Warrell Creek to Nambucca Heads Pacific Highway Upgrade

Commonwealth Approval EPBC 2013/7101 Annual Compliance Report February 2018 – February 2019

Roads and Maritime Services | May 2019

NSW GOVERNMENT

THIS PAGE LEFT INTENTIONALLY BLANK

Document control

Report name	WC2NH EPBC Annual Compliance Report 2018-2019
Document version	Revision 2.0
Date of publication	9 May 2019

Terms and Abbreviations

BOS	Biodiversity Offset Strategy
CEMP	Construction Environmental Management Plan
Clear Milkvine	Marsdenia longiloba
Cryptic Forest Twiner	Tylophora Woollsii
DoEE	Federal Department of Environment and Energy
DPE	State Department of Planning and Environment
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
FFMP	Flora and Fauna Management Plan
GBF	Giant Barred Frog
GBFMP	Giant Barred Frog Management Plan
Geolink	Geolink – Project Ecologist for WC2NH Project
GHFF	Grey-headed Flying-fox
Pacifico	Acciona Ferrovial Joint Venture (the Roads and Maritime's road construction contractor for the project).
STQ	Spotted-Tail Quoll
TFMP	Threatened Flora Management Plan
WC2NH	Warrell Creek to Nambucca Heads Pacific Highway Upgrade Project

Contents

1. Introduction....1
1.1. Purpose of this document....1
1.2. Key dates....1
1.3. Responsibility for compliance....1
1.4. NSW planning approval....1
1.5. Definitions for action status conditions....2
1.6. Non Compliances with EPBC Conditions....2
2. Compliance Tracking Tables....3
2.1. Condition 1....3
2.2. Condition 2....5
2.3. Condition 3....6
2.4. Condition 4....21
2.5. Condition 5....22
2.6. Condition 6....23
2.7. Condition 7....24
2.8. Condition 8....25
2.9. Condition 9....26
2.10. Condition 10....27
2.11. Condition 11....28
2.12. Condition 12....29
2.13. Condition 13....31
2.14. Condition 14....32
2.15. Condition 15....33
2.16. Condition 16....34
2.17. Condition 17....35
2.18. Condition 18....36
2.19. Condition 19....37
2.20. Condition 20....38
2.21. Condition 21....39
2.22. Condition 22....40
2.23. Condition 23....41
2.24. Condition 24....42
2.25. Condition 25....43
2.26. Condition 26....44
Attachment 1 Ecological Monitoring Report 2017-2018....45

1. Introduction

1.1. Purpose of this document

The purpose of this document is to facilitate demonstration by Roads and Maritime Services (Roads and Maritime) of satisfactory compliance with the Commonwealth approval conditions for the Warrell Creek to Nambucca Heads Pacific Highway Upgrade project (the Project) with particular reference to Condition 19 and 20. This report covers the forth reporting period from February 2018 to February 2019.

For each condition, one or more actions are identified which, once implemented, will achieve satisfactory compliance with the condition. Where appropriate, the timing for completion of individual actions is identified.

For each action, the minimum relevant documentation to support demonstration of compliance is identified. This documentation would inform any future compliance audit.

Where an approval condition makes reference to information being provided to the Commonwealth Minister for the Environment, the associated action(s) assumes that this information will be provided, in the first instance, to the Commonwealth Department of the Environment.

1.2. Key dates

The timing for compliance with certain approval conditions is linked to specific dates as follows:

- Commonwealth approval: 11 Dec 2014
- Start of construction: 9 Feb 2015
- Scheduled completion of construction: mid 2019
- Expiry of Commonwealth approval 31 Dec 2064

1.3. Responsibility for compliance

Responsibility for compliance with all approval conditions sits with Roads & Maritime.

1.4. NSW planning approval

Condition 3 and 4 (of the Commonwealth approval) provides for the use of plans, strategies or reports required under the NSW approval to satisfy the requirements of the Commonwealth approval, subject to provision of a separate document demonstrating how the document addresses the relevant Commonwealth approval requirements.

Specialists in the fields of flora and fauna have been engaged by Roads & Maritime and the construction contractor to undertake various ecology-related management activities with regard to complying with the NSW planning approval and the CEMP.

This document contains actions relevant to compliance with the NSW planning approval that are also considered to satisfy compliance with Commonwealth approval requirements.

1.5. Definitions for action status conditions

TBA	To Be Arranged - Further works required prior to starting action.
In progress	Action initiated but not yet complete.
Ongoing	Action in place but ongoing works required to ensure compliance.
Complete	Action completed.

1.6. Non Compliances with EPBC Conditions

No non-compliances against the approval conditions were identified during the third reporting period (February 2018 – February 2019).

2. Compliance Tracking Tables

The following sections provide a compliance status for the reporting period for the 26 conditions of approval. Note: where relevant, the conditions have been amended to reflect the current approval variation.

2.1. Condition 1

The approval holder must not clear more than:

a) 17.80 hectares (ha) of **Slender Marsdenia/Clear Milkvine and Woolls Tylophora/Cryptic Forest Twiner habitat**;

b) 106.6 ha of **Koala habitat**, including 86.50 ha critical to the survival;

c) 106.6 ha of **Grey-headed Flying-fox habitat**, comprised of 103.50 ha of foraging habitat critical to survival and 3.10 ha of roosting habitat critical to survival;

d) 114.1 ha of **Spotted-tail Quoll habitat**;

e) 0.70 ha of **Giant Barred Frog habitat**;

f) 3.40 ha of Australian Painted Snipe (*Rostratula australis*) wetland habitat;

g) 5.3 ha of habitat for the Regent Honeyeater (*Anthochaera phrygia*) and Swift Parrot (*Lathamus discolour*) wintering habitat, comprising dry schlerophyll forests containing Swamp Mahogany; and

h) 26.1 ha of Milky Silkpod (*Parsonsia dorrigoensis*) habitat, comprising Mixed Floodplain Forest, Flooded Gum Open Forest and White Mahogany/Grey Gum/Ironbark Open Forest.

	Action	Timing	Status	Compliance evidence
1.1	Progressive review of area cleared	Regularly during construction	Compliant Ongoing	Record of clearing numbers provided in monthly report from Contractor to RMS. Refer to Table 1.1 below for clearing quantities for the reporting period.
1.2	Confirm clearing limitation targets have been met	Post-construction	TBA	As built survey of actual clearing area. Not able to action until after completion of clearing. Memo/short report

Table 1.1: Clearing Quantities for the reporting period.

Habitat Type	February 2019 Completed Clearing Quantities		
	Limit (ha) as per Condition 1 Approval	Clearing Quantity (ha)	Current Difference showing remaining habitat (ha) under Condition 1 Approval
Slender Marsdenia/Clear milkvine and Woolls Tylophora/Cryptic Forest Twiner habitat	17.80	17.65	0.15
Koala	106.60	83.44	23.16
Koala (Critical Habitat)	86.50	60.18	26.32
Grey-headed Flying-fox	106.60	83.44	23.17
Grey-headed Flying-fox (foraging habitat critical to survival)	103.50	81.33	22.17
Grey-headed Flying-fox (roosting habitat critical to survival)	3.10	2.10	1.00
Giant Barred Frog	0.7	0.64	0.06
Spotted –tail Quoll habitat	114.10	90.28	23.82
Australian Painted Snipe (Rostratula australis)	3.4	2.84	0.56
Regent Honeyeater (Anthochaera phrygia) and Swift Parrot (Lathamus discolour)	5.30	4.34	0.96
Parsonsia dorrigoensis (Milky Silkpod)	26.1	24.11	1.99

NOTE: The above clearing data represents clearing undertaken up to February 2019. Clearing quantities for all habitat types are below the limits as specified in condition one.

It is anticipated that minor ongoing clearing associated with property adjustments and design refinements will be undertaken until the completion of the project.

2.2. Condition 2

Within 30 days of the **complete on of construction**, the **approval holder** must:

a) notify the **Minister** in writing of the **completion of construction**; and

b) provide a report (supported by maps) that clearly shows the location of all **threatened species**, including the number of individuals of threatened flora and their **habitat cleared** as a result of **action**, which demonstrates compliance with Condition 1.

	Action	Timing	Status	Compliance evidence
2.1	Prepare works as executed Environmental and Clearing Plans to show extent of clearing.	anticipated Mid 2019	TBA	Report & supporting mapping
2.2	Calculate final clearing quantity and include in summary table.	anticipated Mid 2019	TBA	Report & supporting mapping
2.3	Provide written notification (letter) of completion of construction and report to Dept. of the Environment	anticipated Mid 2019	TBA	Notification letter Completed document transmittal form or equivalent

2.3. Condition 3

The **approval holder** must undertake the **action** and implement all mitigation measures in accordance with the **Koala Management Plan**, **Grey-headed Flying-Fox Management Plan**, **Spotted-tail Quoll Management Plan** and **Giant Barred Frog Management Plan**. These **Plans** must be implemented.

	Action	Timing	Status	Compliance evidence
3.1	Implement the Koala Management Plan	Pre-construction, Construction and Operation	Compliant Ongoing	Sensitive Area Plans Ecological Monitoring Report Roadkill Quarterly Reports Completed Pre-clearing Checklists Fauna Relocation Register Habitat Tree Hollow Register Environmental Work Method Statements (EWMS) for Activities Project Induction Biodiversity Offset Strategy Urban Design and Landscape Plan Fauna Connectivity Report See summary below

3.2	Implement the Grey-Headed Flying Fox Management Plan	Pre-construction, Construction and Operation	Compliant Ongoing	Sensitive Area Plans Ecological Monitoring Report Roadkill Quarterly Reports Completed Pre-clearing Checklists Fauna Relocation Register Habitat Tree Hollow Register Environmental Work Method Statements (EWMS) for Activities Project Induction Biodiversity Offset Strategy Urban Design and Landscape Plan Fauna Connectivity Report See summary below
3.3	Implement the Spotted-tail Quoll Management Plan	Pre-construction, Construction and Operation	Compliant Ongoing	Sensitive Area Plans Ecological Monitoring Report Roadkill Quarterly Reports Completed Pre-clearing Checklists Fauna Relocation Register Habitat Tree Hollow Register Environmental Work Method Statements (EWMS) for Activities Project Induction Biodiversity Offset Strategy Urban Design and Landscape Plan Fauna Connectivity Report See summary below

3.4	Implement the Giant Barred Frog Management Plan	Pre-construction, Construction and Operation	Compliant Ongoing	Sensitive Area Plans Ecological Monitoring Report Roadkill Quarterly Reports Completed Pre-clearing Checklists Fauna Relocation Register Habitat Tree Hollow Register Environmental Work Method Statements (EWMS) for Activities Project Induction Biodiversity Offset Strategy Urban Design and Landscape Plan Fauna Connectivity Report See summary below

Compliance Tracker

Table 3.1: Compliance with the Koala Management Plan

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
Design Phase/Pre-construction	Minimise areas of Koala habitat to be cleared where feasible and reasonable during the detailed design phase.	The Project design has minimised clearing quantities as much as possible by ensuring the construction corridor is as narrow as possible. Ancillary sites have been located in areas where clearing is minimal.	Design Drawings
Pre-construction	All ancillary sites to be located outside of mapped Koala habitat.	Ancillary sites have been located in areas of minimal clearing and have minimised clearing of Koala habitat trees.	Sensitive Area Plans Ancillary Facility Register
Pre-Construction	Prior to any clearing taking place, the Project Ecologist will undertake	Prior to construction commencing, only minor clearing (<150mm DBH) was undertaken. The Project	Early Works Permits

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
	an inspection of vegetation, to be cleared, to determine if work activities do not constitute "Construction" as defined in the planning approval under the NSW EP&A Act and are excluded from the Referral under the Federal EPBC Act.	Ecologist inspected all areas of clearing to ensure no Koala habitat was removed during Pre-construction activities.	
Pre-Construction/ Construction	The limits of clearing are to be clearly marked on all relevant work plans and protective fencing erected to mark these limits (i.e. 'no-go' areas).	The clearing limits have been included on the Sensitive Area Plans and marked in the field using yellow flagging.	Sensitive Area Plans Early Works Permits Pre-clearing and Ground Disturbance Permits
Detailed Design/Pre-construction	Areas for Koala habitat restoration/connectivity are to be identified and included in the detailed design.	Habitat connectivity planting has been included in the Urban Design and Landscape Plan	Urban Design and Landscape Plan
Pre-construction/ Construction	Preparation of an EWMS would be undertaken for all work/construction activities and would include where necessary measures to minimise risk to Koalas.	An EWMS has been prepared for all work activities which includes measures to protect flora and fauna in accordance with the Flora and Fauna Management Plan (FFMP)	EWMS
	Induction of all personnel involved with pre-construction/construction activities would be undertaken to advise on Koala management requirements	Project Induction includes information about identification of Koala's on site.	Project Induction
	For any areas of vegetation to be cleared during the pre-construction stage of the Project, a suitably qualified ecologist will undertake a search for native fauna (including Koalas) in the vicinity of clearing immediately prior to clearing commencing. During the construction stage, pre-clearing surveys will be	The Project Ecologist undertakes inspections of all areas to be cleared and signs off on the Pre-clearing Inspection Checklist prior to commencement. No Koala's have been identified on site during clearing operations.	Pre-clearing and Ground Disturbance Permit

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
	undertaken within 48 hours of any clearing commencing (These are to include spotlighting surveys within suitable habitat on the night prior to clearing operations commencing in a given area.) In the event that a Koala is identified within 50 metres of a works area, works will be rescheduled until the construction stage of the Project. During the construction phase clearing works, the suitably qualified expert or an experienced wildlife handler under the supervision of the suitably qualified expert will be available to retrieve and provide appropriate care of any displaced matters of NES and release the fauna into adjacent habitats safe from construction work. Immediately prior to (within 2 hours) of clearing commencing in a given area, an additional ecologist inspection is to be undertaken to confirm that clearing areas remain free of fauna (including Koalas). Where Koalas are identified no works would be undertaken within 50 metres of the animal and the measures within the Fauna Management Protocol for Koalas (refer to Table 4.1 of Koala Management Plan) would be implemented. Should relocation of Koalas be required, a Koala Relocation Strategy included in Appendix C of the Koala Management Plan would be implemented.		
Pre-construction	Koala Management Protocol to be implemented requiring all	No Koala roadkill has been identified on the Project	Roadkill records and

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
and Construction	personnel to report Koalas (including road kill). An assessment of future road kill risks including adaptive management actions is to be provided by the Project Ecologist where: - A Koala is detected within/near the site, or - Koala road kill is detected. Prior to the construction of fauna passage locations and installation of fauna fence, where continuous lines of jersey barriers are to be installed, gaps are to be provided to allow escape of any animals off the highway. Where gaps cannot be provided, a suitable material will be placed over the barrier to allow Koalas to climb over the barrier.	during Pre-construction and Construction Phase of the Project. No concrete barriers have been placed through Koala habitat areas.	quarterly report.
Pre-construction/ Construction/ Operation	Appropriate habitat offsets to be identified by including targeted Koala surveys (GeoLINK 2014) using recognised survey approaches to confirm usage of potential offset properties.	Offset properties set up Koala's identified on Norton Property. Refer to CoA 14 for further details	Monitoring Records
Construction	Progressive rehabilitation of identified areas (refer to Appendix B of the Koala Management Strategy) during the construction stage using collected topsoil and seed at specific sites and to develop different successional stages of rehabilitation. Key rehabilitation measures would include: - Progressive revegetation/rehabilitation during the construction phase using collected topsoil and seed at specific sites and to develop different successional stages of rehabilitation.	Progressive rehabilitation of the site has commenced. The worksite will be rehabilitated in accordance with the Urban Design and Landscape Plan. Landscape rehabilitation is monitored monthly with a quarterly report developed during the third year of construction. Weed management is undertaken in accordance with the Weed and Pathogen Management Plan (WPMP).	Urban Design and Landscape Plan Site Inspection Records RMS Specification G36 Weed Management Records

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
	- Planting of locally occurring species, including plants representative of groundcover, understorey and canopy strata. - Planting of preferred food trees for native fauna, including appropriate eucalypt species for the Koala. - Plantings are to be undertaken around fauna crossing structures to optimise utilisation of these structures. - Monitoring and maintenance of plantings. - Managing and controlling weeds.		
Pre-Construction Detailed Design/ Construction	EPA will be consulted during the detailed design phase on fauna crossing structure specific requirements for fauna furniture and treatments in and around fauna crossing structures. This will include, but not necessarily be limited to requirements for refuge poles and/or horizontal rails, pathways and appropriate plantings and/or \sizing /placement of scour rock & treatment of the substrate e.g. soil and/or mulch over the concrete floor and apron. Advice will be provided by the project ecologist on fauna furniture to be installed within fauna crossing structures.	The EPA/Fisheries have been consulted with and have provided input into the detailed design of the fauna crossing structures including the fauna furniture design. The Fauna Connectivity Report prepared by RMS includes detailed information of the consultation process undertaken with the EPA and Fisheries in relation to the fauna crossing structures. The Project has made prototype panels to demonstrate different types of stone pitching that was to be placed in the low flow channel of Butchers Creek. The prototype panels were shown to the EPA and Fisheries to determine the preferred option for frog and fish passage in this waterway. The fauna furniture design has been demonstrated on site using a prototype and shown to the EPA. The EPA	Detailed Design Drawings ERG Minutes Fauna Connectivity Report

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
		are satisfied with the general arrangement. The fauna drop down design has been demonstrated on site using a prototype and shown to the EPA. The EPA are satisfied with the general arrangement.	

Table 3.2: Compliance with Grey Headed Flying Fox Management Plan

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
Pre-construction	Identify exclusion zones and install exclusion fencing or marking. Exclusion fencing or marking is intended to exclude construction activities from occurring in flying-fox habitat.	Orange flagging and no-go zone signage placed prior to the commencement of construction activities. Flagging was removed when confirmation received that the flying foxes were not utilising the roost on site.	Inspection records Sensitive Area Plans
Detailed Design/ Pre-construction	Minimise through detailed design the incidence of clearing vegetation containing Swamp Mahogany, Melaleuca quinquenervia, Banksia integrifolia and Eucalyptus tereticornis that contribute to foraging habitat during known food bottle necks (i.e. winter period).	The width of the road corridor through the flying fox roost area has been minimised. The total quantity of clearing foraging habitat for GHFF has been minimised.	Sensitive Area Plans Detailed Design Drawings
Pre-construction/ Construction	Construction related infrastructure to be planned and sited within cleared or disturbed areas of the ancillary site. Particularly away from water sources and flying-fox movements areas.	Ancillary sites have been located away from the GHFF roost area and potential habitat.	Consistency review documents for Ancillary site facilities. Ancillary Facility Register
Construction	Pre-clearing and clearing surveys of all vegetation within the clearing footprint conducted as per protocol.	Pre-clearing and ground disturbance permits have been signed off by the Project Ecologist prior to commencing clearing	Pre-clearing and ground disturbance checklists.

