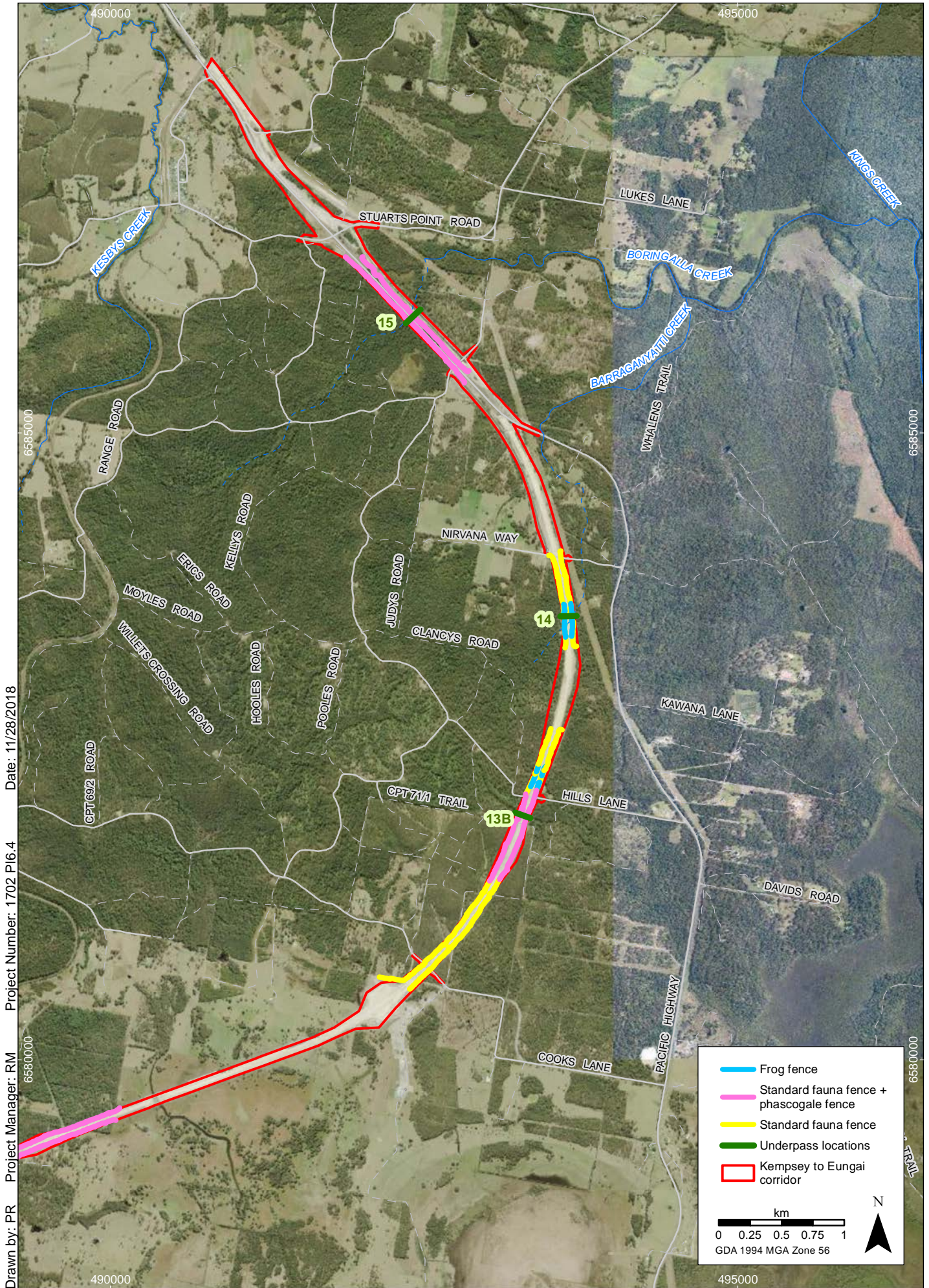


Drawn by: PR Project Manager: RM Date: 11/28/2018 Project Number: 1702_P16.4



2017/2018 road kill records
 Pacific Highway Upgrade - Frederickton to Eungai

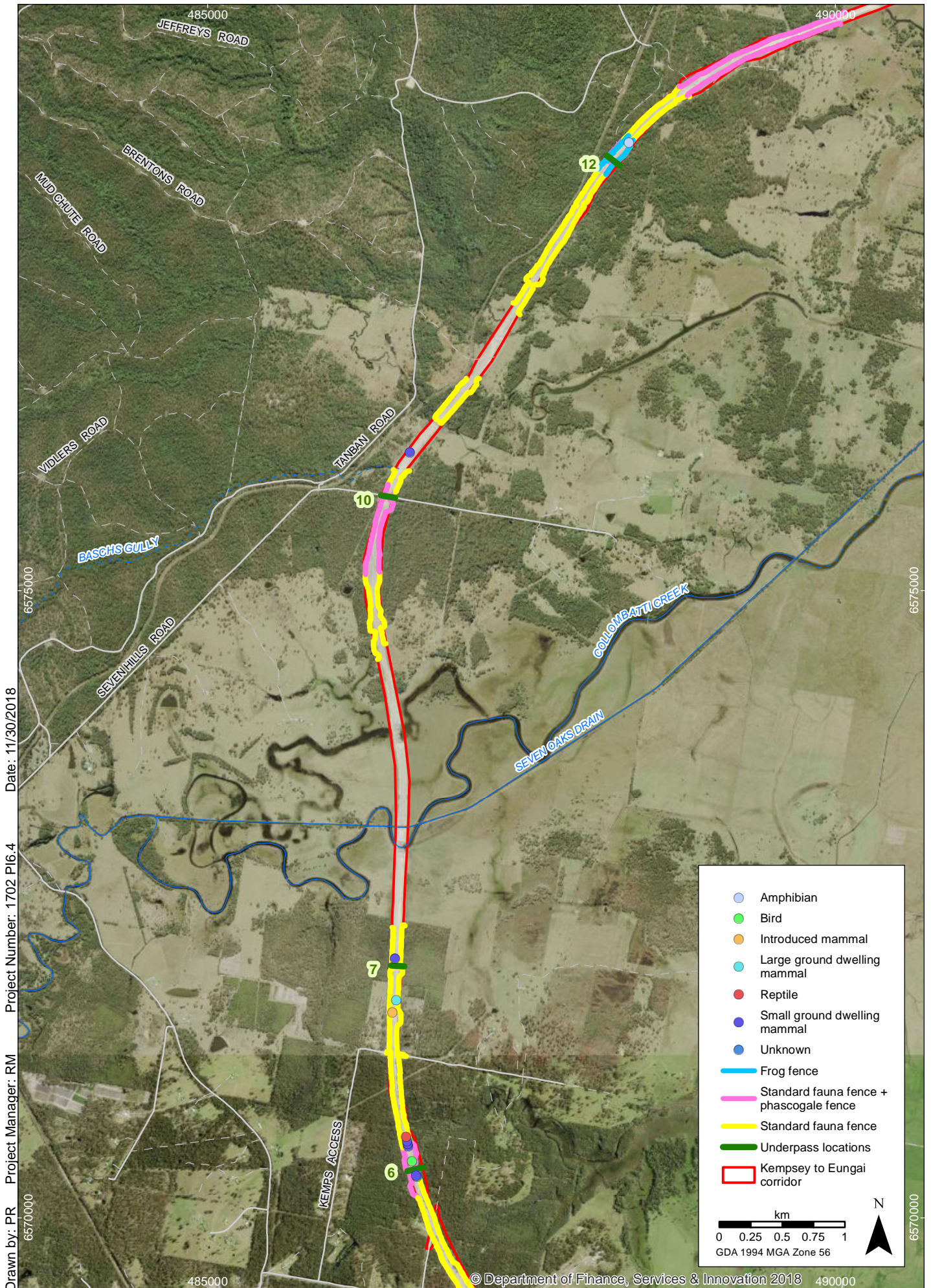
Imagery: (c) LPI NSW 2014 **FIGURE 2b**



Drawn by: PR Project Manager: RM Project Number: 1702 PI6.4 Date: 11/28/2018

2017/2018 road kill within 500 m of underpasses
Pacific Highway Upgrade - Frederickton to Eungai