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
	Implement contingency plan for moving flying-fox out of the clearing corridor during vegetation clearing/construction, refer to Appendix C of the GHFF Management Plan.	activities. Project Ecologist present during clearing operations in GHFF habitat. No GHFF have been moved from the Project site for clearing operations	
Detailed Design	To minimise the risk of flying-fox vehicle strike during take-off from roosting/foraging, road corridor revegetation and ornamental planting is not to include plants that flower prolifically and produce nectar food sources likely to attract flying-foxes.	The Urban Design and Landscape Plan has considered revegetation that is suitable for the GHFF. Tree species have been located away from the sides of the roadway. Fauna exclusion fencing has been designed for this area.	Urban Design and Landscape Plan Road Furniture Design Package (RF01)
Construction	Exclusion zones fenced off and/or clearly marked. Fencing and marking monitored with breaches repaired.	The clearing limits have been clearly marked with yellow flagging and no-go zone signage. Rural fencing has been installed to prevent access beyond the Project Boundary into the exclusion zone.	Inspection records
Construction	Installation of temporary exclusion fencing around ancillary facilities.	No Ancillary Site Facilities have been placed in the vicinity of GHFF habitat.	Sensitive Area Plans
Construction	Impacts to the flying-fox camp from construction noise, vibration and light would be managed through maintaining exclusion zone buffers and fencing. Only low noise / low disturbance construction activities to occur within the exclusion zone buffer during mid-September to the following April. Inclusion of cross drainage and the provision of a permeable, free draining rock platform in the vicinity of the camp. Implement contingency plan for moving flying-fox out of the clearing corridor and 100 metre buffer during vegetation clearing/ construction, refer to Appendix C of the GHFF	No GHFF have been detected using the camp since prior to the commencement of construction. The GHFF colony has been detected using an alternative roost location and have not returned to the roost adjacent to the worksite. During the last reporting period, the GHFF Management Plan has been updated to permit the project to undertake activities such as haulage through the site buffer zone if the GHFF population returns to the roost site. This update was approved in January 2017.	GHFF Monitoring Reports

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
	Management Plan.		
Construction	Implement water quality procedures from the CEMP.	Regular inspections of the erosion and sediment controls in the area is ongoing throughout construction. Water quality monitoring is currently ongoing.	Inspection records Water Quality Monitoring Records

Table 3.3: Compliance with Spotted-tail Quoll Management Plan

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
Detailed Design and Construction	Minimise areas of vegetation (STQ habitat) to be cleared where feasible and reasonable during the detailed design and construction phase. Design changes (e.g. additional ancillary facilities, batch plants etc. to avoid clearing of vegetation (STQ habitat)).	The Project design has minimised clearing quantities as much as possible by ensuring the construction corridor is as narrow as possible. Ancillary sites have been located in areas where clearing is minimal and avoids STQ habitat.	Detailed Design Ancillary Facility Register
Pre-construction	All ancillary sites to be located outside of STQ habitat.	Ancillary sites have been located in areas where clearing is minimal and avoids STQ habitat.	Ancillary Site Facility Consistency Reviews Ancillary Facility Register
Pre-construction	Prior to any clearing taking place, the Project Ecologist will undertake an inspection of vegetation to be cleared to determine if work activities do not constitute “Construction” as defined in the planning approval under the NSW EP&A Act and are excluded from the Referral under the Federal EPBC Act.	Prior to construction commencing, only minor clearing (<150mm DBH) was undertaken. The Project Ecologist inspected all areas of clearing to ensure no STQ habitat was removed during Pre-construction activities.	Early Works Permits
Construction	The limits of clearing are to be clearly marked on all relevant work plans and protective fencing erected to mark these limits (i.e. no-go areas). Fauna	The clearing limits have been included on the Sensitive Area Plans and marked in the field using	Sensitive Area Plans Pre-clearing and Ground

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
	habitat resources for the STQ to be marked by the ecologist and retained within areas adjacent to the clearing footprint and within the Project boundary where appropriate.	yellow flagging. Habitat resources are marked by the Project Ecologist where appropriate	Disturbance Permit
Detailed Design	Areas for STQ habitat restoration/connectivity are to be identified and included in the detailed design.	Habitat connectivity planting has been included in the Urban Design and Landscape Plan	Urban Design and Landscape Plan
Construction	Preparation of an EWMS would be undertaken for all work activities and would include where necessary measures to minimise risk to the STQ.	An EWMS has been prepared for all work activities which includes measures to protect flora and fauna in accordance with the Flora and Fauna Management Plan (FFMP).	EWMS
	Induction of all personnel involved with activities would be undertaken to advise of STQ management requirements.	Project Induction includes information about identification of STQ on site.	Project Induction
	For any area of vegetation to be cleared during the pre-construction stage of the project, a suitably qualified ecologist will undertake a search for native fauna (including STQ) in the vicinity of clearing immediately prior to clearing commencing. During construction a suitably qualified ecologist will undertake pre-clearing surveys for threatened fauna species (including STQs) prior to (within 48 hours) any clearing commencing. For the STQ, these would focus on dens, large hollow-bearing trees, scats and any other potential habitat features such as rock formations. Immediately prior to (within 2 hours) of clearing commencing within a given clearing area an additional ecologist inspection is to be undertaken to confirm that clearing areas remain free of	The Project Ecologist undertakes inspections of all areas to be cleared and signs off on the Pre-clearing Inspection Checklist prior to commencement. No STQ have been identified on site during clearing operations.	Pre-clearing and ground disturbance Permit

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
	fauna (including STQs). In the event that a STQ is identified, no works would be undertaken within 200 metres of the animal and the measures within the Fauna Management Protocol for STQs (refer to Table 4.1) would be implemented. For any STQ detected on/near the site the protocol shown in Table 4.1 is to be implemented.		
Construction	STQ Management Protocol (Table 4-1) to be implemented requiring all personnel to report STQs (including road kill). Assessment of future road kill risk including adaptive management actions to be provided by Project Ecologist where STQ road kill is detected.	No STQ roadkill has been identified on the Project.	Roadkill records and quarterly reports
Construction	Progressive rehabilitation of identified areas refer to Appendix C) during the construction stage using collected topsoil and seed at specific sites and to develop different successional stages of rehabilitation. Key rehabilitation measures would include: - Progressive revegetation/rehabilitation during the construction phase using collected topsoil and seed at specific sites and to develop different successional stages of rehabilitation. -Planting of locally occurring species, including plants representative of groundcover, understorey and canopy strata. - Plantings are to be undertaken around fauna crossing structures to optimise utilisation of these structures. - Monitoring and maintenance of plantings. Managing and	Progressive rehabilitation of the site has commenced. The site will be rehabilitated in accordance with the Urban Design and Landscape Plan which includes habitat connectivity planting around the fauna passage structures.	Inspection records Urban Design and Landscape Plan

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
	controlling weeds.		
Detailed Design and Construction	EPA will be consulted during the detailed design phase on fauna crossing structure specific requirements for fauna furniture and treatments in and around fauna crossing structures. This will include, but not necessarily be limited to requirements for refuge poles and/or horizontal rails, pathways and appropriate plantings and/or sizing /placement of scour rock & treatment of the substrate e.g. soil and/or mulch over the concrete floor and apron. Advice will be provided by the project ecologist on fauna furniture to be installed within fauna crossing structures.	The EPA/Fisheries has been consulted with and have provided input into the detailed design of the fauna crossing structures including the fauna furniture design. The fauna furniture design has been demonstrated on site using a prototype and shown to the EPA. The EPA are satisfied with the general arrangement. The fauna drop down design has been demonstrated on site using a prototype and shown to the EPA. The EPA are satisfied with the general arrangement.	Detailed design drawings

Table 3.4 Compliance with the Giant Barred Frog Management Plan

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
Pre-construction	No areas of Giant Barred Frog habitat to be cleared during preconstruction	No areas of GBF were cleared during pre-construction	Early Works Permits
Pre-construction/ Construction	All ancillary sites to be located outside of mapped Giant Barred Frog habitat.	Ancillary sites are located outside of the mapped GBF habitat.	Sensitive Area Plans Ancillary Facility Register
Pre-construction/ Construction	Perform field surveys at nominated biodiversity offset sites	Offset properties have been surveyed and area of potential habitat assessed	Shown on draft offset management plans
Construction	Any design changes required during the construction stage would minimise clearing of Giant Barred Frog habitat where feasible and reasonable	The clearing of GBF habitat has been minimised where possible. Only necessary infrastructure has been placed in the GBF habitat area.	Sensitive Area Plans

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
Construction	Preparation of an EWMS would be undertaken for all construction activities to clearly communicate relevant measures within this plan to work crews Ongoing induction of all personnel involved with construction activities would be undertaken to advise of Giant Barred Frog management requirements Early Works – Establishing Site Controls (Temporary Frog Fencing) (4.4.2) Pre-clearing Survey for Giant Barred Frogs (4.4.3) Clearing Supervision in Giant Barred Frog areas Dewatering Procedures in Giant Barred Frog areas (4.5.5) Permanent Frog Fencing (4.5.6) Unexpected Finds Procedure (4.5.7) (4.5.4) All mitigation measures applied during construction as per Table 5-1	An EWMS has been prepared for all work activities which includes measures to protect flora and fauna in accordance with the Flora and Fauna Management Plan (FFMP). Project Induction includes information about identification of GBF on site. Temporary frog fencing has been installed prior to the commencement of clearing. The Project Ecologist undertakes inspections of all areas to be cleared and signs off on the Pre-clearing Inspection Checklist prior to commencement. The Project Ecologist has supervised the clearing operations in the GBF habitat. Surveys are undertaken with input sought from the Project Ecologist when the frog fencing is reinstated after a flood event.	EWMS Project Induction Pre-clearing and Ground Disturbance Permit Site Inspection Record Urban Design and Landscape Plan
Construction	Giant Barred Frog road kill to be reported to the Project Ecologist during daily/weekly monitoring An assessment of future road kill risks including adaptive management actions is to be provided by the Project Ecologist where: - A Giant Barred Frog is detected within/ near the site; or - Giant Barred Frog road kill is detected	No GBF roadkill has been identified on the Project.	Roadkill records and quarterly report.

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
Construction	Progressive rehabilitation of identified areas (refer to Appendix C of the GBF Management Plan) Key rehabilitation measures will include planting of the northern bank of Upper Warrell Creek on either side of the bridge Progressive revegetation/ rehabilitation during construction Use of locally endemic native species representative of those currently growing along Upper Warrell Creek Monitoring and maintenance of plantings Managing and controlling weeds	Progressive rehabilitation of the site has commenced. The site will be rehabilitated in accordance with the Urban Design and Landscape Plan which considers GBF habitat in the rehabilitation of Upper Warrell Creek.	Urban Design and Landscape Plan

The Ecological Monitoring Annual Report 2018-2019 provided in Attachment 1 contains the results of the monitoring required for the Management Plans during the reporting period.

2.4. Condition 4

To mitigate impacts to **threatened species**, the **approval holder** must submit the Flora and Fauna Management Sub Plan and Construction Environment Management Plan to the **Department** for approval prior to **commencement**. The Plans must include the additional mitigation measures not included in the **management plans** and as described in the **Biodiversity Offset Strategy**. The approved **plans** must be implemented.

	Action	Timing	Status	Compliance evidence
4.1	Submit Flora and Fauna Management Plan and Construction Environment Management Plan to the Department	Prior to commencement	Compliant Complete	The CEMP and FFMP were submitted to DoEE on the 17 & 22 December 2014.
4.2	Plans must include the additional mitigation measures not included in the management plans as described in the Biodiversity Offset Strategy.	Prior to commencement	Compliant Complete	The plans were accepted by DoEE on the 9 January 2015.
4.3	Implement the FFMP and CEMP	Construction	Compliant Ongoing	Compliance with the FFMP and CEMP is continuously monitored on site. The Project has an independent Environmental Representative to monitor compliance with these documents. See summary below.

Compliance with the CEMP and FFMP is reviewed regularly by Roads and Maritime, the independent Environmental Representative (ER) and Pacifico. There were no non-compliances relating to the FFMP reported in the 6-monthly compliance report provided to the state DPE. The Project is continuing to implement the CEMP.

2.5. Condition 5

In the event of any inconsistency, ambiguity or discrepancy between the **management plans** and the Flora and Fauna Management Plan or the Construction Environmental Management Plan, the **management plans** have precedence.

	Action	Timing	Status	Compliance evidence
5.1	Identify discrepancies in the CEMP/FFMP and Management Plans	Construction	Compliant Ongoing	No discrepancies noted

2.6. Condition 6

Prior to commencement, the approval holder must amend the monitoring program proposed in the Threatened Flora Management Plan to:

a) include detailed monitoring methodology designed to monitor the success of the management and mitigation measures proposed for pre-construction, construction and operations; and
b) ensure all performance thresholds, corrective actions and monitoring/timing frequency are specific, measurable, auditable, enforceable and time-bound to monitor the success of the management and mitigation measures proposed.

Action	Timing	Status	Compliance evidence
6.1 Update the TFMP to include detailed monitoring methodology designed to monitor the success of the management and mitigation measures	Prior to commencement	Compliant Complete	The TFMP has been approved by DoEE on the 9 January 2015;
6.2 Update the TFMP to ensure all performance thresholds, corrective actions and monitoring/timing frequency are specific, measurable auditable, enforceable and time-bound	Prior to commencement	Compliant Complete	The TFMP has been approved by DoEE on the 9 January 2015.

2.7. Condition 7

The **approval** holder must not **commence** the **action** until the **Threatened Flora Management Plan** has been approved by the **Minister.** The approved **Threatened Flora Management Plan** must be implemented.

	Action	Timing	Status	Compliance evidence
7.1	The action must not commence until the TFMP is approved by the Minister	Prior to commencement	Compliant Complete	The TFMP was approved by DoEE on the 9 January 2015.
7.2	Implement the TFMP	Construction	Compliant Ongoing	Translocation Annual Report Ecological Monitoring Report

Further details on the monitoring undertaken are provided in the Annual Ecological Monitoring Report in Attachment 1.

2.8. Condition 8

The **approval holder** must monitor all mitigation measures until they are demonstrated to be successful, and with written agreement from the **Department**.

	Action	Timing	Status	Compliance evidence
8.1	Monitor implementation of the mitigation measures	Construction and Operation	Compliant Ongoing	Ecological Monitoring Annual Report This Report
8.2	Obtain written agreement from the Department that all mitigation measures have been demonstrated as successful	Completion of construction and operation	Compliant TBA	Written agreement with the Department

2.9. Condition 9

If **MNES** not previously identified and reported to the **Department**, are found in the **action** area, the **approval holder** must notify the **Department** in writing within five business days of finding the **MNES**, and within a further 30 business days, the **approval holder** must outline in writing how **impacts** to these **MNES** will be avoided, mitigated and/or **offset**.

	Action	Timing	Status	Compliance evidence
9.1	Notify the Department in writing within five business days of finding MNES	Pre-Construction, Construction, Operation	Ongoing	No additional EPBC listed species have been identified during the reporting period.
9.2	Outline in writing within 30 business days how the impacts to MNES will be avoided, mitigated and/or offset	Pre-Construction, Construction, Operation	Ongoing	No additional EPBC listed species have been identified during the reporting period.

2.10. Condition 10

Prior to **commencement**, all **management plans** must be made publicly available on the **approval holder's website**, for 10 years following **commencement**. The monitoring results must also be made available on request for the duration of the **approval**.

	Action	Timing	Status	Compliance evidence
10.1	Upload Management Plans on to the public website	Construction	Compliant Complete	All management plans uploaded to the RMS website.
10.2	Monitoring results must be made available on request for the duration of the approval	Construction	Compliant Ongoing	Monitoring results are available on request.

2.11. Condition 11

The **approval** holder must make all monitoring results required by the **management plans** publicly available on the **approval holder's website** within two months of the monitoring event, for 10 years following **commencement**. The monitoring results must also be made available on request for the duration of the **approval.**

	Action	Timing	Status	Compliance evidence
11.1	All monitoring results to be uploaded to the Project website	Construction	Compliant Ongoing	please refer to Condition 25

2.12. Condition 12

To compensate for the loss of threatened species habitat, within 12 months of the approval of the action, the approval holder must submit to the Minister for approval a Biodiversity Offset Package. The Package must:

a) provide known **habitat** and compensate for the residual significant **impacts** on the **threatened species** and their **habitat** in Condition 1a) to e);

b) demonstrate consistency with and meets the requirements of the **EPBC Act Environmental Offsets Policy**;

a) detail the **offset attributes** (including maps in electronic Geographic Information System (GIS) format with accompanying **shapefiles**), site descriptions environmental values relevant to **threatened species** being **offset**, connectivity with other **habitat** and biodiversity corridors;

b) include detailed surveys and quantitative and qualitative descriptions of any proposed **offset areas** which clearly identify **baseline** conditions. This must include:

    i. a **baseline** description (prior to any management activities) of the current **quality** of the **habitat** for each relevant **threatened species** in each **offset area**, including the location of survey points (GPS reference);

    ii. the quantity (in hectares) of suitable **habitat** present within the **offsets areas** for the **threatened species** the **quality** of the **habitat** for the relevant **threatened species** found within the **offset areas**;

    iii. vegetation condition mapping; and

    iv. photo reference points.

c) be prepared by a **suitably qualified ecologist**;

d) include conservation and management measures for long-term protection and adaptive management of the **offsets** to improve **habitat** for **threatened species** within the **offset areas** from **baseline** conditions, including but not limited to:

    i. a map showing **offset areas** to be managed;

    ii. conservation management actions for each **offset area** and the details of methods to be used;

    iii. **offset** management must be consistent with **threat abatement plans** for **threatened species**;

    iv. the timing of management activity for each **offset area** and anticipated timeframes for achieving performance objectives;

    v. clear performance measures and performance indicators for each **offset area** including contingency actions, criteria for triggering contingency actions and a commitment to the implementation of these actions in the event that performance objectives are not met that will enable maintenance and enhancement of **habitat** within the **offset area**, as well as contribute to the better protection of individuals and/or populations of **threatened species** and their **habitat**;

        i. a monitoring program to assess the effectiveness of the management actions measured against the **baseline** condition. This must include, but not be limited to, control sites and periodic ecological surveys to be undertaken by a **suitably qualified ecologist**;

        ii. a risk assessment and a description of the contingency measures that would be implemented to mitigate these risks;

iii. details of the various parties responsible for the management, monitoring and implementing the management activities, including their experience and qualifications and employment or engagement status; and

iv. details of qualifications and experience of persons responsible for undertaking monitoring, review, and implementation of the Biodiversity Offset Package, including the role of the **independent expert** in preparing, reviewing, and implementing the Biodiversity Offset Package; and

a description of protection and funding arrangements or agreements including work programs and responsible entities

Action	Timing	Status	Compliance evidence
12.1 Submit a BOP to Minister of DoEE for approval	Within 12 months of the approved action	Compliant Complete	The action was approved on 11 December 2014. The Biodiversity Offset Package was submitted for approval on 11 December 2015.

2.13. Condition 13

The **approval holder** must implement the approved Biodiversity Offset Package within 24 months of the date of this **approval**.

	Action	Timing	Status	Compliance evidence
13.1	Implement the actions approved under the BOP	Within 24 months off approval	Compliant –	The BOP was approved by DoEE on 5/7/2017 and is currently being implemented. BioBanking applications for two sites were submitted to OEH on the 25 February 2018. The Norton offset site was secured on 18 February 2019 and the Swain offset site was secured on 22 February 2019.

A revised draft was submitted to DoEE for approval in November 2016. The revised Plan was approved by DoEE on 5 July 2017.

2.14. Condition 14

If an **offset** site proposed as a part of the Offset Package is already required to be protected as a result of a separate **EPBC Act** approval, only the management actions which can be demonstrated to be additional to those required for the separate approval, can be considered as an **offset** for this project. The legal protection of the site and management action required for separate approvals cannot be considered a part of the **offsets**, in accordance with the **Environmental Offsets Policy**.

	Action	Timing	Status	Compliance evidence
14.1	Allocate offsets under the BOP from one section of a designated property. No cross over of allocation to occur.	Pre During and post construction	Compliant	There is no overlap between the WC2NH offset areas and any other project's offset areas.

To comply with the EPBC Act offset policy, RMS has allocated separate areas of the Norton property (503 ha in total) to each project as follows:

NH2U: 281 ha (includes 5 ha domestic exclusion area)

WC2NH: 185 ha

OH2K: 37 ha

A map showing the area dedicated to each property was included in the revised draft of WC2NH OMP (submitted for approval November 2016) and the NGOMP for NH2U. This will give DoEE confidence that no doubling or cross over of allocations between the approved projects has or will occur.

To-date in assessing the OH2K OMP and earlier drafts of the NGOMP and WC2NH OMP, DoEE have not raised any concerns with this approach.

2.15. Condition 15

The **approval holder** must, within 36 months of the **approval** of the Biodiversity Offset Package, register a legally binding conservation mechanism to provide long-term protection to the **offsets** approved by the **Minister** in the Biodiversity Offset Package, which prohibits any activities that are not conservation activities from being undertaken in the **offsets.**

Action	Timing	Status	Compliance evidence
15.1 Register within 36 months of the approval of the Biodiversity Offset Package, a legally binding conservation mechanism to provide long-term protection to the offsets approved by the Minister in the Biodiversity Offset Package, which prohibits any activities that are not conservation activities from being undertaken in the offsets	36 months from BOP approval date	Ongoing	The BOP was approved by DoEE on 5 July 2017 and is currently being implemented.

The WC2NH Biodiversity Offset Package was approved by DoEE in July 2017. RMS is progressing with securing the offset properties as follows:

Offset property (tenure)	Offset mechanism	Status
Norton (RMS)	Bio Banking Agreement (provides a legally binding conservation mechanism under the Threatened Species Conservation Act)	BioBanking Agreement have been executed by OEH and registered on title on 18 February 2019.
Boambee (Forestry Corporation NSW)	Newly declared Flora Reserve which provides a legally binding conservation mechanism under the Forestry Act.	Forestry Corporation NSW has supplied their compensation terms for this site which were approved by RMS in April 2018. FCNSW will now undertake the formal gazettal process to create the Flora Reserve but it will be unlikely to be gazetted by 5 July 2018. We anticipate FCNSW finalising the gazettal process by the end of 2019 to declare the new Flora Reserve.
Swain (private)	Bio Banking Agreement.	BioBanking Agreement have been executed by OEH and registered on title on 22 February 2019.