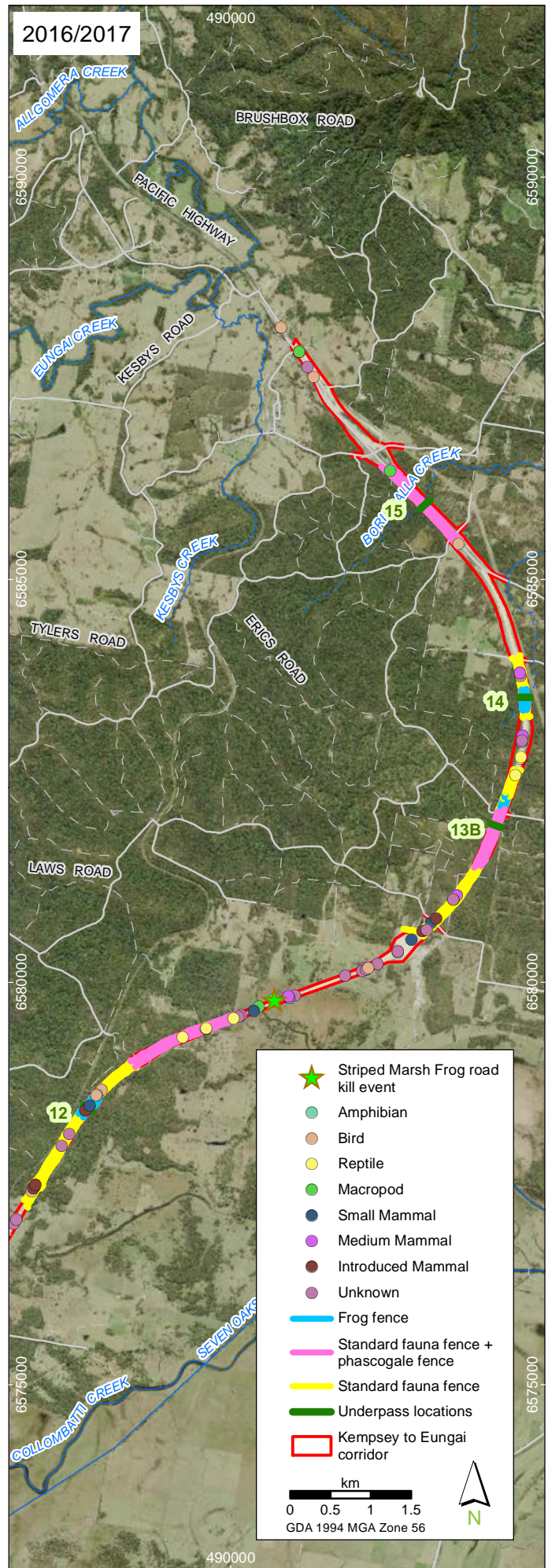
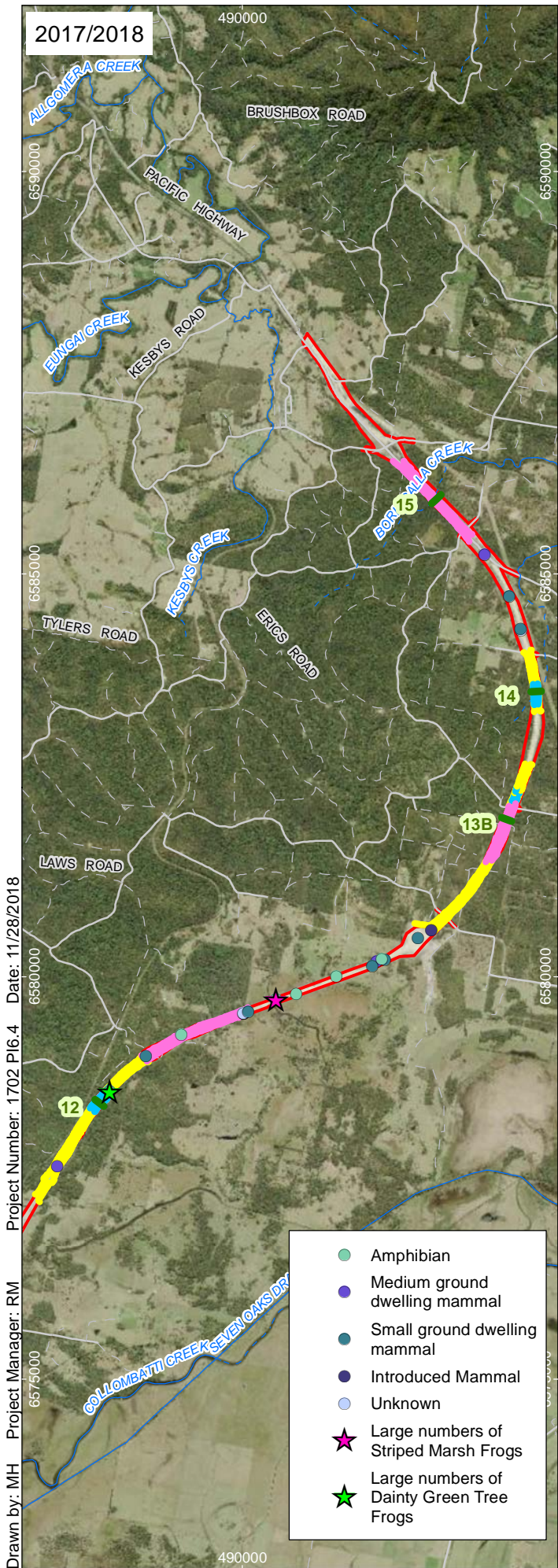
Imagery: (c) LPI NSW 2014 **FIGURE 3a**



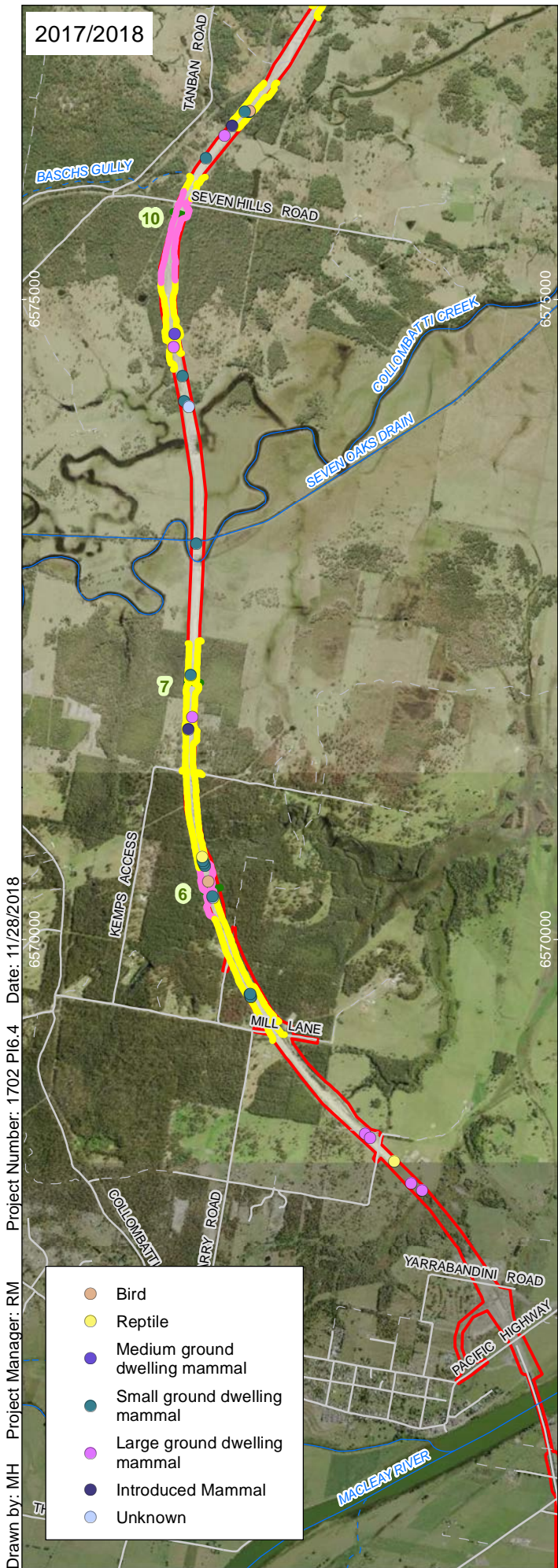
Drawn by: PR Project Manager: RM Date: 11/30/2018 Project Number: 1702 PI6.4

2017/2018 road kill within 500 m of underpasses
Pacific Highway Upgrade - Frederickton to Eungai

Imagery: (c) LPI NSW 2014 **FIGURE 3b**



Comparison of 2016/2017 and 2017/2018 road kill records
Pacific Highway Upgrade - Frederickton to Eungai



Comparison of 2016/2017 and 2017/2018 road kill records
 Pacific Highway Upgrade - Frederickton to Eungai