RMS sought a variation to this condition, providing detail on the progress with implementing the package and requesting a further 24 months to finalise the protection mechanisms on the 3 offset sites. This variation was approved by DoEE on 25 September 2018

2.16. Condition 16

If within 6 years, after impacts to Grey-headed Flying-fox habitat, the results of the monitoring required in the Grey-headed Flying-fox Management Plan, show that the Macksville Grey-headed Flying-fox Camp is abandoned by the Grey-headed Flying-fox, between September and May for two consecutive years, the approval holder must then offset the entire 23.50 ha roosting habitat critical to survival within 24 months, rather than 3.10 ha required by Condition 1.

Note: The provision of the additional offset, if required, would be additional to the requirements of Condition 13-16.

Action	Timing	Status	Compliance evidence
16.1 Monitoring GHFF camp. From monitoring results, determine if camp unoccupied continually for 2 consecutive years within a 6 year monitoring period. If unoccupied provide for the full 23.50 Ha offset area else provide for the 3.1 Ha.	Completion by 1 May 2021	Ongoing	Monitoring of the Macksville Grey-headed Flying-fox Camp was found it to be abandoned by the Grey-headed Flying-fox, between September and May for two consecutive years on 31 May 2017. Roads and Maritime is in the process of investigating suitable offset habitat and is currently in discussions with the Department regarding a proposal to vary the condition to extend the time to secure offset properties.

2.17. Condition 17

Within 14 days after the **commencement** of the **action**, the person taking the **action** must advise the **Department** in writing of the actual date of **commencement**.

	Action	Timing	Status	Compliance evidence
17.1	Advice in writing to be provided to DoEE 14 days prior to the commencement of the action.	14 days prior to the commencement of the action	Complete	A letter was provided to DoEE by RMS on the 17 February 2015. The Commencement date for the action was the 9 February 2015.

2.18. Condition 18

The **approval holder** must notify the **Department** in writing of potential non-compliance with any condition of this **approval** as soon as practical and within no later than two business days of becoming aware of the non-compliance. The notice provided to the **Department** under this condition must specify:

a) the condition which the **approval holder** has potentially breached;

b) the nature of the non-compliance; and

c) when and how the **approval holder** became aware of the non-compliance.

Further to providing any such notice, the **approval holder** must provide the following information within 10 business days of becoming aware of a potential non-compliance:

a) how the non-compliance will affect the anticipated impacts of the **approved action**, in particular how the non-compliance will affect the impacts on the **MNES**;

b) the measures the **approval holder** will take to address the impacts of the non-compliance on the **MNES** and rectify the non-compliance; and

c) the time by when the **approval holder** will rectify the non-compliance.

	Action	Timing	Status	Compliance evidence
18.1	Details of any non-compliance to be reported to DoEE within 2 business days of being made aware of the non-compliance	Construction	Compliant Ongoing	No non-compliances were reported to the Department during the reporting period.

2.19. Condition 19

Within three months of every 12 month anniversary of the **commencement** of the **action**, the **approval holder** must publish a report on its **website** addressing compliance with each of the conditions of this **approval**, including implementation of any **management plan, package** as specified in the conditions. **Documentary** evidence providing proof of the date of publication must be included in the published **compliance report**. The **compliance report** must remain on the **website**, for 10 years following **commencement**. The monitoring results must also be made available on request for the duration of the **approval**. Reports of any non-compliance must also be included in the annual **compliance report.**

	Action	Timing	Status	Compliance evidence
24.1	Prepare compliance report and upload to project website	By 9 May 2016	Compliant	Report uploaded to project website. Advice provided to Dept. on date of publication.
24.2	Prepare compliance report and upload to project website	By 9 May 2017	Compliant	Report uploaded to project website. Advice provided to Dept. on date of publication.
24.3	Prepare compliance report and upload to project website	By 9 May 2018	Compliant	Report uploaded to project website. Advice provided to Dept. on date of publication.
24.4	Prepare compliance report and upload to project website	By 9 May 2019	Compliant	Report uploaded to project website. Advice provided to Dept. on date of publication.

2.20. Condition 20

The **approval holder** must maintain accurate **compliance records** substantiating all activities associated with or relevant to the conditions of **approval**, including measures taken to implement the **management plans, package** required by this **approval**, and make them available upon request to the **Department**. Such **compliance records** may be subject to audit by the **Department** or an independent auditor in accordance with section 458 of the **EPBC Act**, or used to verify compliance with the conditions of **approval**. Summaries of audits will be posted on the **Department's website**. The results of audits may also be publicised through the general media.

	Action	Timing	Status	Compliance evidence
20.1	Maintain compliance records for the management plans	Construction, operation	Ongoing	Compliance records are maintained on the relevant RMS document management systems, available on the Project Website or internally via Teambinder.
20.2	Maintain compliance records for the Biodiversity Offset Strategy	Construction, operation	Ongoing	Throughout the reporting period, RMS has undertaken routine property inspections and maintenance of the Norton and Griffin properties. This has included weed control and track maintenance.

2.21. Condition 21

Upon the direction of the **Minister**, the **approval holder** must ensure that an independent audit of compliance with the conditions of **approval** is conducted and a report submitted to the **Minister**. The audit must not commence unless and until the **Minister** has approved the independent auditor and audit criteria. The audit report must address the criteria to the satisfaction of the **Minister.**

	Action	Timing	Status	Compliance evidence
21.1	Prepare independent audit of compliance with the conditions of approval if directed by the Minister to do so.	When Directed	TBA	An independent audit of the conditions of approval has not been required during the reporting period.

2.22. Condition 22

If the **approval holder** wishes to carry out any activity otherwise than in accordance with a **management plans, strategy, package** as specified in the conditions, the **approval holder** must submit to the **Department** for the **Minister's** written approval a revised version of that **management plan, package**. The varied activity must not commence until the **Minister** has approved the varied **management plan, package** in writing. The **Minister** will not approve a varied **management plan, package** unless the revised **management plan, package** would result in an equivalent or improved environmental outcome over time. If the **Minister** approves the revised **management plan, package** that **management plan, package** must be implemented in place of the **management plan, package** originally approved.

Action	Timing	Status	Compliance evidence
22.1 Provide updated management plan or package for approval	Construction, operation	Compliant Ongoing	STQ Management Plan and Koala Management Plan varied on 22 January 2015. STQ Management Plan and Koala Management Plan varied on 3 October 2016. GHFF Management Plan, STQ Management Plan and Koala Management Plan were updated to change the road kill monitoring program prior to the partial opening of Stage 2A. The updated plans were approved by DoEE on 12 of January 2018.

2.23. Condition 23

If the **Minister** believes that it is necessary or convenient for the better protection of **MNES** to do so, the **Minister** may request that the **approval holder** make specified revisions to a **management plan, package** required by the conditions and submit the revised **management plan, package** for the **Minister's** written approval. The **approval holder** must comply with any such request. The revised **management plan, package** must be implemented. Until the **Minister** has approved a revised **management plan, package**, the **approval holder** must continue to implement the previously approved **management plan, package**, as specified in the conditions.

	Action	Timing	Status	Compliance evidence
23.1	Update the Management Plan or Package in response to a direction from the Minister and provide for approval.	As directed	TBA	No updates to the management plans or package have been required.

2.24. Condition 24

If, at any time after five years from the date of this **approval**, the **approval holder** has not **commenced** the **action**, then the **approval holder** must not **commence** the **action** without the written agreement of the **Minister.**

	Action	Timing	Status	Compliance evidence
24.1	Notify the Minister of the commencement of the action	Prior to Commencement	Compliant Complete	RMS notified the Minister of the commencement of the action on the 17 February 2015.

2.25. Condition 25

Unless otherwise agreed to in writing by the **Minister**, the **approval holder** must publish the **management plans, package**, monitoring data in these conditions of **approval** on its **website**. Each **management plans, package**, monitoring data must be published on the **website** within one month of being approved (unless otherwise specified in these conditions) or within one month of data collection.

	Action	Timing	Status	Compliance evidence
25.1	Publish management plans on the Project Website	Within one month of being approved	Compliant Complete	Management Plans uploaded onto the project website
25.2	Publish the Biodiversity Offset Package on the Project Website	Within one month of being approved	Compliant Complete	The Biodiversity Offset Package has been published on the project website
25.3	Publish monitoring data onto the website	Within one month of undertaking the monitoring	Compliant Ongoing	Monitoring data has been published on the project website in accordance with the timeframes.

2.26. Condition 26

The **approval holder** must notify the **Department** within 5 business days of publishing the **management plan, package**, monitoring data on their website and the **management plan, package**, monitoring data must remain on the website for the life of this **approval**.

	Action	Timing	Status	Compliance evidence
26.1	Management plans uploaded on RMS website	With 5 days	Compliant	The CEMP TFMP and FFMP were uploaded on the project web site on 17 February 2015. Plan revisions have been uploaded onto the project website with notification provided to DoEE within 5 business days of publication.
26.2	Monitoring data	Within 2 months of receipt	Compliant	RMS provides email notification to the Department's 'EPBC Monitoring' mailbox within 5 days of publishing relevant information onto the project website

Attachment 1 Ecological Monitoring Report 2018-2019

Warrell Creek to Nambucca Heads Pacific Highway Upgrade

Annual Ecological Monitoring Report

February 2018 - February 2019

Roads and Maritime Services | April 2019

NSW GOVERNMENT

THIS PAGE LEFT INTENTIONALLY BLANK

Contents

Introduction.....1
Statutory and planning framework.....2

Appendix A Grey-headed Flying-fox population
Appendix B Grey-headed Flying-fox habitat
Appendix C Koala
Appendix D Fauna Underpass
Appendix E Giant Barred Frog
Appendix F Microbat habitat
Appendix G Microbat roost
Appendix H Road Kill
Appendix I Landscape Monitoring
Appendix H Threatened Flora

Introduction

This report provides an update on the ecological issues associated with the Warrell Creek to Nambucca Heads Pacific Highway upgrade. This report covers the period from 9 February 2018 to 8 February 2019. This report has been prepared in accordance with the Warrell Creek to Nambucca Heads Ecological Monitoring Program (Roads and Maritime 2018), for submission to the Department of Planning and Environment and Environment Protection Authority (EPA).

This report includes Koala, Fauna Underpass, Giant Barred Frog, Grey-headed Flying-fox, microbat, road kill and landscape monitoring undertaken in 2018/19.

In some instances, monitoring of a particular species or mitigation measure requires several monitoring events throughout the year. In these instances it is considered more informative to wait until all monitoring events have been conducted for that year, before reporting on the results. This allows, for example, analysis between seasons and further statistical analysis to be conducted than if individual monitoring events are reported on. Table 1 details those species / mitigation measures where further monitoring is to be conducted in the remainder of 2019, and as such a combined report for all of the results for 2019 will be reported on in the 2019/20 ecological monitoring report.

Table 1 Ecological monitoring requirements during the last reporting period.

Species monitored	Timing	Done/ yet to be done	Reporting
Grey-headed Flying-fox population	Monthly following operation of Stage 2A	July, August, September, October and November 2018 done.	Results included in this report.
Grey-headed Flying-fox habitat	Seasonally following operation of each stage	Summer 2018 Stage 2A. Autumn 2018 Stage 2A. Winter 2018 Stage 2A and Stage 2B. Spring 2018 Stage 2A and Stage 2B. Summer 2019 Stage 2B.	Results included in this report.
Koala	Spring	Spring (Nov) 2018	Results included in this report.
Fauna Underpass	Spring / Summer	Spring / Summer 2018 done.	Results included in this report.
Giant Barred Frog	Spring, Summer and Autumn	Spring (Oct) 2018 done	Results of Spring 2018 included in this report. Summer and Winter Year one will be to be included in 2019/20 annual report as part of the operational annual report.
Yellow-bellied Glider	August to October population August to February song meter	August to October population monitoring done. August to January song meters done.	Analysis of song meters to be completed - results to be included in 2019/20 annual report as part of the operational

Species monitored	Timing	Done/ yet to be done	Reporting
	deployment		annual report.
Microbat habitat	Monthly during construction	February, March, April, May and June 2018 done.	Results of this monitoring are included in this report.
Microbat roost	Summer, Autumn, Winter and Spring	Summer (Feb), Autumn (Apr) and Winter (July) and Spring 2018 done.	Results of Summer, Autumn and Winter are included in this report. Spring 2018 monitoring will be to be included in 2019/20 annual report as part of the operational annual report.
Road kill	12 weeks following commencement of operation of each stage. Thereafter seasonally	Section 2A initial 12 week monitoring. Section 2A Autumn (April) 2018. Section 2A Winter (July) 2018 Section 2B initial 12 week monitoring Complete Spring (October) 2018. Complete Summer (January) 2019.	Results included in this report.
Landscape Monitoring	Quarterly	Summer (Feb) and Autumn (May) 2018 construction monitoring done	Results of Summer and Autumn are included in this report. Winter and Spring 2018 monitoring will be to be included in 2019/20 annual report as part of the operational annual report.
Threatened Flora	Spring	Threatened Flora Translocations In-situ Threatened Plants Slender Marsdenia and Woolls' Tylophora Habitat Condition	Results included in this report.

Statutory and planning framework

Approval for the Warrell Creek to Urunga Pacific Highway Pacific Highway upgrade was granted by the then Department of Planning & Infrastructure on 19 July 2011 subject to the Minister's Conditions of Approval (CoA) being met. Roads and Maritime has constructed and opened the project in stages. The three main stages of the project are:

- Stage 1 - The Nambucca Heads to Urunga (NH2U) project involved construction of approximately 21.6km of new highway between Nambucca Heads, to the south of Nambucca Heads Interchange, at (Ch19500) and the existing Waterfall Way Interchange at Raleigh, north of Urunga. Stage 1 of the project opened to traffic in July 2016.
- Stage 2 - The Warrell Creek to Nambucca Heads (WC2NH) project involves construction of approximately 19.5km of new highway between the existing Allgomera deviation south of Warrell Creek and extends to the southern extent of the NH2U stage 1. This stage of the project opened to traffic in two parts initially on 19 December 2017 and finally in its entirety on 29 June 2018.

The Warrell Creek to Nambucca Heads Pacific Highway upgrade approval included the requirement to develop an ecological monitoring program:

> *Prior to the commencement of any construction work that will result in the disturbance of any native vegetation, the Proponent shall develop an Ecological Monitoring Program to monitor the effectiveness of the mitigation measures implemented as part of the project. The program shall be developed in consultation with EPA and prepared by a suitably qualified ecologist and shall include but not necessarily be limited to:*
>
> *(a) an adaptive monitoring program to assess the effectiveness of the mitigation measures identified in condition B1 to B6, B7(b), B7(d), B21(c) and B31(b) and allow amendment to the measures if necessary. The monitoring program shall nominate appropriate and justified monitoring periods and performance targets against which effectiveness will be measured. The monitoring shall include operational road kill surveys to assess the effectiveness of fauna crossing and exclusion fencing implemented as part of the project;*
> *(b) mechanism for developing additional monitoring protocols to assess the effectiveness of any additional mitigation measures implemented to address additional impacts in the case of design amendments or unexpected threatened species finds during construction (where these additional impacts are generally consistent with the biodiversity impacts identified for the project in the documents listed under condition A1);*
> *(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 five successive monitoring periods (i.e. 5 years) after opening of the project to traffic, unless otherwise agreed to by the Director General. The monitoring period may be reduced with the agreement of the Director General in consultation with EPA, depending on the outcomes of the monitoring;*
> *(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 contingency measures that will 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 EPA, or as otherwise agreed by those agencies.*
>
> *The Program shall be submitted for the Director General's approval prior to the commencement of any construction work that will result in the disturbance of any native vegetation. Unless otherwise agreed, the Program shall be submitted to the Director General for approval no later than 6 weeks prior to the commencement of any construction that will result in the disturbance of any native vegetation.*

The Warrell Creek to Nambucca Heads ecological monitoring program was approved by the Department of Planning & Environment on 14 March 2018 with a minor change updated by the Department of Planning & Environment independent environmental representative on 1 June 2018.

Appendix A Grey-headed Flying-fox population

Warrell Creek to Nambucca Heads

Grey-headed Flying Fox Population Monitoring

Operational Phase

Roads and Maritime Services | 2018

NSW GOVERNMENT

THIS PAGE LEFT INTENTIONALLY BLANK

Document control

Report name	Warrell Creek to Nambucca Heads - Grey-headed Flying Fox Population Monitoring 2018	
Date	August 2018	
Document version	Revision 1	December 2017 monitoring report
	Revision 2	January 2018 monitoring report
	Revision 3	February 2018 monitoring report
	Revision 4	March 2018 monitoring report
	Revision 5	April 2018 monitoring report
	Revision 6	May 2018 monitoring report
	Revision 7	June 2018 monitoring report
	Revision 8	July 2018 monitoring report
	Revision 9	August 2018 monitoring report
	Revision 10	September 2018 monitoring report
	Revision 11	October 2018 monitoring report
	Revision 12	November 2018 monitoring report

Contents

1.Introduction 1

2.Purpose of this report..... 1

Appendix 1 December 2017.monitoring report.

Appendix 2 January 2018 monitoring report.

Appendix 3 February 2018 monitoring report

Appendix 4 March 2018 monitoring report.

Appendix 5 April 2018 monitoring report.

Appendix 6 May 2018 monitoring report

Appendix 7 June 2018 monitoring report

Appendix 8 July 2018 monitoring report

Appendix 9 August 2018 monitoring report

Appendix 10 September 2018 monitoring report

Appendix 11 October 2018 monitoring report

Appendix 12 November 2018 monitoring report

1. Introduction

Grey-headed Flying Fox population monitoring is a requirement of the approved Warrell Creek to Nambucca Heads Flying-fox management plan and the Ecological Monitoring Program. Following the opening of the Warrell Creek to Nambucca Heads highway upgrade to traffic in December 2017, Roads and Maritime is required to undertake monthly field monitoring for a period of 12 months following the methodology outlined in the Management Plan.

2. Purpose of this report

The purpose of this report is to provide the monitoring data for the twelve months from December 2017 to November 2018 inclusive.

This report is updated with the results of the monthly monitoring as they become available. The monthly population monitoring reports are provided in the Appendices.

Appendix 1 December 2017 monitoring report.

Flying-fox Monitoring December 2017

Warrell Creek to Nambucca Heads Pacific Highway Upgrade

PO Box 119
Lennox Head NSW 2478
T 02 6687 7666

PO Box 1446
Coffs Harbour NSW 2450
T 02 6651 7666

PO Box 1267
Armidale NSW 2350
T 02 6772 0454

PO Box 229
Lismore NSW 2480
T 02 6621 6677

info@geolink.net.au

Prepared for: Roads and Maritime Services

© GeoLINK, 2018

UPR	*Description*	*Date Issued*	*Issued By*
2692-1073	First issue	09/01/2018	David Andrighetto

Table of Contents

1. Introduction 1

1.1 Introduction 1

2. Flying-fox Survey 2

2.1 Methodology 2
2.2 Results 3

2.2.1 Roost Footprint 3
2.2.2 Population Estimates 6
2.2.3 Detailed Data 6

2.3 Discussion 9

2.3.1 Population Estimates 9
2.3.2 Species Composition and Demographic Data 10
2.3.3 Phenology of Trees in the Region 10

2.4 Summary and Conclusion 12

Illustrations

Illustration 2.1 Location of Regional Flying-fox Camps 4
Illustration 2.2 Macksville Cemetery Roost Footprint 5

Tables

Table 2.1 Demographic Data of GHFF at the Macksville Cemetery Camp 7
Table 2.2 Demographic Data of GHFF at the Bellingen Island Camp 8

Figures

Figure 2.1 Water level measurements at the site 9
Figure 2.2 Population trends at the site and regional camps over past 12 months 11

1. Introduction

1.1 Introduction

NSW Roads and Maritime Services have been monitoring a Grey-headed Flying-fox (*Pteropus poliocephalus*) (GHFF) camp that was intermittently present within the approved alignment of the Warrell Creek to Nambucca Heads (WC2NH) Pacific Highway upgrade project near Macksville. The camp is located in a patch of swamp sclerophyll forest north of Bald Hill Road (henceforth referred to as 'the site').

GeoLINK has undertaken monitoring at the site on at least a monthly basis since July 2013. Prior to this, irregular monitoring of flying-foxes at the site has been undertaken since the initial establishment of the camp in December 2011 (Eby 2012).

This report details the December 2017 flying-fox monitoring results.

2. Flying-fox Survey

2.1 Methodology

The following GeoLINK personnel undertook fieldwork for the December 2017 flying-fox monitoring:

- Tom Pollard (ecologist).
- Frank Makin (ecologist).
- Jeremy Clifford (environmental scientist).
- Kale Hardie-Porter (environmental scientist).

Fieldwork followed the methodology developed by Dr Eby for the project. Refer to Eby (2013) for full details of the methodology. A summary of the main procedures used for the monitoring is provided below.

The fieldwork was undertaken on 21 December 2017. The presence of flying-foxes at the site was assessed by undertaking a traverse of the area previously known to support flying-foxes in conjunction with a few sharp handclaps aimed at eliciting a vocal response from any flying-foxes roosting at the site.