Plate 1: Echidna at underpass 13B, autumn 2018



Plate 2: Brush-tailed Phascogale at underpass 12, autumn 2018

Annex 1 – Underpasses

Table 16: Summer 2017/2018 camera details

Site	Camera	Operating for entire period	Total # photos	Install date	Retrieve date	operational days	Location (top/bottom)	direction facing (E/W)	# of fauna records	Note
6	68	Yes	438	04/12/2017	23/02/2018	65	top	E	78	
6	175	Yes	207	04/12/2017	23/02/2018	79	bottom	E	26	
7	60	Yes	434	04/12/2017	21/02/2018	80	top	W	58	
7	174	Yes	202	04/12/2017	21/02/2018	79	bottom	W	41	
10	162	No	5953	04/12/2017	21/02/2018	21	bottom	W	5	Frequent vegetation triggers – battery expiry
10	166	No	7323	04/12/2017	21/02/2018	40	bottom	E	0	Frequent vegetation triggers – battery expiry
12	167	Yes	658	04/12/2017	22/02/2018	81	top	E	95	
12	171	Yes	293	04/12/2017	22/02/2018	78	bottom	E	43	
13B	163	Yes	203	04/12/2017	22/02/2018	78	bottom	E	25	
13B	173	Yes	131	04/12/2017	22/02/2018	81	top	E	17	
14	169	No	35	04/12/2017	22/02/2018	20	bottom	E	12	Last photo 24/12/17
14	170	Yes	283	04/12/2017	22/02/2018	79	top	E	52	
15	63	No	54	04/12/2017	22/02/2018	26	bottom	E	2	Camera malfunction 30/12/17
15	177	Yes	121	04/12/2017	22/02/2018	80	top	E	26	

Table 17: Autumn 2018 camera details

Site	Camera	Operating for entire period	Total # photos	Install date	Retrieve date	operational days	Location (top/bottom)	direction facing (E/W)	# of fauna records	Note
6	173	Yes	629	15/03/2018	29/05/2018	75	top	E	123	
6	171	No	15	15/03/2018	29/05/2018	5	bottom	E	2	Possible malfunction
7	167	Yes	525	15/03/2018	29/05/2018	75	top	W	98	
7	177	No	0	15/03/2018	04/04/2018	0	bottom	W	0	Malfunction due to flooding
10	163	No	0	15/03/2018	stolen	0	bottom	E	0	Stolen
10	176	Yes	4560	15/03/2018	29/05/2018	72	bottom	S	38	
12	179	Yes	306	15/03/2018	29/05/2018	75	top	E	49	
12	160	Yes	86	15/03/2018	29/05/2018	75	bottom	E	0	
13B	162	Yes	81	15/03/2018	29/05/2018	72	top	E	0	
13B	178	Yes	420	15/03/2018	29/05/2018	75	bottom	E	46	
14	166	Yes	97	15/03/2018	29/05/2018	72	top	E	12	
14	170	No	23	15/03/2018	04/04/2018	5	bottom	W	1	Malfunction due to flooding
15	68	No	180	15/03/2018	29/05/2018	38	top	W	38	
15	168	No	36	15/03/2018	04/04/2018	20	bottom	W	0	Malfunction due to flooding

Table 18: 2017/2018 remote camera records

Species	Underpass 6		Underpass 7		Underpass 10		Underpass 12		Underpass 13B		Underpass 14		Underpass 15	
	summer	autumn	summer	autumn	summer	autumn	summer	autumn	summer	autumn	summer	autumn	summer	autumn
<i>Rattus sp.</i>	Y	Y	Y	Y			Y	Y	Y	Y	Y	Y	Y	
<i>Rattus rattus</i>	Y	Y	Y	Y			Y	Y	Y	Y	Y	Y	Y	Y
<i>Rattus fuscipes</i>				Y						Y			Y	Y
Unknown rodent		Y					Y	Y		Y	Y	Y		Y
Water Rat (<i>Hydromys chrysogaster</i>)							Y							
Small mammal/probable Antechinus	Y						Y				Y			Y
Brush-tailed Phascogale (<i>Phascogale tapoatafa</i>)								Y						
Red-necked Wallaby (<i>Macropus rufogriseus</i>)	Y													
Eastern Grey Kangaroo (<i>Macopus giganteus</i>)										Y				
Unknown Macropod	Y		Y				Y	Y		Y				
Brushtail Possum (<i>Trichosurus sp.</i>)			Y	Y			Y							
Mountain Brushtail Possum (<i>Trichosurus caninus</i>)								Y						
Bandicoot					Y	Y			Y		Y			
Northern Brown Bandicoot (<i>Isodon macrourus</i>)	Y										Y			
Echidna (<i>Tachyglossus aculeatus</i>)			Y			Y				Y				
Bat				Y			Y							
Water Dragon (<i>Intellagama lesueurii</i>)	Y						Y	Y	Y		Y	Y	Y	Y
Lace Monitor (<i>Varanus varius</i>)	Y	Y	Y				Y		Y	Y	Y	Y		
Skink			Y	Y										
Amphibian							Y							
Pacific Black Duck (<i>Anas superciliosa</i>)							Y							
Bird							Y	Y						Y

Species	Underpass 6		Underpass 7		Underpass 10		Underpass 12		Underpass 13B		Underpass 14		Underpass 15	
	summer	autumn	summer	autumn	summer	autumn	summer	autumn	summer	autumn	summer	autumn	summer	autumn
Cat (<i>Felis catus</i>)			Y		Y	Y								
Dog	Y					Y	Y							
Hare (<i>Lepus europeaus</i>)			Y											
Fox (<i>Vulpes vulpes</i>)										Y				

Table 19: 2017/2018 hair tube results

Underpass	6		7		10		12		13B		14		15	
Species	S	A	S	A	S	A	S	A	S	A	S	A	S	A
<i>Antechinus</i> sp.					√									
<i>Rattus</i> sp.		√				√			√		√		√	
Rodent		√	√	√		√	√		√	√	√		√	√
House Mouse (<i>Mus musculus</i>)										√				
Bandicoot (<i>Isodon macrourus</i>)		√										√		

Table 20: 2017/2018 scats and tracks

Underpass	6		7		10		12		13B		14		15	
Fauna group	S	A	S	A	S	A	S	A	S	A	S	A	S	A
Possum	C		T				C							
Rodent	C	C	T	C										
Macropod	C													
Microbat		C		C				C		C		C		
Reptile		C				I								

S = summer, A = autumn, I = observed, C = scat, T = track

Annex 2 – Fauna Fence

Table 21: 2017/2018 250 metre fauna fence inspections

Period	Breach	Site	Bearing	Easting	Northing	Observation / maintenance required
summer	N	6	NE	NA	NA	Overgrown vegetation along length.
autumn	N	6	NE	NA	NA	Extensive vegetation clearing required. Inspection and access difficult.
summer	N	6	SE	NA	NA	Overgrown vegetation in vicinity of underpass
autumn	N	6	SE	NA	NA	Vegetation clearing required.
summer	N	6	SW	486670.00	6570156	Hole under gate
autumn	N	6	SW	486634	6570327	Gap under gate
autumn	N	6	SW	NA	NA	Vegetation clearing required immediately south of underpass
summer	N	7	NE	NA	NA	Vegetation removal required
autumn	N	7	NE	NA	NA	Extensive vegetation clearing required. Inspection and access difficult.
summer	N	7	NW	NA	NA	Vegetation removal required
summer	N	7	NW	486478	6572130	Gap under fence
autumn	N	7	NW	NA	NA	Vegetation clearing required.
autumn	N	7	NW	NA	NA	Gap under fence - erosion and digging
summer	N	7	SE	NA	NA	Vegetation removal required
autumn	N	7	SE	486525	6571857	Vegetation clearing required
autumn	N	7	SE	NA	NA	Vegetation clearing required in vicinity of underpass
autumn	N	7	SE	486525	6571770	Gap under fence
summer	N	7	SW	NA	NA	Vegetation removal required
autumn	N	7	SW	NA	NA	Vegetation clearing required.
summer	N	10	NE	486491	6575770	Gate stuck open
summer	N	10	NE	486478	6572130	200m vegetation control required
autumn	N	10	NE	NA	NA	Gate stuck open
autumn	N	10	NE	NA	NA	Extensive vegetation clearing required. Inspection and access difficult.
summer	N	10	NW	NA	NA	Vegetation removal required
summer	N	10	SE	486396	6575559	Frog fence fallen down
summer	N	10	SE	NA	NA	First 50-100m vegetation control required
autumn	N	10	SE	NA	NA	Vegetation clearing required.
summer	N	10	SW	NA	NA	Vegetation removal required
autumn	N	10	SW	486343	6575592	Overgrown vegetation on frog fence
autumn	N	10	SW	486352	6575615	Vegetation clearing required.
autumn	N	10	SW	486467	6575915	Tree fallen on fence
summer	N	12	NE	NA	NA	Overgrown vegetation on fence, almost impassable
autumn	N	12	NE	488232	6578420	Opening in frog fence
autumn	N	12	NE	NA	NA	Extensive vegetation clearing required. Inspection and access difficult.