When flying-foxes are present at the site, the following data is collected:

- The area of the roost footprint (mapped by GPS).
- Species composition.
- Demographics.
- Reproductive status.
- Behaviour.

When the site is unoccupied and flying-foxes are present at the nearby seasonally-occupied flying-fox camp within two kilometres of the site adjacent to Macksville Cemetery, the above-mentioned data is collected here instead. This data provides relevant information on the status of flying-foxes that are camped in the Macksville area.

The water level at the site was measured at GPS location 492866, 6600756 (UTM coordinates, GDA 94, Zone 56). The water level at this location is representative of the average level at the site and is tracked over time to provide information on water level fluctuations that occur at the site.

A dusk exit count survey was undertaken at both the site and the Macksville Cemetery camp to confirm the presence/ absence of flying-foxes and to provide an estimate of the current population at each camp.

Two observers were strategically located for the exit count on a northern and a southern ridge overlooking the site. Specifically, the two observers were located at the following vantage points:

- In a paddock to the north of the swamp sclerophyll forest (off Wedgewood Drive).
- On a prominent ridge to the south (at 41 Bald Hill Road).

Two observers were also located adjacent to the Macksville Cemetery camp at the following vantage points:

- At the Macksville Cemetery gate off Wallace Street (west of the camp).
- Adjacent to the Macksville Golf Course next to the Pacific Highway (east of the camp).

The exit counts extended over approximately 30 minutes from sunset until dark (approximately 7:45 pm to 8:15 pm).

Other regional flying-fox camps at Gordon Park, Nambucca Heads (approximately 12 kilometres north-east of the site), Bowraville (approximately 10.5 kilometres north-west of the site), Bellingen Wheatley Street Camp (approximately 30 kilometres north of the site) and Bellingen Island (approximately 31 kilometres north of the site) were also visited and observational comments made. Refer to **Illustration 2.1** for the location of the subject regional camps.

2.2 Results

2.2.1 Roost Footprint

No flying-foxes were recorded roosting at the site in the traverse.

Flying-foxes were observed to be roosting at the Macksville Cemetery camp. The roost extended over approximately 2.70 hectares (refer to **Illustration 2.2**).

Flying-foxes were not recorded at the Wheatley Street camp in Bellingen or at Bowraville.

Regionally, flying-foxes were observed to be roosting at Bellingen Island and Gordon Park (Nambucca Heads). The extent of the roost footprint at both Bellingen Island and Gordon Park was similar to that observed in the previous monthly monitoring event.

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: DSA Date: 9/01/2018
Source of base data: Roads and Maritime Services

0 4 km

North

Location of Regional Flying-fox Camps

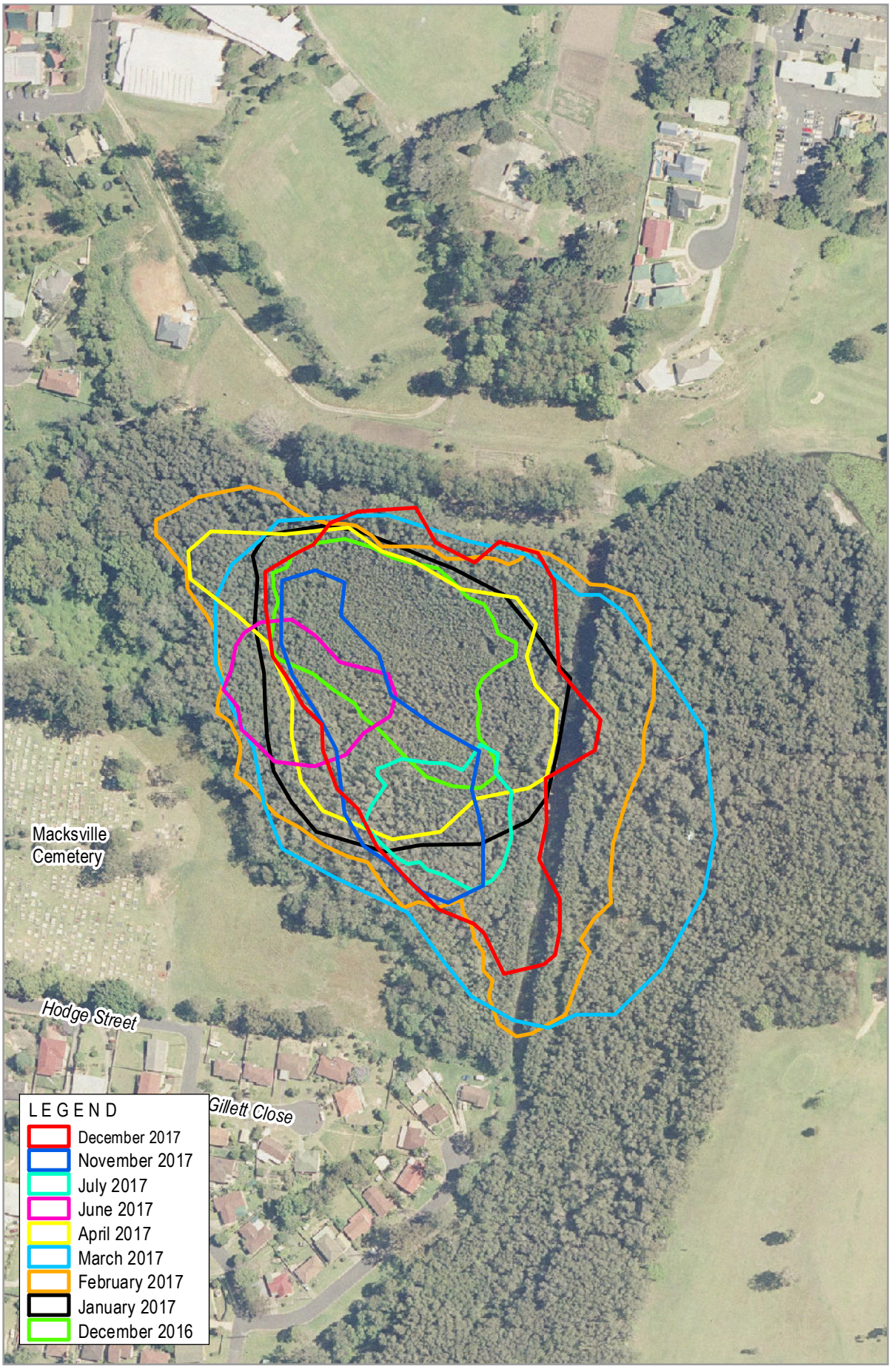
GeoLINK environmental management and design

Flying-fox Monitoring December 2017 - Warrell Creek to Nambucca Heads
Pacific Highway Upgrade
2692-1075

Illustration 2.1

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: DSA Date: 9/01/2018
Source of base data: Roads and Maritime Services



North

0 60

Macksville Cemetery Flying-fox Roost Footprint

GeoLINK environmental management and design

Flying-fox Monitoring December 2017 - Warrell Creek to Nambucca Heads
Pacific Highway Upgrade
2692-1076

Illustration 2.2

2.2.2 Population Estimates

2.2.2.1 Exit Counts

No flying-foxes were observed flying from the site during the exit count.

Approximately 22,000 individuals were recorded exiting the Macksville Cemetery camp in the exit count. The majority of these flying-foxes were exiting in a north to north-westerly stream.

2.2.2.2 Direct Counts

With the exception of the Macksville Cemetery camp, no exit counts were conducted at any of the remaining regional camps. However, rough population estimates for these camps based on extrapolation of counts in individual trees and the roost footprint are as follows:

- Gordon Park: approximately 10,000 individuals.
- Bellingen Island: approximately 15,000 individuals.
- Wheatley Street, Bellingen: no individuals recorded.
- Bowraville: no individuals recorded.

2.2.3 Detailed Data

2.2.3.1 Species Composition

The species composition and proportions observed at occupied camps were as follows:

- Macksville Cemetery: 95% GHFF and 5% Black Flying-fox.
- Bellingen Island: 95% GHFF and 5% Black Flying-fox.
- Gordon Park: 80% GHFF and 20% Black Flying-fox.

2.2.3.2 Habitat Characteristics and Demographic Composition

As flying-foxes were not recorded at the site in the current monitoring event, detailed demographic composition data was not collected. This has been the case since April 2014 (excluding a brief return in January 2015). During this period of absence the Macksville Cemetery camp has been the alternative site for collection of this data.

Both male and female GHFF were present at the Macksville Cemetery camp. The weather during this part of the monitoring was not ideal for sexing animals, with rain falling and low light levels. Consequently, only five demographic point counts could be completed. Nonetheless, data collected at these demographic point counts indicated that the proportion of female GHFF present was generally high and ranged from 77% to 100% of all individuals (refer to **Table 2.1**). The percentage of females with dependent young GHFF at demographic point counts averaged 54% (ranging between 30% and 70%).

Both male and female GHFF were also present at the Bellingen Island camp. Data collected in demographic point counts indicated that the proportion of female GHFF present was generally moderate to high and ranged between 47% and 91% of all individuals (refer to **Table 2.2**). The percentage of females with dependent young GHFF at demographic point counts averaged 49% (ranging between 10% and 70%).

General observations of the GHFF currently roosting at the Gordon Park camp indicated that males and females were present, as well as females with dependent young.

Table 2.1 Demographic Data of GHFF at the Macksville Cemetery Camp

Tree Code	*GPS Location (UTM coordinates GDA94, Zone 56)*	*Tree Species*	*Height (m)*	*DBH (cm)*	*Demographic Ratio (female:male)*	*Presence of Dependant Young (yes/no)*	*% Females with Dependant Young*
MC1	492067, 6601756	Broad-leaved Paperbark	10	20	10:3	Yes	60
MC2	492068, 6601743	Broad-leaved Paperbark	12	20	10:0	Yes	70
MC3	492079, 6601733	Broad-leaved Paperbark	10	20	10:3	Yes	30
MC4	492092, 6601710	Broad-leaved Paperbark	12	25	10:1	Yes	50
MC5	492111, 6601672	Broad-leaved Paperbark	15	30	10:2	Yes	60
MC6	Data not collected due to poor weather conditions	Data not collected due to poor weather conditions	Data not collected due to poor weather conditions	Data not collected due to poor weather conditions	Data not collected due to poor weather conditions	Data not collected due to poor weather conditions	Data not collected due to poor weather conditions
MC7	“	“	“	“	“	“	“
MC8	“	“	“	“	“	“	“
MC9	“	“	“	“	“	“	“
MC10	“	“	“	“	“	“	“

Table 2.2 Demographic Data of GHFF at the Bellingen Island Camp

Tree Code	*GPS Location (UTM coordinates GDA94, Zone 56)*	*Tree Species*	*Height (m)*	*DBH (cm)*	*Demographic Ratio (female:male)*	*Presence of Dependant Young (yes/no)*	*% Females with Dependant Young*
BI1	489956, 6631585	Moreton Bay Fig	10	50	10:9	Yes	10
BI2	489968, 6631574	Creek Sandpaper Fig	10	20	10:2	Yes	40
BI3	489979, 6631565	Creek Sandpaper Fig	8	15	10:3	Yes	50
BI4	489995, 6631551	Creek Sandpaper Fig	8	30	10:5	Yes	50
BI5	490021, 6631538	Moreton Bay Fig	10	35	10:1	Yes	70
BI6	490037, 6631533	Creek Sandpaper Fig	10	15	10:4	Yes	70
BI7	490049, 6631536	Creek Sandpaper Fig	12	20	10:4	Yes	60
BI8	490023, 6631574	Giant Stinging Tree	12	35	10:1	Yes	30
BI9	490023, 6631616	Small-leaved Fig	8	50	10:3	Yes	60
BI10	490009, 6631623	Sandpaper Fig	8	30	10:5	Yes	50

2.2.3.3 Water Level at the Site

Water level at the site measured at the representative measurement location was approximately 45 cm in depth and has been declining since peaking in October (refer to **Figure 2.1**).

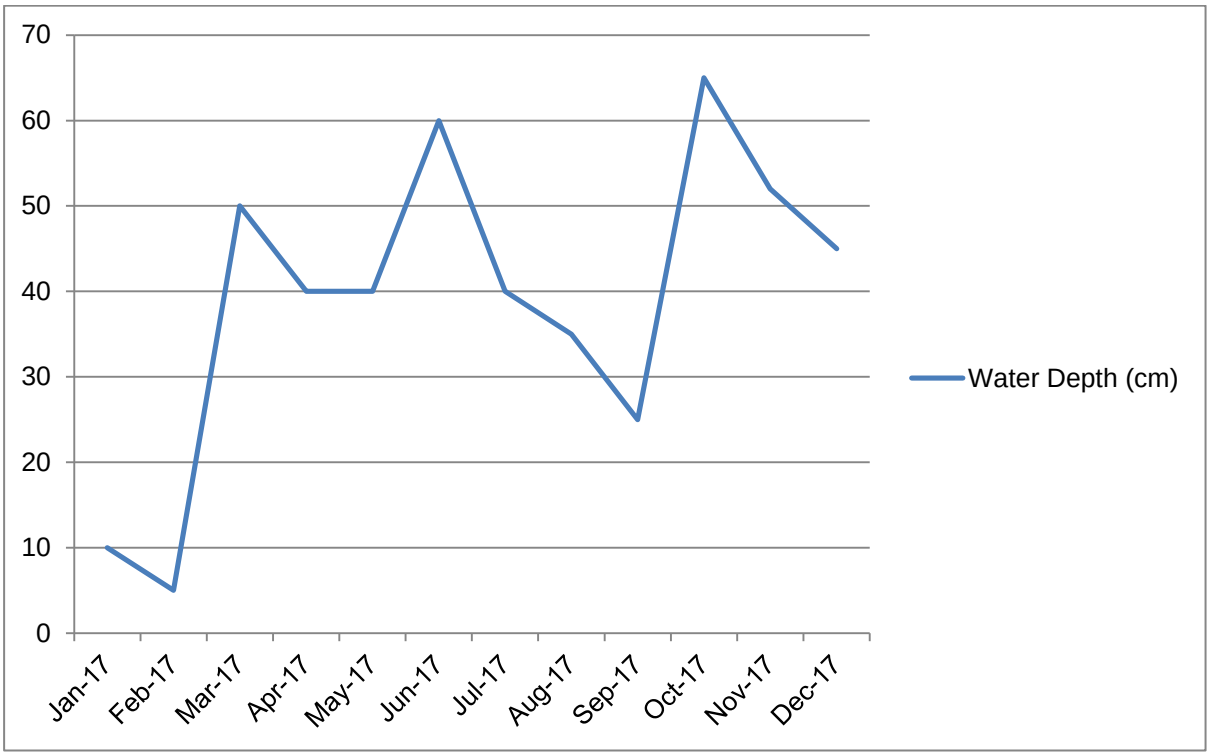


Figure 2.1 Water level measurements at the site

2.3 Discussion

2.3.1 Population Estimates

The trend in flying-fox numbers over the last 12-month period at the site and other monitored regional flying-fox camps is shown in **Figure 2.2**. No flying-foxes were recorded at the site again this month. Flying-foxes have not occupied the site (excluding a brief return in January 2015) since mid-April 2014.

The number of flying-foxes at the Macksville Cemetery camp has continued to increase from the low levels or absence that typically occurs over winter and early spring at this camp. Less than half the number of flying-foxes observed in the current monitoring event were present at this camp in December 2016 (GeoLINK 2016).

At both the Bellingen Island and Gordon Park camps a similar trend in flying-fox numbers is evident over the past 6 months, with the highest numbers in winter, a brief low in October, and then an increasing trend over the past two months (refer to **Figure 2.2**). These camps were supporting a similar number of individuals at this time last year (GeoLINK 2016).

No flying-foxes were recorded at Bowraville in the current monitoring event. Over the past 12-month period, flying-foxes have only been present at this camp in very low numbers during late spring and early summer of 2016/17.

As can be seen in the 12-monthly population comparisons (refer to **Figure 2.2**), after reaching a low point in October the overall population levels at occupied camps are generally showing an increasing trend.

2.3.2 Species Composition and Demographic Data

At occupied camps, GHFF dominated the species composition making up between 80% and 95% of all individuals. These proportions are within the range that has been typically observed for these camps in previous monitoring events.

Female GHFF dominated the occupied camps in the current monitoring event, with demographic point counts averaging 74% at Bellingen Island and 84% at Macksville Cemetery. Similar proportions were recorded in the previous monthly monitoring event.

At the Macksville Cemetery camp dependent young were present at a moderate level alongside 54% of all female GHFF (ranging between 30% and 70% at individual demographic point counts). This is a substantial increase from the previous monitoring event where only 23% of female GHFF were recorded with dependent young. In contrast, the results of the December 2016 monitoring recorded no dependent young GHFF at the Macksville Cemetery camp (GeoLINK 2016).

The percentage of female GHFF with dependent young at Bellingen Island in this monitoring event averaged 49% (ranging between 10% and 70% at individual demographic point counts). A similar percentage was recorded in both the previous monitoring event and in the monitoring in December 2016 (GeoLINK 2017; GeoLINK 2016).

2.3.3 Phenology of Trees in the Region

December/January bi-monthly flowering of a number of highly productive nectar source trees in the upper North Coast region of NSW includes various *Corymbia* spp. (Bloodwoods and Spotted Gums), New England Blackbutt (*Eucalyptus andrewsii*), River Red Gum (*E. camaldulensis*), Coastal Blackbutt (*E. pilularis* - foothills and ranges), Grey Ironbark (*E. siderophloia* - foothills and ranges), Forest Red Gum (*E. tereticornis – high altitude*) and Black Bean (*Castanospermum australe*). These are considered key diet species for GHFF in the region (Eby 2012; Eby and Law 2008).

Observations when travelling between regional flying-fox camps recorded light flowering of Pink Bloodwood (*Corymbia intermedia*).

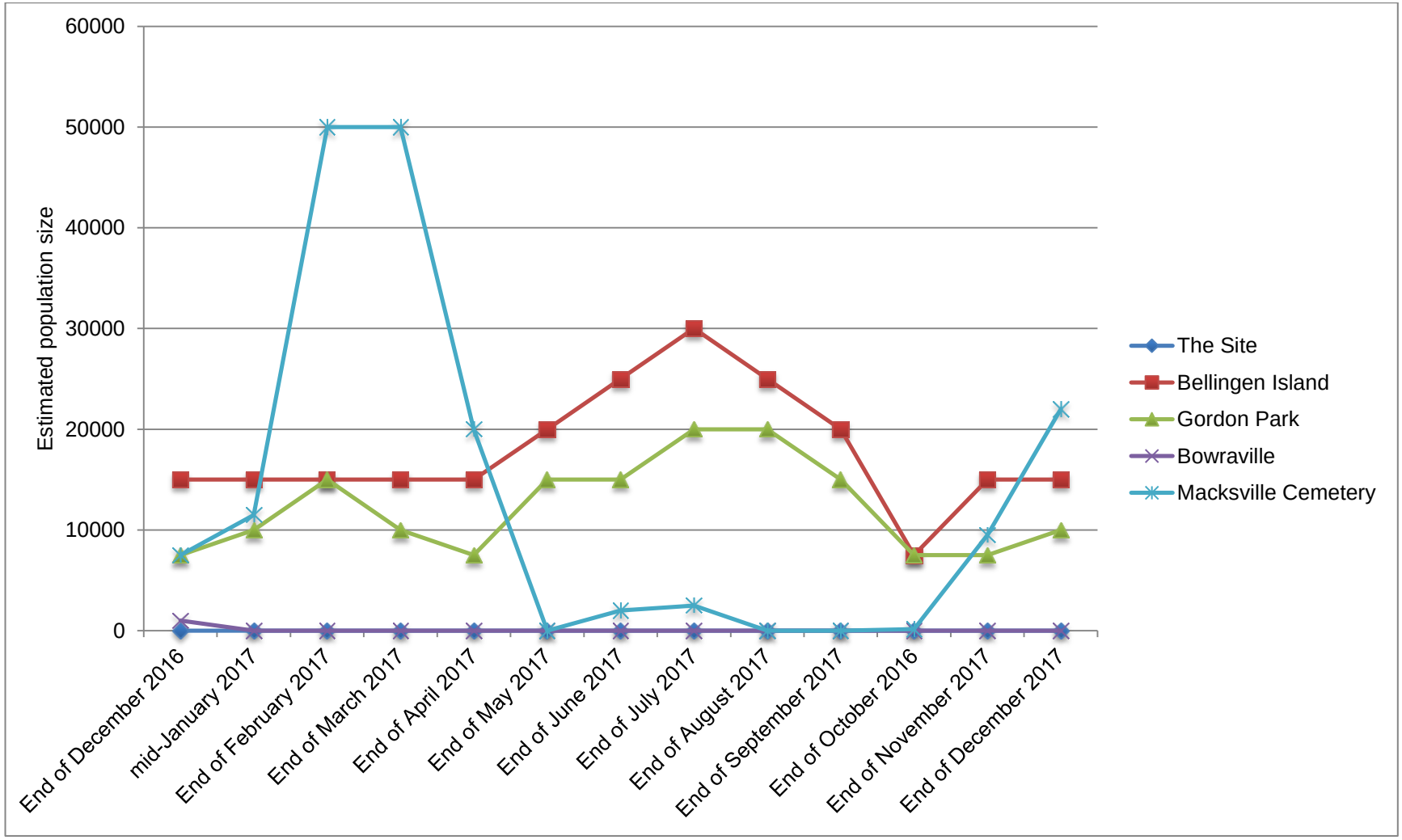


Figure 2.2 Population trends at the site and regional camps over past 12 months

2.4 Summary and Conclusion

The results of the December 2017 flying-fox monitoring indicate that excluding a brief stopover at the site observed in mid-January 2015, flying-foxes have been absent from the site since April 2014.

The number of flying-foxes at the Macksville Cemetery camp has continued to increase from the low levels/ absence that typically occurs over winter and early spring at this camp.

Over the past 6 months at both the Bellingen Island and Gordon Park camps, flying-fox numbers have followed a similar trend with highest numbers present in winter, a brief low in October, and then an increasing trend over the past two months (late spring/ early summer).

Flying-foxes remain absent from Bowraville and Wheatley Street, Bellingen.

GHFF dominated the species composition of the Bellingen Island and Gordon Park camps making up between 80% and 95% of all individuals present.

Dependent young GHFF were present at a moderate level within occupied camps in the current monitoring event.

Light flowering of Pink Bloodwood, a key diet species for the GHFF, was observed to be currently occurring in the region.

David Andrighetto
Senior Ecologist

References

Eby, P. (2012). *An Assessment of the Flying-fox Camp at Macksville*. Unpublished report to NSW Roads and Maritime Services.

Eby, P. (2013). *A Field Monitoring Program Proposed for the Macksville Flying-fox Roost*. Unpublished report to Sinclair Knight Merz.

GeoLINK. (2016). *Flying-fox Monitoring December 2016: Warrell Creek to Nambucca Heads Pacific Highway Upgrade*. Unpublished report to NSW Roads and Maritime Services.

GeoLINK. (2017). *Flying-fox Monitoring November 2017: Warrell Creek to Nambucca Heads Pacific Highway Upgrade*. Unpublished report to NSW Roads and Maritime Services.

Appendix 2 January 2018 monitoring report.

Flying-fox Monitoring January 2018

Warrell Creek to Nambucca Heads Pacific Highway Upgrade

PO Box 119
Lennox Head NSW 2478
T 02 6687 7666

PO Box 1446
Coffs Harbour NSW 2450
T 02 6651 7666

PO Box 1267
Armidale NSW 2350
T 02 6772 0454

PO Box 229
Lismore NSW 2480
T 02 6621 6677

info@geolink.net.au

Prepared for: Roads and Maritime Services

© GeoLINK, 2018

UPR	*Description*	*Date Issued*	*Issued By*
2692-1077	First issue	08/02/2018	David Andrighetto

Table of Contents

1. Introduction 1

1.1 Introduction 1

2. Flying-fox Survey 2

2.1 Methodology 2
2.2 Results 3

2.2.1 Roost Footprint 3
2.2.2 Population Estimates 7
2.2.3 Detailed Data 7

2.3 Discussion 10

2.3.1 Population Estimates 10
2.3.2 Species Composition and Demographic Data 11
2.3.3 Phenology of Trees in the Region 11

2.4 Summary and Conclusion 13

Illustrations

Illustration 2.1 Location of Regional Flying-fox Camps 5
Illustration 2.2 Macksville Cemetery Roost Footprint 6

Plates

Plate 2.1 GHFF roosting in the upper canopy of figs at Bellingen Island 4

Tables

Table 2.1 Demographic Data of GHFF at the Macksville Cemetery Camp 8
Table 2.2 Demographic Data of GHFF at the Bellingen Island Camp 9

Figures

Figure 2.1 Water level measurements at the site 10
Figure 2.2 Population trends at the site and regional camps over past 12 months 12

1. Introduction

1.1 Introduction

NSW Roads and Maritime Services have been monitoring a Grey-headed Flying-fox (*Pteropus poliocephalus*) (GHFF) camp that was intermittently present within the approved alignment of the Warrell Creek to Nambucca Heads (WC2NH) Pacific Highway upgrade project near Macksville. The camp is located in a patch of swamp sclerophyll forest north of Bald Hill Road (henceforth referred to as 'the site').

GeoLINK has undertaken monitoring at the site on at least a monthly basis since July 2013. Prior to this, irregular monitoring of flying-foxes at the site has been undertaken since the initial establishment of the camp in December 2011 (Eby 2012).

This report details the January 2018 flying-fox monitoring results.

2. Flying-fox Survey

2.1 Methodology

The following GeoLINK personnel undertook fieldwork for the January 2018 flying-fox monitoring:

- Tom Pollard (ecologist).
- Dylan Hisselli (environmental scientist/ ecologist).
- Jeremy Clifford (environmental scientist).
- Kale Hardie-Porter (environmental scientist).

Fieldwork followed the methodology developed by Dr Eby for the project. Refer to Eby (2013) for full details of the methodology. A summary of the main procedures used for the monitoring is provided below.

The fieldwork was undertaken on 24 January 2018. The presence of flying-foxes at the site was assessed by undertaking a traverse of the area previously known to support flying-foxes in conjunction with a few sharp handclaps aimed at eliciting a vocal response from any flying-foxes roosting at the site.

When flying-foxes are present at the site, the following data is collected:

- The area of the roost footprint (mapped by GPS).
- Species composition.
- Demographics.
- Reproductive status.
- Behaviour.

When the site is unoccupied and flying-foxes are present at the nearby seasonally-occupied flying-fox camp within two kilometres of the site adjacent to Macksville Cemetery, the above-mentioned data is collected here instead. This data provides relevant information on the status of flying-foxes that are camped in the Macksville area.

The water level at the site was measured at GPS location 492866, 6600756 (UTM coordinates, GDA 94, Zone 56). The water level at this location is representative of the average level at the site and is tracked over time to provide information on water level fluctuations that occur at the site.

A dusk exit count survey was undertaken at both the site and the Macksville Cemetery camp to confirm the presence/ absence of flying-foxes and to provide an estimate of the current population at each camp.

Two observers were strategically located for the exit count on a northern and a southern ridge overlooking the site. Specifically, the two observers were located at the following vantage points:

- In a paddock to the north of the swamp sclerophyll forest (off Wedgewood Drive).
- On a prominent ridge to the south (at 41 Bald Hill Road).

Two observers were also located adjacent to the Macksville Cemetery camp at the following vantage points:

- At the Macksville Cemetery gate off Wallace Street (west of the camp).
- Adjacent to the Macksville Golf Course next to the Pacific Highway (east of the camp).

The exit counts extended over approximately 30 minutes from sunset until dark (approximately 7:45 pm to 8:15 pm).

Other regional flying-fox camps at Gordon Park, Nambucca Heads (approximately 12 kilometres north-east of the site), Bowraville (approximately 10.5 kilometres north-west of the site), Bellingen Wheatley Street Camp (approximately 30 kilometres north of the site) and Bellingen Island (approximately 31 kilometres north of the site) were also visited and observational comments made. Refer to **Illustration 2.1** for the location of the subject regional camps.

2.2 Results

2.2.1 Roost Footprint

No flying-foxes were recorded roosting at the site in the traverse.

Flying-foxes were observed to be roosting at the Macksville Cemetery camp. The roost extended over a comparatively large area of approximately 6.1 hectares (refer to **Illustration 2.2**).

Flying-foxes were not recorded at the Wheatley Street camp in Bellingen or at Bowraville.

Regionally, flying-foxes were observed to be roosting at Bellingen Island and Gordon Park (Nambucca Heads). The extent of the roost footprint at Bellingen Island was observed to be covering a larger area than that recorded in the previous monthly monitoring event (GeoLINK 2017), including substantial roosting in the upper canopy of the emergent fig trees within the rainforest remnant (refer to Plate 2.1). In contrast, at Gordon Park the roost extent had not changed from that recorded in the previous monitoring event.

Plate 2.1 GHFF roosting in the upper canopy of figs at Bellingen Island

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: DSA Date: 9/02/2018
Source of base data: Roads and Maritime Services

0 4 km

North

Location of Regional Flying-fox Camps

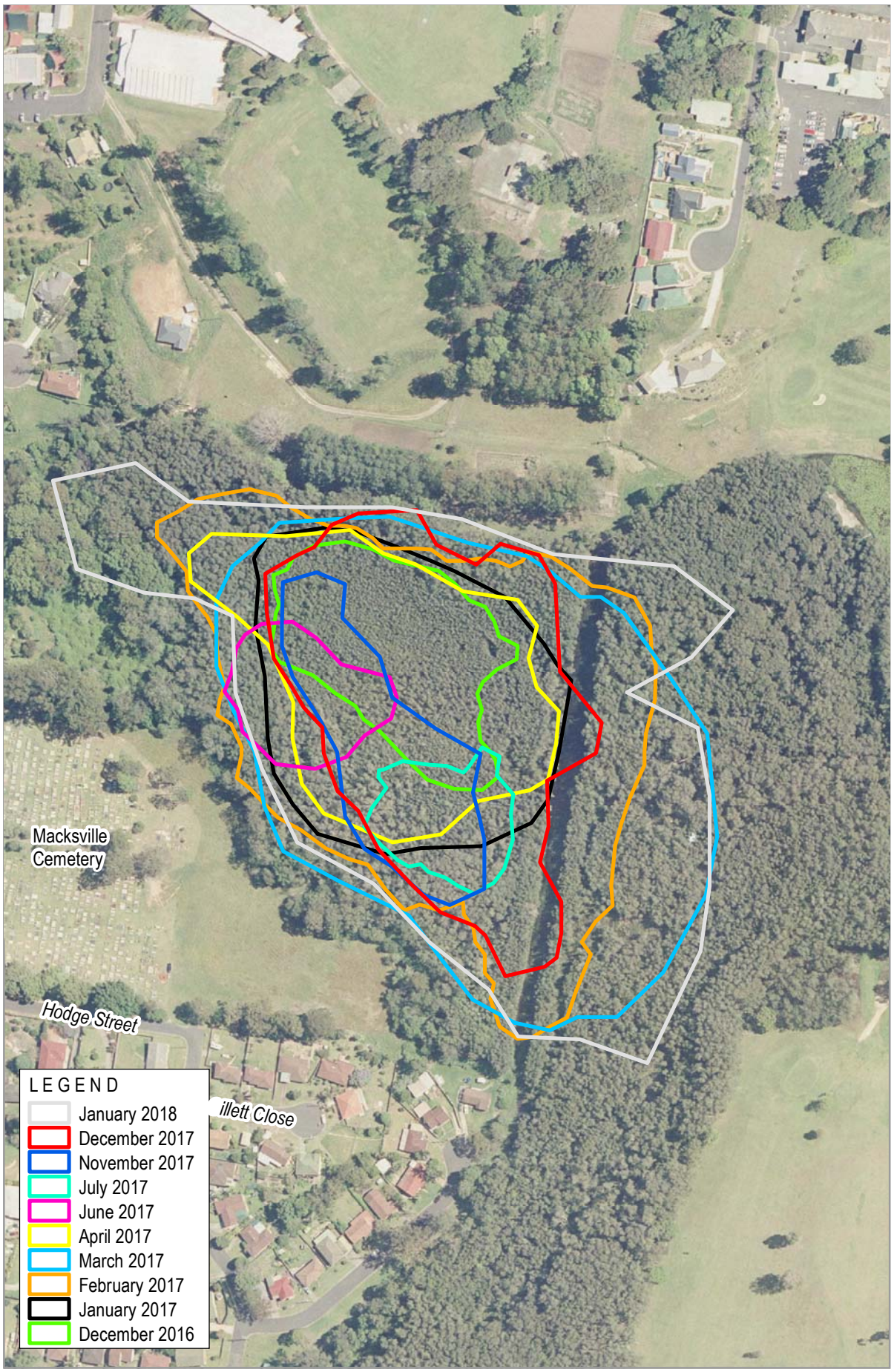
GeoLINK environmental management and design

Flying-fox Monitoring January 2018 - Warrell Creek to Nambucca Heads
Pacific Highway Upgrade
2692-1079

Illustration 2.1

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: DSA Date: 9/02/2018
Source of base data: Roads and Maritime Services



North

0 60

Macksville Cemetery Flying-fox Roost Footprint

GeoLINK environmental management and design

Flying-fox Monitoring January 2018 - Warrell Creek to Nambucca Heads
Pacific Highway Upgrade
2692-1080

Illustration 2.2

2.2.2 Population Estimates

2.2.2.1 Exit Counts

No flying-foxes were observed flying from the site during the exit count.

Approximately 50,000 individuals were recorded exiting the Macksville Cemetery camp in the exit count. The flying-foxes were exiting in two broad streams, one in a north to north-westerly direction and another in a south to south-easterly direction

2.2.2.2 Direct Counts

With the exception of the Macksville Cemetery camp, no exit counts were conducted at any of the remaining regional camps. However, rough population estimates for these camps based on extrapolation of counts in individual trees and the roost footprint are as follows:

- Gordon Park: approximately 10,000 individuals.
- Bellingen Island: approximately 30,000 individuals.
- Wheatley Street, Bellingen: no individuals recorded.
- Bowraville: no individuals recorded.

2.2.3 Detailed Data

2.2.3.1 Species Composition

The species composition and proportions observed at occupied camps were as follows:

- Macksville Cemetery: 95% GHFF and 5% Black Flying-fox.
- Bellingen Island: 95% GHFF and 5% Black Flying-fox.
- Gordon Park: 90% GHFF and 10% Black Flying-fox.

2.2.3.2 Habitat Characteristics and Demographic Composition

As flying-foxes were not recorded at the site in the current monitoring event, detailed demographic composition data was not collected. This has been the case since April 2014 (excluding a brief return in January 2015). During this period of absence the Macksville Cemetery camp has been the alternative site for collection of this data.

Both male and female GHFF were present at the Macksville Cemetery camp. The data collected indicated that the proportion of female GHFF present was high, ranging between 56% and 100% of all individuals at individual demographic point counts (83% average), (refer to **Table 2.1**). The percentage of females with dependent young GHFF at demographic point counts was moderate, ranging between 30% and 80% (55% average).

Both male and female GHFF were also present at the Bellingen Island camp. Data collected indicated that the proportion of female GHFF present was high was high, ranging between 58% and 91% of all individuals at individual demographic point counts (83% average), (refer to **Table 2.2**). The percentage of females with dependent young GHFF at demographic point counts was also generally high, ranging between 50% and 80% (70% average).

General observations of the GHFF currently roosting at the Gordon Park camp indicated that males and females were present. Dependent young were also observed with many of the females.

Table 2.1 Demographic Data of GHFF at the Macksville Cemetery Camp

Tree Code	*GPS Location (UTM coordinates GDA94, Zone 56)*	*Tree Species*	*Height (m)*	*DBH (cm)*	*Demographic Ratio (female:male)*	*Presence of Dependant Young (yes/no)*	*% Females with Dependant Young*
MC1	492036, 6601830	Broad-leaved Paperbark	15	30	10:3	Yes	60
MC2	492047, 6601840	Broad-leaved Paperbark	12	20	10:8	Yes	30
MC3	492036, 6601809	Broad-leaved Paperbark	12	30	10:2	Yes	80
MC4	492058, 6601775	Broad-leaved Paperbark	12	20	10:0	Yes	60
MC5	492080, 6601772	Broad-leaved Paperbark	15	30	10:2	Yes	50
MC6	492073, 6601735	Broad-leaved Paperbark	15	20	10:2	Yes	50
MC7	492107, 6601677	Broad-leaved Paperbark	12	20	10:0	Yes	50
MC8	492124, 6601680	Broad-leaved Paperbark	15	30	10:3	Yes	50
MC9	492117, 6601664	Broad-leaved Paperbark	12	30	10:1	Yes	60
MC10	492145, 6601645	Broad-leaved Paperbark	15	30	10:3	Yes	60

Table 2.2 Demographic Data of GHFF at the Bellingen Island Camp

Tree Code	*GPS Location (UTM coordinates GDA94, Zone 56)*	*Tree Species*	*Height (m)*	*DBH (cm)*	*Demographic Ratio (female:male)*	*Presence of Dependant Young (yes/no)*	*% Females with Dependant Young*
BI1	489984, 6631558	Creek Sandpaper Fig	12	15	10:1	Yes	70
BI2	489995, 6631544	Creek Sandpaper Fig	10	20	10:3	Yes	80
BI3	490008, 6631528	Unkown sp.	12	30	10:7	Yes	80
BI4	490047, 6631522	White Cedar	12	40	10:2	Yes	50
BI5	490058, 6631496	Giant Stinging Tree	20	100	10:1	Yes	80
BI6	490074, 6631487	White Booyong	20	40	10:3	Yes	70
BI7	490091, 6631489	Creek Sandpaper Fig	12	20	10:3	Yes	70
BI8	490101, 6631503	Giant Stinging Tree	12	20	10:1	Yes	70
BI9	490088, 6631527	Giant Stinging Tree	20	30	10:1	Yes	70
BI10	490097, 6631534	Giant Stinging Tree	15	30	10:1	Yes	60

2.2.3.3 Water Level at the Site

Water level at the site measured at the representative measurement location was approximately 55 cm in depth, which is a 10 cm increase from the level recorded last month (refer to **Figure 2.1**).

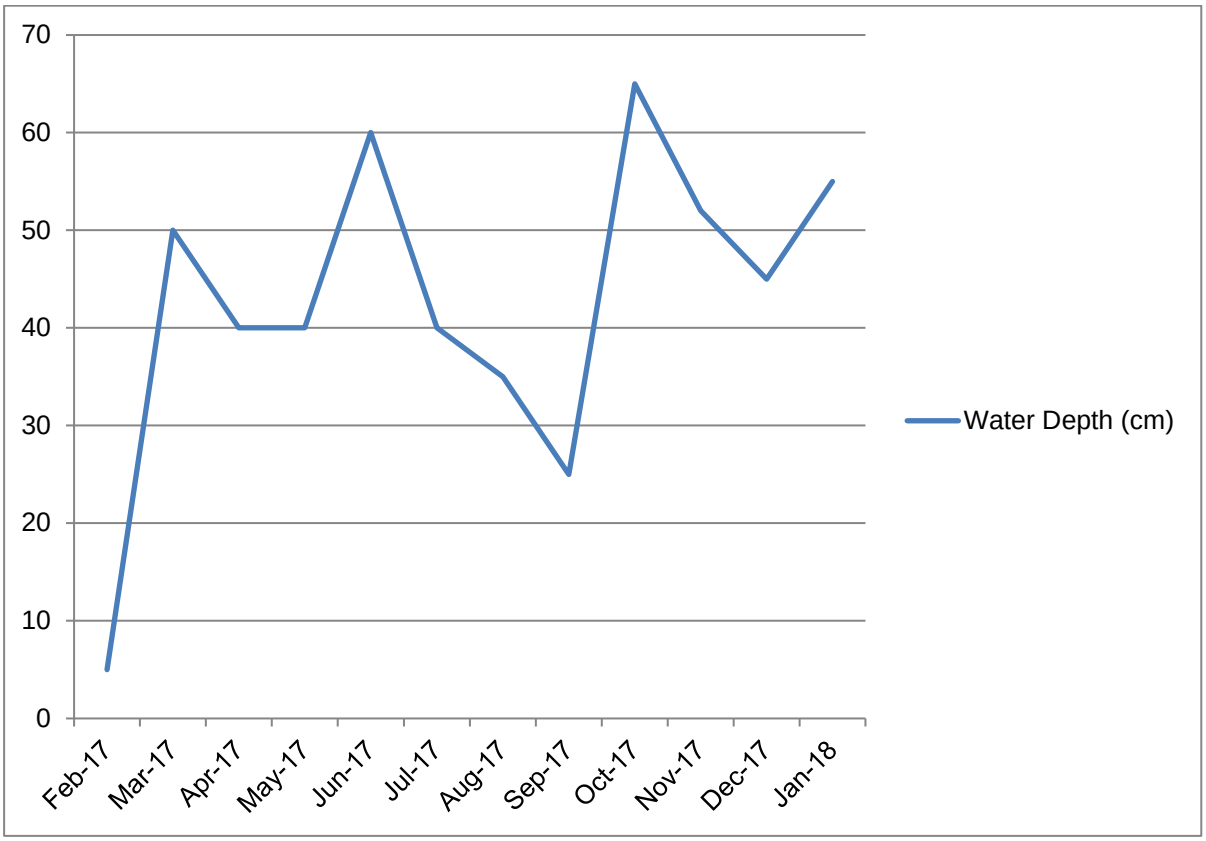


Figure 2.1 Water level measurements at the site

2.3 Discussion

2.3.1 Population Estimates

The trend in flying-fox numbers over the last 12-month period at the site and other monitored regional flying-fox camps is shown in **Figure 2.2**. No flying-foxes were recorded at the site again this month. Flying-foxes have not occupied the site (excluding a brief return in January 2015) since mid-April 2014.