Period	Breach	Site	Bearing	Easting	Northing	Observation / maintenance required
autumn	N	12	NW	488274	6578555	Gap under frog fence
summer	N	12	SE	NA	NA	Overgrown vegetation on fence
autumn	N	12	SE	NA	NA	Extensive vegetation clearing required. Inspection and access difficult.
summer	N	12	SW	488081	6578323	Tree growing on fence
autumn	N	12	SW	488427	6578873	Gap in frog fence
autumn	N	12	SW	488142	6578408	Fence damage and frog fence down
autumn	N	12	SW	488190	6578444	Gaps in frog fence around underpass and culverts at corners.
autumn	N	12	SW	NA	NA	Vegetation clearing required.
summer	N	14	NE	NA	NA	Frog fence requires replacement (burnt) and maintenance
autumn	N	14	NE	493678	6583575	Gap in frog fence and burnt frog fence
autumn	N	14	NE	493672	6583609	Gap in frog fence
summer	N	14	NW	493618	6583576	Frog fence tear
autumn	N	14	NW	493613	6583585	Frog fence gaps and fallen down at corner
summer	N	14	SE	NA	NA	Some vegetation removal required
autumn	N	14	SE	493688	6583315	Vegetation clearing required- growth through fence.
summer	N	14	SW	493622	6583434	Gap frog fence
summer	N	14	SW	493617	6583408	Frog fence down
summer	N	14	SW	493622	6583385	Frog fence down
autumn	N	14	SW	493614	6583401	Frog fence down in three locations
summer	N	15	NE	NA	NA	Vegetation removal required within sediment retention area
autumn	N	15	NE	492311	6586050	Gaps in phascogale fence
autumn	N	15	NE	492299	6586077	Gaps in phascogale fence
autumn	N	15	NE	NA	NA	Vegetation clearing required within 100 m of underpass
autumn	N	15	NW	NA	NA	Patchy areas requiring vegetation clearing.
summer	N	15	SE	NA	NA	Vegetation removal required
autumn	N	15	SE	NA	NA	Vegetation clearing required within 100 m of underpass
autumn	N	15	SW	NA	NA	Vegetation clearing required from 100 m
autumn	N	13B	NE	493430	6582187	Vegetation clearing required. Frog fence overgrown.
summer	N	13B	NW	NA	NA	Vegetation removal required
autumn	N	13B	NW	NA	NA	Some vegetation clearing required, notably in vicinity of underpass
summer	N	13B	SE	493315	6581942	Gap in drainage channel
summer	N	13B	SE	NA	NA	Frog Fence Gap
autumn	N	13B	SE	493322	6581915	Gap in frog fence and under frog fence in drainage channel
autumn	N	13B	SE	493313	6581880	Vegetation clearing required
summer	N	13B	SW	NA	NA	Vegetation removal required
autumn	N	13B	SW	493254	6581950	Branch fallen on fence
autumn	N	13B	SW	NA	NA	Vegetation clearing required