The number of flying-foxes at the Macksville Cemetery camp has continued to increase from the low levels or absence that typically occurs over winter and early spring at this camp. An estimated 50,000 individuals were recorded in the current monitoring event. A similar increase in flying-fox numbers was also recorded at the Bellingen Island camp over the past month. This relatively high number of flying-foxes at both of these camps is most likely a reflection of the current availability of key food resources in the locality (refer to (**Section 2.3.3**).

In contrast, at the Gordon Park camp there has not been a recent sharp increase in flying-fox numbers. The comparatively moderate flying-fox numbers at the Gordon Park camp possibly reflects the overall poor condition of the rainforest canopy caused by a consistent flying-fox presence, resulting in an altered (and potentially less favourable) microclimate for roosting.

No flying-foxes were recorded at Bowraville in the current monitoring event. Over the past 12-month period, flying-foxes have only been present at this camp in very low numbers during late spring and early summer of 2016/17.

As can be seen in the 12-monthly population comparisons (refer to **Figure 2.2**), after reaching a low point in October the overall population levels at occupied camps are generally continuing to increase as summer progresses (with the exception of the Gordon Park camp).

2.3.2 Species Composition and Demographic Data

At occupied camps, GHFF dominated the species composition making up between 80% and 95% of all individuals, similar to the proportions recorded in the previous monthly monitoring event (GeoLINK 2017).

Female GHFF dominated the occupied camps in the current monitoring event, with demographic point counts averaging 83% at both the Bellingen Island and Macksville Cemetery camps. A similar proportion was recorded in the previous monitoring event (GeoLINK 2017).

At the Macksville Cemetery camp dependent young were present at a moderate level alongside 55% of all female GHFF, similar to the proportion recorded in the previous monitoring event (GeoLINK 2017). In contrast the percentage of female GHFF with dependent young at Bellingen Island has increased substantially from 49% in the previous monitoring event (GeoLINK 2017) to 70% in the current monitoring event.

2.3.3 Phenology of Trees in the Region

December/January bi-monthly flowering of a number of highly productive nectar source trees in the upper North Coast region of NSW includes various *Corymbia* spp. (Bloodwoods and Spotted Gums), New England Blackbutt (*Eucalyptus andrewsii*), River Red Gum (*E. camaldulensis*), Coastal Blackbutt (*E. pilularis* - foothills and ranges), Grey Ironbark (*E. siderophloia* - foothills and ranges), Forest Red Gum (*E. tereticornis – high altitude*) and Black Bean (*Castanospermum australe*). These are considered key diet species for GHFF in the region (Eby 2012; Eby and Law 2008).

Observations when travelling between regional flying-fox camps recorded moderate to heavy flowering of Pink Bloodwood (*Corymbia intermedia*).

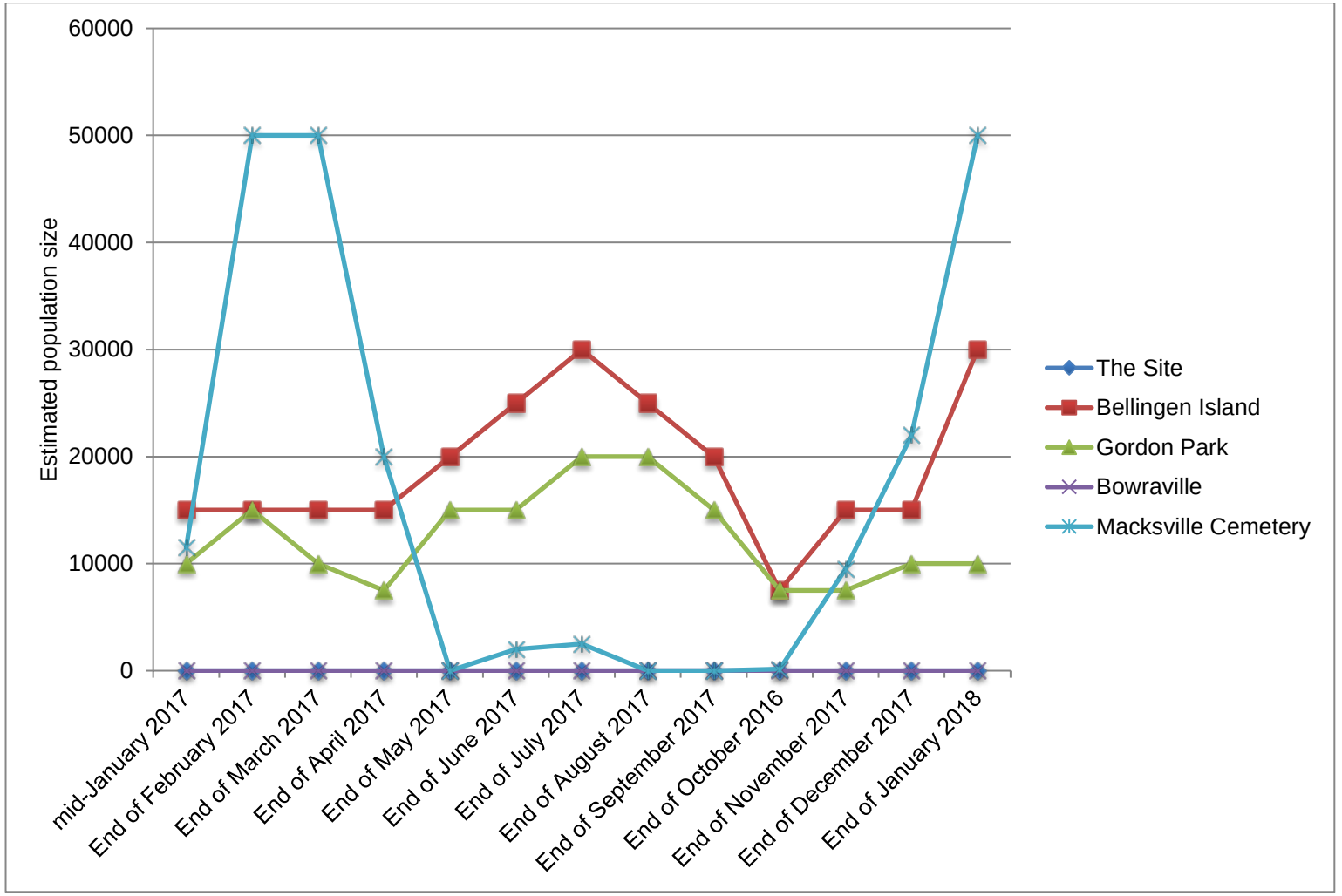


Figure 2.2 Population trends at the site and regional camps over past 12 months

2.4 Summary and Conclusion

The results of the January 2018 flying-fox monitoring indicate that excluding a brief stopover at the site observed in mid-January 2015, flying-foxes have been absent from the site since April 2014.

The number of flying-foxes at both the Macksville Cemetery and Bellingen Island camps have increased substantially over the last month, and are now at around 50,000 and 30,000 individuals respectively. The relatively high number of flying-foxes at these camps is most likely a reflection of the current availability of key food resources in the locality (e.g. flowering Pink Bloodwood).

The Gordon Park camp has not seen this recent sharp increase in flying-fox numbers. The comparatively moderate flying-fox numbers at the Gordon Park camp possibly reflects the overall poor condition of the rainforest canopy caused by a consistent flying-fox presence, resulting in an altered (and potentially less favourable) microclimate for roosting.

Flying-foxes remain absent from Bowraville and Wheatley Street, Bellingen.

GHFF dominated the species composition at occupied camps making up between 80% and 95% of all individuals present.

Dependent young GHFF were present at a moderate to high level within occupied camps in the current monitoring event.

Moderate to heavy flowering of Pink Bloodwood, a key diet species for the GHFF, was observed to be currently occurring in the region.

David Andrighetto
Senior Ecologist

References

Eby, P. (2012). *An Assessment of the Flying-fox Camp at Macksville*. Unpublished report to NSW Roads and Maritime Services.

Eby, P. (2013). *A Field Monitoring Program Proposed for the Macksville Flying-fox Roost*. Unpublished report to Sinclair Knight Merz.

GeoLINK. (2017). *Flying-fox Monitoring December 2017: Warrell Creek to Nambucca Heads Pacific Highway Upgrade*. Unpublished report to NSW Roads and Maritime Services.

Appendix 3 February 2018 monitoring report

Flying-fox Monitoring February 2018

Warrell Creek to Nambucca Heads Pacific Highway Upgrade

PO Box 119
Lennox Head NSW 2478
T 02 6687 7666

PO Box 1446
Coffs Harbour NSW 2450
T 02 6651 7666

PO Box 1267
Armidale NSW 2350
T 02 6772 0454

PO Box 229
Lismore NSW 2480
T 02 6621 6677

info@geolink.net.au

Prepared for: Roads and Maritime Services

© GeoLINK, 2018

UPR	*Description*	*Date Issued*	*Issued By*
2692-1084	First issue	13/03/2018	David Andrighetto

Table of Contents

1. Introduction 1

1.1 Introduction 1

2. Flying-fox Survey 2

2.1 Methodology 2
2.2 Results 3

2.2.1 Roost Footprint 3
2.2.2 Population Estimates 6
2.2.3 Detailed Data 6

2.3 Discussion 9

2.3.1 Population Estimates 9
2.3.2 Species Composition and Demographic Data 10
2.3.3 Phenology of Trees in the Region 10

2.4 Summary and Conclusion 12

Illustrations

Illustration 2.1 Location of Regional Flying-fox Camps 4
Illustration 2.2 Macksville Cemetery Roost Footprint 5

Tables

Table 2.1 Demographic Data of GHFF at the Macksville Cemetery Camp 7
Table 2.2 Demographic Data of GHFF at the Bellingen Island Camp 8

Figures

Figure 2.1 Water level measurements at the site 9
Figure 2.2 Population trends at the site and regional camps over past 12 months 11

1. Introduction

1.1 Introduction

NSW Roads and Maritime Services have been monitoring a Grey-headed Flying-fox (*Pteropus poliocephalus*) (GHFF) camp that was intermittently present within the approved alignment of the Warrell Creek to Nambucca Heads (WC2NH) Pacific Highway upgrade project near Macksville. The camp was located in a patch of swamp sclerophyll forest north of Bald Hill Road (henceforth referred to as 'the site').

GeoLINK has undertaken monitoring at the site on at least a monthly basis since July 2013. Prior to this, irregular monitoring of flying-foxes at the site has been undertaken since the initial establishment of the camp in December 2011 (Eby 2012).

This report details the February 2018 flying-fox monitoring results.

2. Flying-fox Survey

2.1 Methodology

The following GeoLINK personnel undertook fieldwork for the February 2018 flying-fox monitoring:

- Tom Pollard (ecologist).
- Jess O'Leary (ecologist).
- Jeremy Clifford (environmental scientist).
- Kale Hardie-Porter (environmental scientist).

Fieldwork followed the methodology developed by Dr Eby for the project. Refer to Eby (2013) for full details of the methodology. A summary of the main procedures used for the monitoring is provided below.

The fieldwork was undertaken on 28 February 2018. The presence of flying-foxes at the site was assessed by undertaking a traverse of the area previously known to support flying-foxes in conjunction with a few sharp handclaps aimed at eliciting a vocal response from any flying-foxes roosting at the site.

When flying-foxes are present at the site, the following data is collected:

- The area of the roost footprint (mapped by GPS).
- Species composition.
- Demographics.
- Reproductive status.
- Behaviour.

When the site is unoccupied and flying-foxes are present at the nearby seasonally-occupied flying-fox camp within two kilometres of the site adjacent to Macksville Cemetery, the abovementioned data is collected here instead. This data provides relevant information on the status of flying-foxes that are camped in the Macksville area.

The water level at the site was measured at GPS location 492866, 6600756 (UTM coordinates, GDA 94, Zone 56). The water level at this location is representative of the average level at the site and is tracked over time to provide information on water level fluctuations that occur at the site.

A dusk exit count survey was undertaken at both the site and the Macksville Cemetery camp to confirm the presence/ absence of flying-foxes and to provide an estimate of the current population at each camp.

Two observers were strategically located for the exit count on a northern and a southern ridge overlooking the site. Specifically, the two observers were located at the following vantage points:

- In a paddock to the north of the swamp sclerophyll forest (off Wedgewood Drive).
- On a prominent ridge to the south (at 41 Bald Hill Road).

Two observers were also located adjacent to the Macksville Cemetery camp at the following vantage points:

- At the Macksville Cemetery gate off Wallace Street (west of the camp).
- Adjacent to the Macksville Golf Course next to the Pacific Highway (east of the camp).

The exit counts extended over approximately 30 minutes from sunset until dark (approximately 7:30 pm to 8:00 pm).

Other regional flying-fox camps at Gordon Park, Nambucca Heads (approximately 12 kilometres north-east of the site), Bowraville (approximately 10.5 kilometres north-west of the site), Bellingen Wheatley Street Camp (approximately 30 kilometres north of the site) and Bellingen Island (approximately 31 kilometres north of the site) were also visited and observational comments made. Refer to **Illustration 2.1** for the location of the subject regional camps.

2.2 Results

2.2.1 Roost Footprint

No flying-foxes were recorded roosting at the site in the traverse.

Flying-foxes were observed to be roosting at the Macksville Cemetery camp. The roost extended over a relatively large area of approximately 3.3 hectares (refer to **Illustration 2.2**).

Flying-foxes were not recorded at the Wheatley Street camp in Bellingen or at Bowraville.

Regionally, flying-foxes were observed to be roosting at Bellingen Island and Gordon Park (Nambucca Heads). The extent of the roost footprint at Bellingen Island has remained much the same as that recorded in the previous monthly monitoring event (GeoLINK 2018), with the exception of a minor enlargement of the roost to include isolated trees in the old caravan park grounds alongside Dowle Street. In contrast to the previous monthly monitoring event, only a few small groups of roosting flying-foxes were observed in the upper canopy of the emergent fig trees.

At the Gordon Park camp the roost extent has not substantially changed from that recorded in the previous monitoring event, with a general absence of flying-foxes from the upper canopy of the rainforest that supports nil to sparse foliage cover from previous roosting by large numbers of flying-foxes.

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: DSA Date: 12/03/2018
Source of base data: Roads and Maritime Services

0 4 km

North

Location of Regional Flying-fox Camps

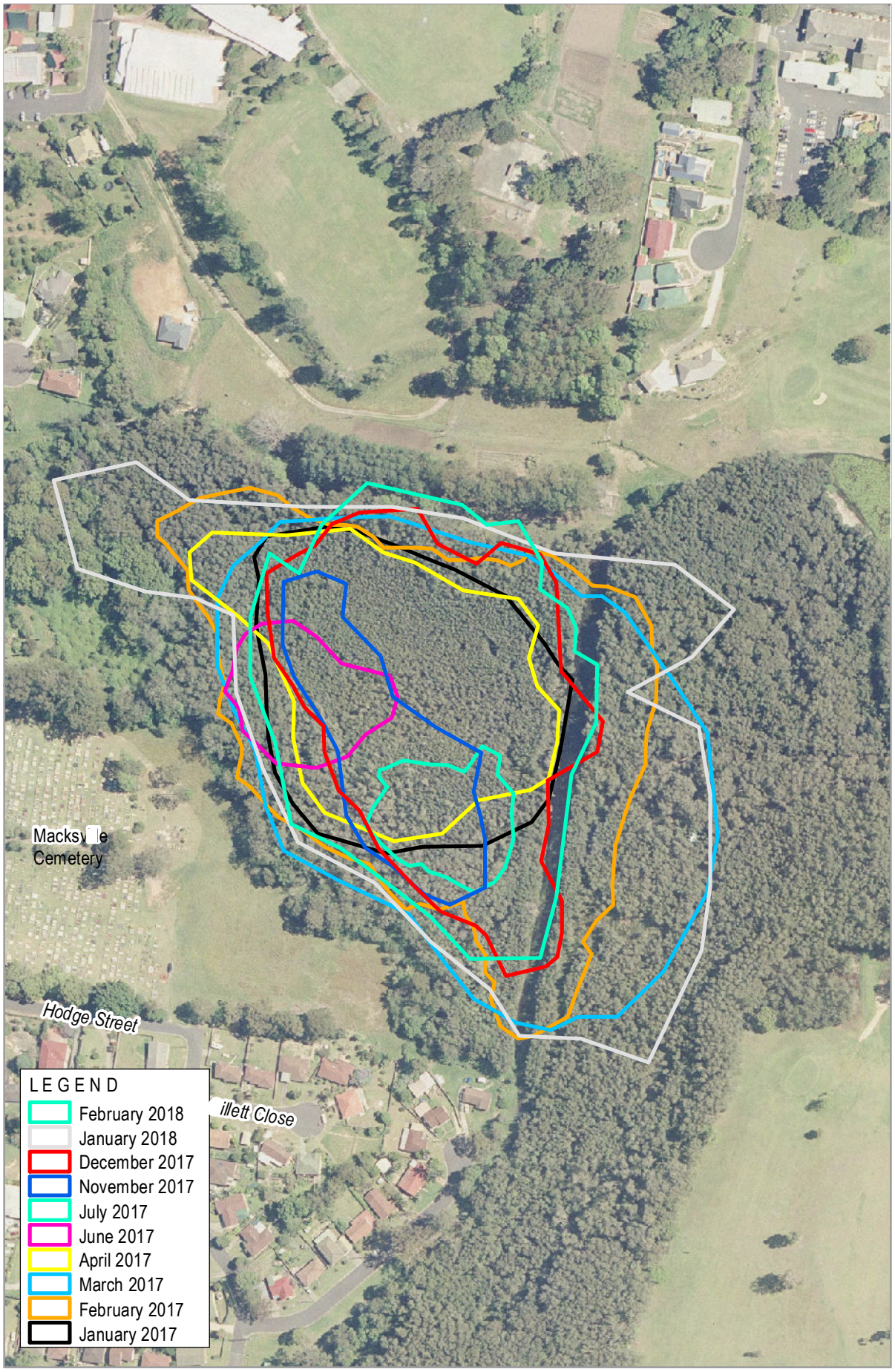
GeoLINK environmental management and design

Flying-fox Monitoring February 2018 - Warrell Creek to Nambucca Heads
Pacific Highway Upgrade
2692-1086

Illustration 2.1

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: DSA Date: 12/03/2018
Source of base data: Roads and Maritime Services



North

0 60

Macksville Cemetery Flying-fox Roost Footprint

GeoLINK environmental management and design

Flying-fox Monitoring February 2018 - Warrell Creek to Nambucca Heads
Pacific Highway Upgrade
2692-1087

Illustration 2.2

2.2.2 Population Estimates

2.2.2.1 Exit Counts

No flying-foxes were observed flying from the site during the exit count.

Approximately 30,000 individuals were recorded exiting the Macksville Cemetery camp in the exit count. The flying-foxes were exiting in two broad streams, one in a north to north-westerly direction and another in a south to south-easterly direction.

2.2.2.2 Direct Counts

With the exception of the Macksville Cemetery camp, no exit counts were conducted at any of the remaining regional camps. However, rough population estimates for these camps based on extrapolation of counts in individual trees and the roost footprint are as follows:

- Gordon Park: approximately 10,000 individuals.
- Bellingen Island: approximately 25,000 individuals.
- Wheatley Street, Bellingen: no individuals recorded.
- Bowraville: no individuals recorded.

2.2.3 Detailed Data

2.2.3.1 Species Composition

The species composition and proportions observed at occupied camps were as follows:

- Macksville Cemetery: 80% GHFF and 20% Black Flying-fox.
- Bellingen Island: 95% GHFF and 5% Black Flying-fox.
- Gordon Park: 80% GHFF and 20% Black Flying-fox.

2.2.3.2 Habitat Characteristics and Demographic Composition

As flying-foxes were not recorded at the site in the current monitoring event, detailed demographic composition data was not collected. This has been the case since April 2014 (excluding a brief return in January 2015). During this period of absence, the Macksville Cemetery camp has been the alternative site for collection of this data.

Both male and female GHFF were present at the Macksville Cemetery camp. Young dependent GHFF were present, although some individuals were beginning to display semi-independent behaviour by spending periods of time roosting alongside their mothers. The data collected indicated that the proportion of female GHFF present was high, ranging between 58% and 100% of all individuals at individual demographic point counts (75% average), (refer to **Table 2.1**). The percentage of females with dependent young GHFF at demographic point counts was moderate to high, ranging between 50% and 80% (62% average).

Both male and female GHFF were also present at the Bellingen Island camp. As was observed at the Macksville cemetery camp, dependent young GHFF were present with these individuals showing some semi-independent behaviour by spending time roosting alongside their mothers. Data collected indicated that the proportion of female GHFF present was high, ranging between 76% and 100% of all individuals at individual demographic point counts (91% average), (refer to **Table 2.2**). The percentage of females with dependent young GHFF at demographic point counts was moderate to high, ranging between 60% and 90% (74% average).

General observations of the GHFF currently roosting at the Gordon Park camp indicated that males and females were present. Dependent young (including semi-independent individuals) were also observed with many of the females.

Table 2.1 Demographic Data of GHFF at the Macksville Cemetery Camp

Tree Code	*GPS Location (UTM coordinates GDA94, Zone 56)*	*Tree Species*	*Height (m)*	*DBH (cm)*	*Demographic Ratio (female:male)*	*Presence of Dependant Young (yes/no)*	*% Females with Dependant Young*
MC1	492137, 6601656	Broad-leaved Paperbark	12	20	10:5	Yes	60
MC2	492126, 6601658	Broad-leaved Paperbark	12	20	10:7	Yes	50
MC3	492098, 6601685	Broad-leaved Paperbark	12	30	10:0	Yes	80
MC4	492081, 6601727	Broad-leaved Paperbark	15	30	10:1	Yes	70
MC5	492065, 6601731	Broad-leaved Paperbark	12	30	10:4	Yes	50
MC6	492057, 6601762	Broad-leaved Paperbark	15	20	10:5	Yes	50
MC7	492036, 6601812	Broad-leaved Paperbark	12	20	10:3	Yes	60
MC8	492044, 6601833	Broad-leaved Paperbark	15	30	10:5	Yes	60
MC9	492095, 6601861	Broad-leaved Paperbark	15	20	10:3	Yes	70
MC10	492103, 6601850	Broad-leaved Paperbark	12	20	10:4	Yes	70

Table 2.2 Demographic Data of GHFF at the Bellingen Island Camp

Tree Code	*GPS Location (UTM coordinates GDA94, Zone 56)*	*Tree Species*	*Height (m)*	*DBH (cm)*	*Demographic Ratio (female:male)*	*Presence of Dependant Young (yes/no)*	*% Females with Dependant Young*
BI1	489984, 6631555	Stag (dead tree)	8	50	10:3	Yes	70
BI2	489999, 6631549	Creek Sandpaper Fig	8	40	10:2	Yes	80
BI3	490025, 6631541	Creek Sandpaper Fig	10	30	10:0	Yes	80
BI4	490038, 6631535	Creek Sandpaper Fig	8	30	10:1	Yes	70
BI5	490043, 6631514	White Booyong	12	40	10:1	Yes	90
BI6	490069, 6631503	Giant Stinging Tree	12	40	10:0	Yes	70
BI7	490084, 6631491	Giant Stinging Tree	15	50	10:1	Yes	90
BI8	490098, 6631503	Giant Stinging Tree	10	30	10:0	Yes	60
BI9	490098, 6631549	Creek Sandpaper Fig	8	20	10:2	Yes	70
BI10	490086, 6631567	Unidentified sp.	8	30	10:1	Yes	60

2.2.3.3 Water Level at the Site

Water level at the site measured at the representative measurement location was approximately 50 cm in depth, which is a five centimetre decrease from the level recorded last month (refer to **Figure 2.1**).

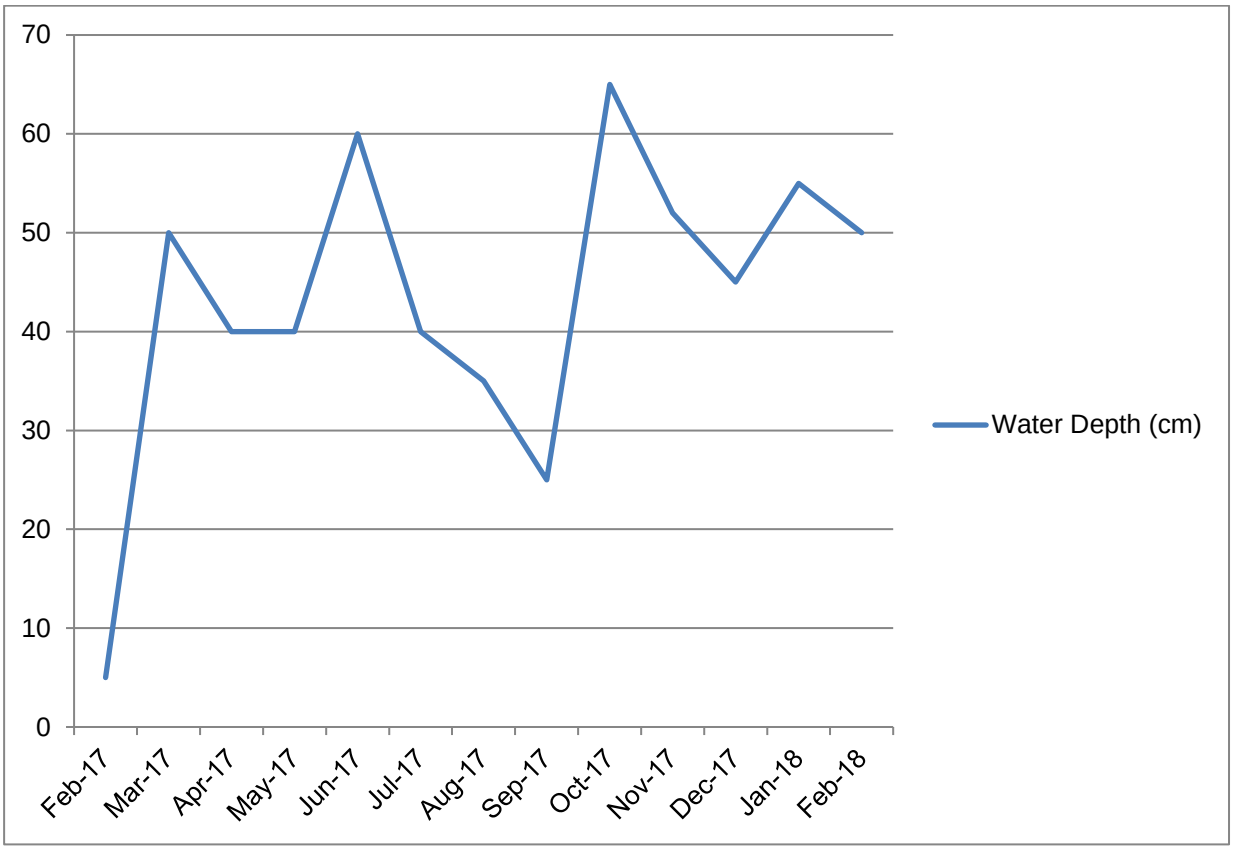


Figure 2.1 Water level measurements at the site

2.3 Discussion

2.3.1 Population Estimates

The trend in flying-fox numbers over the last 12-month period at the site and other monitored regional flying-fox camps is shown in **Figure 2.2**. No flying-foxes were recorded at the site again this month. Flying-foxes have not occupied the site (excluding a brief return in January 2015) since mid-April 2014.

The number of flying-foxes at the Macksville Cemetery camp has decreased from approximately 50,000 individuals in the previous monthly monitoring event to 30,000 in the current monitoring event. In February 2017 flying-fox numbers were still at a summer peak of approximately 50,000 individuals (GeoLINK 2017). It was estimated that approximately 25,000 flying-foxes were present at the Bellingen Island camp in the current monitoring event, which is similar to the number recorded in the previous monthly monitoring event. In February 2017 the estimated number of flying-foxes roosting at the Bellingen Island camp was approximately 15,000 (GeoLINK 2017); substantially fewer than was recorded in the current monitoring event.

The number of flying-foxes estimated to be roosting at the Gordon Park camp has remained steady over the past three months at around 10,000 individuals. A similar population level was present in February 2017, when it was estimated that approximately 15,000 individuals were roosting at this camp (GeoLINK 2017).

No flying-foxes were recorded at Bowraville in the current monitoring event. Flying-foxes have been absent from this site for over 12 months, and were last recorded in December 2016 in low numbers.

As can be seen in the 12-monthly population comparisons (refer to **Figure 2.2**), numbers of flying-foxes at the regional camps appear to have now reached a summer maximum, as is generally the case in response to a seasonal increase in the availability of key foraging resources.

2.3.2 Species Composition and Demographic Data

At occupied camps, GHFF dominated the species composition making up between 80% and 95% of all individuals, similar to the proportions recorded in the previous monthly monitoring event (GeoLINK 2018).

Female GHFF dominated the occupied camps in the current monitoring event, with demographic point counts averaging 91% the Bellingen Island camp and 75% at the Macksville Cemetery camp. Similarly, high proportions were recorded in the previous monitoring event (GeoLINK 2018).

At both the Macksville Cemetery camp and the Bellingen Island camp dependent young were present at a moderate to high level, and in similar proportions to that recorded in the previous monitoring event, at 62% and 74% respectively (GeoLINK 2018).

2.3.3 Phenology of Trees in the Region

February/ March bi-monthly flowering of a number of highly productive nectar source trees in the upper North Coast region of NSW includes various *Corymbia* spp. (Bloodwoods and Spotted Gums), New England Blackbutt (*Eucalyptus andrewsii*), Coastal Blackbutt (*E. pilularis* - foothills and ranges), Sydney Blue Gum (*E. saligna*) and Broad-leaved Paperbark (*Melaleuca quinquenervia*). These are considered key diet species for GHFF in the region (Eby 2012; Eby and Law 2008).

Observations when travelling between regional flying-fox camps recorded moderate flowering of Broad-leaved Paperbark.

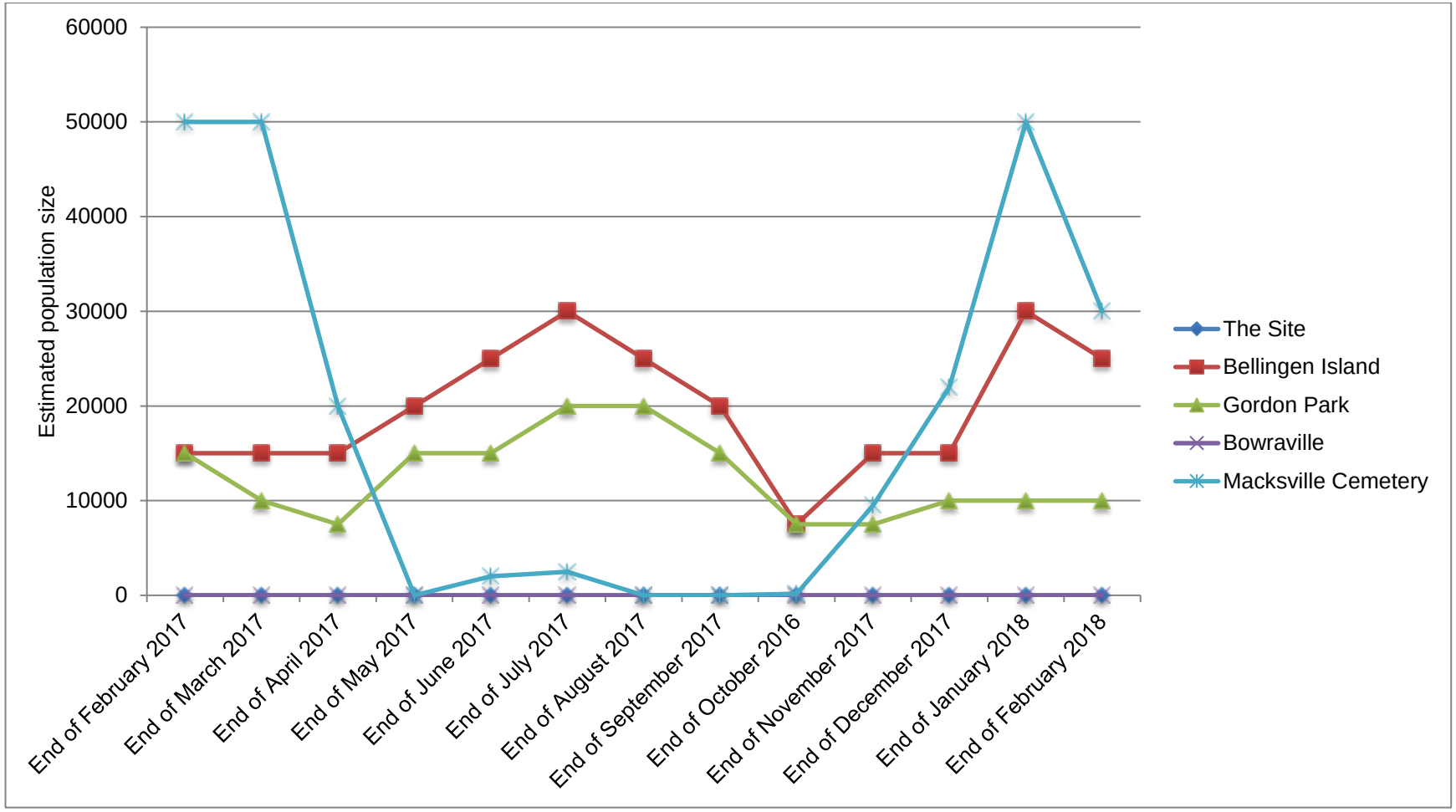


Figure 2.2 Population trends at the site and regional camps over past 12 months

2.4 Summary and Conclusion

The results of the February 2018 flying-fox monitoring indicate that excluding a brief stopover at the site observed in mid-January 2015, flying-foxes have been absent from the site since April 2014. T

The number of flying-foxes at the Macksville Cemetery camp has decreased from approximately 50,000 individuals in the previous monthly monitoring event to 30,000 in the current monitoring event. Over the same period at the Bellingen Island camp the number of flying-foxes has decreased marginally from 30,000 individuals to 25,000 individuals.

The number of flying-foxes estimated to be roosting at the Gordon Park camp has remained steady over the past three months at around 10,000 individuals.

Flying-foxes remain absent from Bowraville and Wheatley Street, Bellingen.

GHFF dominated the species composition at occupied camps making up between 80% and 95% of all individuals present.

Dependent young GHFF were present at a moderate to high level within occupied camps in the current monitoring event. Some young were displaying semi-independent behaviour (roosting alongside their mothers).

Moderate flowering of Broad-leaved Paperbark, a key diet species for the GHFF, was observed to be currently occurring in the region.

David Andrighetto
Senior Ecologist

References

Eby, P. (2012). *An Assessment of the Flying-fox Camp at Macksville*. Unpublished report to NSW Roads and Maritime Services.

Eby, P. (2013). *A Field Monitoring Program Proposed for the Macksville Flying-fox Roost*. Unpublished report to Sinclair Knight Merz.

GeoLINK. (2017). *Flying-fox Monitoring February 2017: Warrell Creek to Nambucca Heads Pacific Highway Upgrade*. Unpublished report to NSW Roads and Maritime Services.

GeoLINK. (2018). *Flying-fox Monitoring January 2018: Warrell Creek to Nambucca Heads Pacific Highway Upgrade*. Unpublished report to NSW Roads and Maritime Services.

Appendix 4 March 2018 monitoring report.

Flying-fox Monitoring March 2018

Warrell Creek to Nambucca Heads Pacific Highway Upgrade

PO Box 119
Lennox Head NSW 2478
T 02 6687 7666

PO Box 1446
Coffs Harbour NSW 2450
T 02 6651 7666

PO Box 1267
Armidale NSW 2350
T 02 6772 0454

PO Box 229
Lismore NSW 2480
T 02 6621 6677

info@geolink.net.au

Prepared for: Roads and Maritime Services

© GeoLINK, 2018

UPR	*Description*	*Date Issued*	*Issued By*
2692-1093	First issue	02/04/2018	David Andrighetto

Table of Contents

1. Introduction 1

1.1 Introduction 1

2. Flying-fox Survey 2

2.1 Methodology 2
2.2 Results 3

2.2.1 Roost Footprint 3
2.2.2 Population Estimates 6
2.2.3 Detailed Data 6

2.3 Discussion 9

2.3.1 Population Estimates 9
2.3.2 Species Composition and Demographic Data 10
2.3.3 Phenology of Trees in the Region 10

2.4 Summary and Conclusion 12

Illustrations

Illustration 2.1 Location of Regional Flying-fox Camps 4
Illustration 2.2 Macksville Cemetery Roost Footprint 5

Tables

Table 2.1 Demographic Data of GHFF at the Macksville Cemetery Camp 7
Table 2.2 Demographic Data of GHFF at the Bellingen Island Camp 8

Figures

Figure 2.1 Water level measurements at the site 9
Figure 2.2 Population trends at the site and regional camps over past 12 months 11

1. Introduction

1.1 Introduction

NSW Roads and Maritime Services has been monitoring a Grey-headed Flying-fox (*Pteropus poliocephalus*) (GHFF) camp that was intermittently present within the approved alignment of the Warrell Creek to Nambucca Heads (WC2NH) Pacific Highway upgrade project near Macksville. The camp was located in a patch of swamp sclerophyll forest north of Bald Hill Road (henceforth referred to as 'the site').

GeoLINK has undertaken monitoring at the site on at least a monthly basis since July 2013. Prior to this, irregular monitoring of flying-foxes at the site has been undertaken since the initial establishment of the camp in December 2011 (Eby 2012).

This report details the March 2018 flying-fox monitoring results.

2. Flying-fox Survey

2.1 Methodology

The following GeoLINK personnel undertook fieldwork for the March 2018 flying-fox monitoring:

- Tom Pollard (ecologist).
- Frank Makin (ecologist).
- Jeremy Clifford (environmental scientist).
- Kale Hardie-Porter (environmental scientist).

Fieldwork followed the methodology developed by Dr Eby for the project. Refer to Eby (2013) for full details of the methodology. A summary of the main procedures used for the monitoring is provided below.

The fieldwork was undertaken on 26 March 2018. The presence of flying-foxes at the site was assessed by undertaking a traverse of the area previously known to support flying-foxes in conjunction with a few sharp handclaps aimed at eliciting a vocal response from any flying-foxes roosting at the site.

When flying-foxes are present at the site, the following data is collected:

- The area of the roost footprint (mapped by GPS).
- Species composition.
- Demographics.
- Reproductive status.
- Behaviour.

When the site is unoccupied and flying-foxes are present at the nearby seasonally-occupied flying-fox camp within two kilometres of the site adjacent to Macksville Cemetery, the abovementioned data is collected here instead. This data provides relevant information on the status of flying-foxes that are camped in the Macksville area.

The water level at the site was measured at GPS location 492866, 6600756 (UTM coordinates, GDA 94, Zone 56). The water level at this location is representative of the average level at the site and is tracked over time to provide information on water level fluctuations that occur at the site.

A dusk exit count survey was undertaken at both the site and the Macksville Cemetery camp to confirm the presence/ absence of flying-foxes and to provide an estimate of the current population at each camp.

Two observers were strategically located for the exit count on a northern and a southern ridge overlooking the site. Specifically, the two observers were located at the following vantage points:

- In a paddock to the north of the swamp sclerophyll forest (off Wedgewood Drive).
- On a prominent ridge to the south (at 41 Bald Hill Road).

Two observers were also located adjacent to the Macksville Cemetery camp at the following vantage points:

- At the Macksville Cemetery gate off Wallace Street (west of the camp).
- Adjacent to the Macksville Golf Course next to the Pacific Highway (east of the camp).

The exit counts extended over approximately 30 minutes from sunset until dark (approximately 6:50 pm to 7:20 pm).

Other regional flying-fox camps at Gordon Park, Nambucca Heads (approximately 12 kilometres north-east of the site), Bowraville (approximately 10.5 kilometres north-west of the site), Bellingen Wheatley Street Camp (approximately 30 kilometres north of the site) and Bellingen Island (approximately 31 kilometres north of the site) were also visited and observational comments made. Refer to **Illustration 2.1** for the location of the subject regional camps.

2.2 Results

2.2.1 Roost Footprint

No flying-foxes were recorded roosting at the site in the traverse.

Flying-foxes were observed to be roosting at the Macksville Cemetery camp. The roost extended over a relatively large area of approximately 3.9 hectares (refer to **Illustration 2.2**).

Flying-foxes were not recorded at the Wheatley Street camp in Bellingen or at Bowraville.

Regionally, flying-foxes were observed to be roosting at Bellingen Island and Gordon Park (Nambucca Heads). When compared with observations from the previous monitoring event (GeoLINK 2018), the extent of the roost footprint at Bellingen Island has expanded further to the east to include many of the mature trees in the old caravan park grounds alongside Dowle Street. More individuals were also observed to be roosting in the upper canopy of the emergent fig trees.