Annex 3 – Road Kill

Table 22: 2017/2018 road kill data

Period	Date	Latitude	Longitude	Species/vertebrate group	Animal group
Summer	01/12/2017	-30.94686	152.86134	Kangaroo	Large ground dwelling mammal
Summer	01/12/2017	-31.01722	152.87271	Large Mammal	Large ground dwelling mammal
Summer	01/12/2017	-30.99944	152.85994	Pigeon	Bird
Summer	01/12/2017	-31.00737	152.86332	Unk small mammal	Small ground dwelling mammal
Summer	01/12/2017	-30.98487	152.85852	Unk small mammal	Small ground dwelling mammal
Summer	01/12/2017	-30.9452	152.86337	Unk small mammal	Small ground dwelling mammal
Summer	01/12/2017	-30.99835	152.85964	Unk small mammal	Small ground dwelling mammal
Summer	07/12/2017	-30.8661	152.92693	Bandicoot	Medium ground dwelling mammal
Summer	07/12/2017	-30.91745	152.8956	Rodent	Small ground dwelling mammal
Summer	07/12/2017	-30.87453	152.93162	Unk mammal	Unknown
Summer	07/12/2017	-31.00058	152.86033	Unk mammal	Unknown
Summer	14/12/2017	-31.00758	152.86341	Rabbit	Introduced mammal
Summer	14/12/2017	-30.99817	152.85959	Rodent	Small ground dwelling mammal
Summer	14/12/2017	-31.00758	152.86341	Unk small mammal	Small ground dwelling mammal
Summer	14/12/2017	-30.91746	152.8956	Unk small mammal	Small ground dwelling mammal
Summer	20/12/2017	-30.94513	152.86339	Bird	Bird
Summer	20/12/2017	-30.91169	152.91289	Medium mammal	Medium ground dwelling mammal
Summer	20/12/2017	-31.02071	152.87648	Wallaby	Large ground dwelling mammal
Summer	21/12/2017	-30.98873	152.85832	Rabbit	Introduced mammal
Summer	21/12/2017	-30.9462	152.86197	Rabbit	Introduced mammal
Summer	21/12/2017	-30.90819	152.91995	Rabbit	Introduced mammal
Summer	21/12/2017	-30.94846	152.85982	Small mammal	Small ground dwelling mammal
Summer	21/12/2017	-30.9452	152.86299	Small mammal	Small ground dwelling mammal
Summer	21/12/2017	-30.87443	152.93153	Small mammal	Small ground dwelling mammal
Summer	21/12/2017	-30.91152	152.9139	Small mammal	Small ground dwelling mammal
Summer	21/12/2017	-30.91215	152.9123	Small mammal	Small ground dwelling mammal
Summer	21/12/2017	-30.96382	152.85787	Small mammal	Small ground dwelling mammal
Summer	21/12/2017	-30.99799	152.85951	Small mammal	Small ground dwelling mammal
Summer	21/12/2017	-31.00049	152.86026	Small mammal	Small ground dwelling mammal
Summer	21/12/2017	-30.91748	152.89552	Unknown	Unknown
Summer	21/12/2017	-31.0074	152.86336	Unk small mammal	Small ground dwelling mammal
Summer	21/12/2017	-30.9656	152.85803	Unk small mammal	Small ground dwelling mammal
Autumn	22/03/2018	-30.92622	152.87812	Dainty Green Tree Frogs	Amphibian
Autumn	22/03/2018	-30.99769	152.85946	Diamond Python	Reptile
Autumn	22/03/2018	-30.91139	152.91351	End of Frog Kills	Amphibian

Period	Date	Latitude	Longitude	Species/vertebrate group	Animal group
Autumn	22/03/2018	-30.91335	152.90765	Green Tree Frogs	Amphibian
Autumn	22/03/2018	-30.96179	152.85715	Kangaroo	Large ground dwelling mammal
Autumn	22/03/2018	-30.98786	152.85862	Kangaroo	Large ground dwelling mammal
Autumn	22/03/2018	-30.97561	152.85897	Rodent	Small ground dwelling mammal
Autumn	22/03/2018	-30.91985	152.88743	Striped Marsh Frogs	Amphibian
Autumn	22/03/2018	-30.91587	152.89976	Striped Marsh Frogs	Amphibian
Autumn	22/03/2018	-30.91532	152.90238	Striped Marsh Frogs	Amphibian
Autumn	22/03/2018	-31.02123	152.87737	unk large mammal	Large ground dwelling mammal
Autumn	22/03/2018	-31.01754	152.87313	Unk macropod	Large ground dwelling mammal
Autumn	22/03/2018	-30.96601	152.85838	Unk mammal	Unknown
Autumn	28/03/2018	-30.93459	152.87135	medium mammal	Medium ground dwelling mammal
Autumn	28/03/2018	-30.92226	152.88288	small mammal	Small ground dwelling mammal
Autumn	28/03/2018	-30.90906	152.91822	small mammal	Small ground dwelling mammal
Autumn	28/03/2018	-30.91728	152.89614	small mammal	Small ground dwelling mammal
Autumn	04/04/2018	-30.96084	152.85724	Bandicoot	Medium ground dwelling mammal
Autumn	04/04/2018	-30.87076	152.93013	small mammal	Small ground dwelling mammal
Autumn	04/04/2018	-31.01917	152.87511	Snake/Lizard	Reptile
Autumn	11/04/2018	486454	6575772	bird	Bird
Autumn	11/04/2018	488529	6567708	macropod	Large ground dwelling mammal
Autumn	11/04/2018	487278	6569061	macropod	Large ground dwelling mammal
Autumn	11/04/2018	492214	6580496	small mammal	Small ground dwelling mammal
Autumn	11/04/2018	492608	6580847	Snake/Lizard	Reptile

Niche Environment and Heritage

A specialist environmental and heritage consultancy.

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