At the Gordon Park camp the roost extent has not substantially changed from that recorded in the previous monitoring event. There was a general absence of flying-foxes roosting in the upper canopy of the central rainforest that currently supports nil to sparse foliage cover from previous roosting by large numbers of flying-foxes.

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: DSA Date: 2/04/2018
Source of base data: Roads and Maritime Services

0 4 km

North

Location of Regional Flying-fox Camps

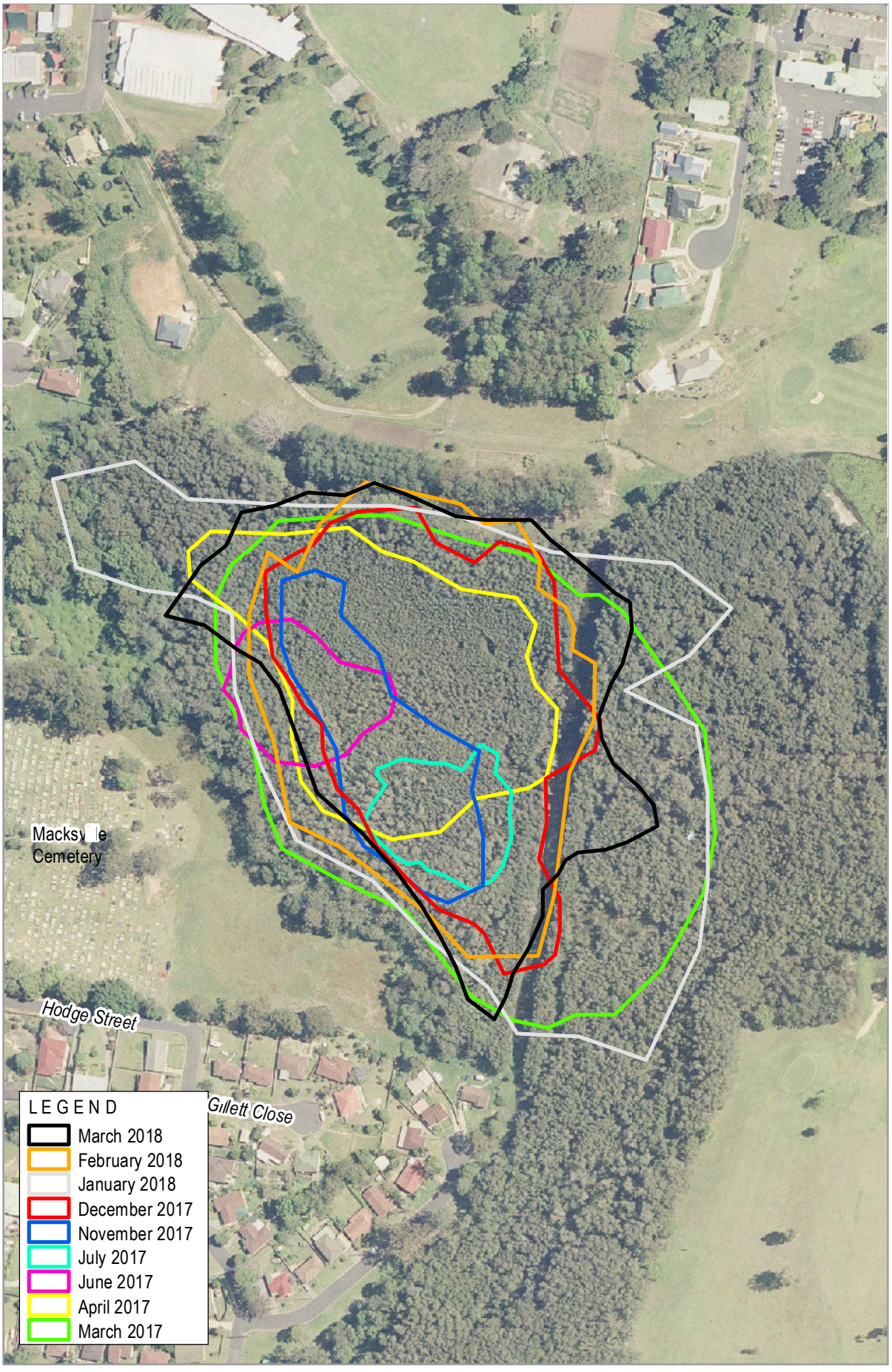
GeoLINK environmental management and design

Flying-fox Monitoring March 2018 - Warrell Creek to Nambucca Heads
Pacific Highway Upgrade
2692-1095

Illustration 2.1

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: DSA Date: 2/04/2018
Source of base data: Roads and Maritime Services



North

0 60

Macksville Cemetery Flying-fox Roost Footprint

GeoLINK environmental management and design

Flying-fox Monitoring March 2018 - Warrell Creek to Nambucca Heads
Pacific Highway Upgrade
2692-1096

Illustration 2.2

2.2.2 Population Estimates

2.2.2.1 Exit Counts

No flying-foxes were observed flying from the site during the exit count.

Approximately 45,000 individuals were recorded exiting the Macksville Cemetery camp in the exit count. As was recorded in the previous monitoring event (GeoLINK 2018), the flying-foxes were exiting in two broad streams, one in a north to north-westerly direction and another in a south to south-easterly direction.

2.2.2.2 Direct Counts

With the exception of the Macksville Cemetery camp, no exit counts were conducted at any of the remaining regional camps. However, rough population estimates for these camps based on extrapolation of counts in individual trees and the roost footprint are as follows:

- Gordon Park: approximately 10,000 individuals.
- Bellingen Island: approximately 40,000 individuals.
- Wheatley Street, Bellingen: no individuals recorded.
- Bowraville: no individuals recorded.

2.2.3 Detailed Data

2.2.3.1 Species Composition

The species composition and proportions observed at occupied camps were as follows:

- Macksville Cemetery: 80% GHFF and 20% Black Flying-fox.
- Bellingen Island: 90% GHFF and 10% Black Flying-fox.
- Gordon Park: 90% GHFF and 10% Black Flying-fox.

2.2.3.2 Habitat Characteristics and Demographic Composition

As flying-foxes were not recorded at the site in the current monitoring event, detailed demographic composition data was not collected. This has been the case since April 2014 (excluding a brief return in January 2015). During this period of absence, the Macksville Cemetery camp has been the alternative site for collection of this data.

Both male and female GHFF were present at the Macksville Cemetery camp. Young dependent GHFF were observed, as well as semi-independent individuals that were roosting alongside their mothers. The data collected indicated that the proportion of female GHFF present was high, ranging between 67% and 100% of all individuals at individual demographic point counts (86% average), (refer to **Table 2.1**). The percentage of females with dependent young GHFF at demographic point counts was moderate, ranging between 20% and 60% (35% average).

Both male and female GHFF were also present at the Bellingen Island camp. As was observed at the Macksville cemetery camp, dependent young GHFF were present with these individuals showing semi-independent behaviour by spending time roosting alongside their mothers. Data collected indicated that the proportion of female GHFF present was relatively high, ranging between 67% and 91% of all individuals at individual demographic point counts (80% average), (refer to **Table 2.2**). The percentage of females with dependent young GHFF at demographic point counts was moderate, ranging between 30% and 70% (54% average).

General observations of the GHFF currently roosting at the Gordon Park camp indicated that males and females were present. Dependent young (including semi-independent individuals) were also observed with many of the females.

Table 2.1 Demographic Data of GHFF at the Macksville Cemetery Camp

Tree Code	*GPS Location (UTM coordinates GDA94, Zone 56)*	*Tree Species*	*Height (m)*	*DBH (cm)*	*Demographic Ratio (female:male)*	*Presence of Dependant Young (yes/no)*	*% Females with Dependant Young*
MC1	492064, 6601725	Broad-leaved Paperbark	15	30	10:5	Yes	20
MC2	492094, 6601720	Broad-leaved Paperbark	8	20	10:2	Yes	40
MC3	492052, 6601755	Broad-leaved Paperbark	15	30	10:1	Yes	20
MC4	492061, 6601788	Broad-leaved Paperbark	8	20	10:1	Yes	60
MC5	492068, 6601776	Broad-leaved Paperbark	8	15	10:0	Yes	40
MC6	492024, 6601792	Broad-leaved Paperbark	15	30	10:3	Yes	20
MC7	492046, 6601819	Broad-leaved Paperbark	12	20	10:1	Yes	30
MC8	492044, 6601833	Broad-leaved Paperbark	10	20	10:2	Yes	30
MC9	492036, 6601840	Broad-leaved Paperbark	15	30	10:1	Yes	60
MC10	491999, 6601824	Broad-leaved Paperbark	18	30	10:1	Yes	30

Table 2.2 Demographic Data of GHFF at the Bellingen Island Camp

Tree Code	*GPS Location (UTM coordinates GDA94, Zone 56)*	*Tree Species*	*Height (m)*	*DBH (cm)*	*Demographic Ratio (female:male)*	*Presence of Dependant Young (yes/no)*	*% Females with Dependant Young*
BI1	489955, 6631588	Creek Sandpaper Fig	8	20	10:2	Yes	40
BI2	489986, 6631557	Creek Sandpaper Fig	8	20	10:2	Yes	70
BI3	490017, 6631519	Creek Sandpaper Fig	8	20	10:5	Yes	70
BI4	490050, 6631507	White Booyong	10	30	10:3	Yes	70
BI5	490066, 6631486	Creek Sandpaper Fig	10	30	10:1	Yes	60
BI6	490087, 6631489	Giant Stinging Tree	12	40	10:3	Yes	60
BI7	490097, 6631499	Giant Stinging Tree	12	40	10:2	Yes	60
BI8	490101, 6631505	White Booyong	8	30	10:2	Yes	30
BI9	490115, 6631506	Giant Stinging Tree	12	40	10:3	Yes	40
BI10	490110, 6631534	Unidentified sp.	8	40	10:2	Yes	30

2.2.3.3 Water Level at the Site

Water level at the site measured at the representative measurement location was approximately 65 cm in depth. This is a 15 cm increase in the level that was recorded in the previous monitoring event, reflecting recent heavy rainfall in the area (refer to **Figure 2.1**).

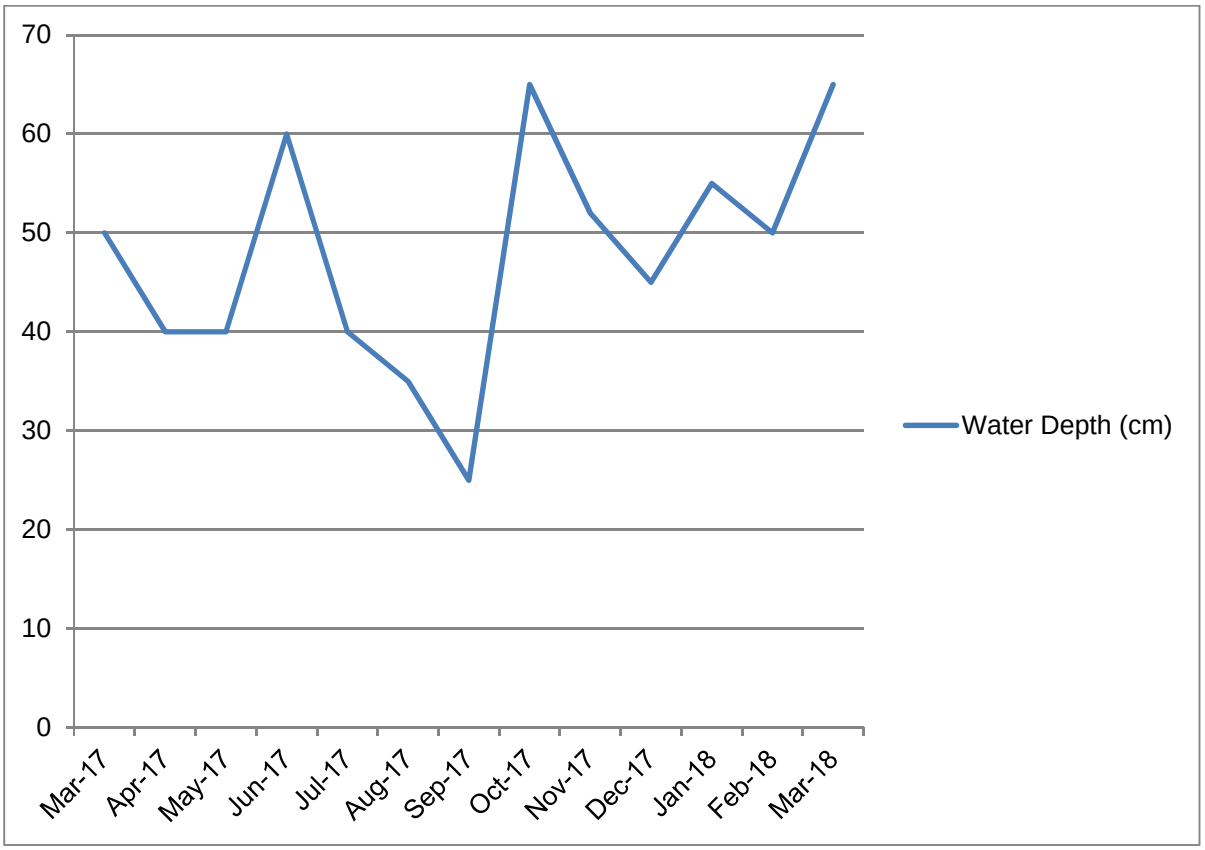


Figure 2.1 Water level measurements at the site

2.3 Discussion

2.3.1 Population Estimates

The trend in flying-fox numbers over the last 12-month period at the site and other monitored regional flying-fox camps is shown in **Figure 2.2**. No flying-foxes were recorded at the site again this month. Flying-foxes have not occupied the site (excluding a brief return in January 2015) since mid-April 2014.

The number of flying-foxes at the Macksville Cemetery camp has increased by 15,000 individuals in February 2018 (from 30,000) and is now approximately 45,000 individuals. Flying-fox numbers at this camp have been between 22,500 and 50,000 individuals over the last three months. In March 2017 flying-fox numbers were similar at approximately 50,000 individuals (GeoLINK 2017). It was estimated that approximately 40,000 flying-foxes were present at the Bellingen Island camp in the current monitoring event, which is a substantial increase from the previous monthly monitoring event when 25,000 individuals were estimated to be present (GeoLINK 2018). In March 2017 the estimated number of flying-foxes roosting at the Bellingen Island camp was approximately 15,000 (GeoLINK 2017); substantially fewer than was recorded in the current monitoring event.

The number of flying-foxes estimated to be roosting at the Gordon Park camp has remained steady over the past three months at around 10,000 individuals. A similar population level was present in February 2017, when it was estimated that approximately 10,000 individuals were roosting at this camp (GeoLINK 2017). This comparatively low number of flying-foxes at this camp is likely the result of the ongoing poor condition of the rainforest canopy and consequent change in roosting suitability.

No flying-foxes were recorded at Bowraville in the current monitoring event. Flying-foxes have been absent from this site for over 12 months, and were last recorded in December 2016 in low numbers.

As can be seen in the 12-monthly population comparisons (refer to **Figure 2.2**), numbers of flying-foxes at the regional camps are still relatively high (apart from the Gordon Park camp), which is likely to be reflecting the regional availability of key foraging resources.

2.3.2 Species Composition and Demographic Data

At occupied camps, GHFF dominated the species composition making up between 80% and 90% of all individuals, similar to the proportions recorded in the previous monthly monitoring event (GeoLINK 2018).

Female GHFF dominated the occupied camps in the current monitoring event, with demographic point counts averaging 80% the Bellingen Island camp and 80% at the Macksville Cemetery camp. Similarly, high proportions were recorded in the previous monitoring event (GeoLINK 2018).

At both the Macksville Cemetery camp and the Bellingen Island camp dependent young were present at moderate levels (54% and 35% respectively). The number of dependent young has decreased compared with the levels recorded in the previous monitoring event as many young are now becoming independent from their mothers (GeoLINK 2018).

2.3.3 Phenology of Trees in the Region

February/ March bi-monthly flowering of a number of highly productive nectar source trees in the upper North Coast region of NSW includes various *Corymbia* spp. (Bloodwoods and Spotted Gums), New England Blackbutt (*Eucalyptus andrewsii*), Coastal Blackbutt (*E. pilularis* - foothills and ranges), Sydney Blue Gum (*E. saligna*) and Broad-leaved Paperbark (*Melaleuca quinquenervia*). These are considered key diet species for GHFF in the region (Eby 2012; Eby and Law 2008).

Observations when travelling between regional flying-fox camps recorded moderate flowering of Broad-leaved Paperbark.

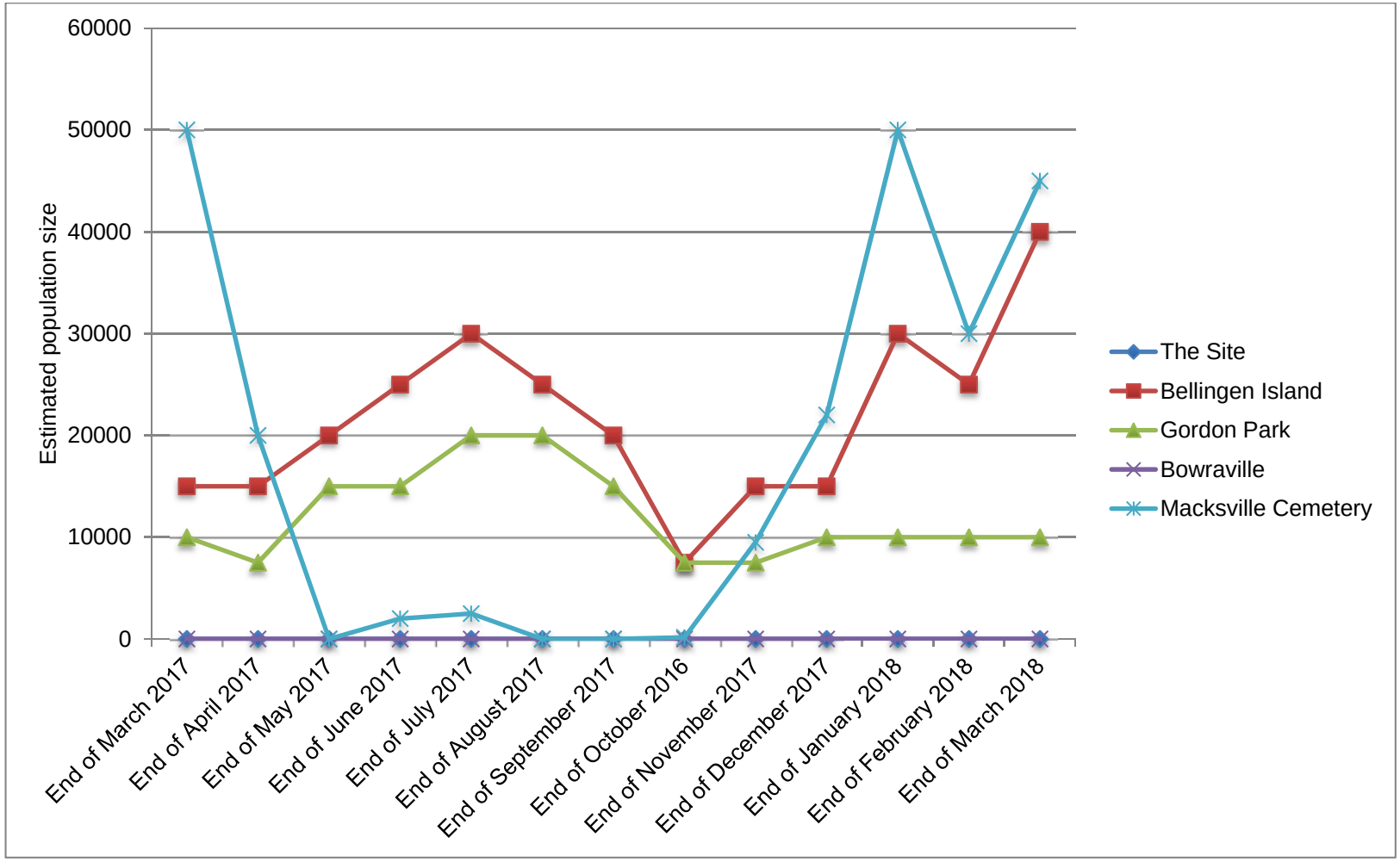


Figure 2.2 Population trends at the site and regional camps over past 12 months

2.4 Summary and Conclusion

The results of the March 2018 flying-fox monitoring indicate that, excluding a brief stopover at the site observed in mid-January 2015, flying-foxes have been absent from the site since April 2014.

The number of flying-foxes at the Macksville Cemetery camp has increased by 15,000 individuals and is now approximately 45,000 individuals. Flying-fox numbers at this camp have been between 22,500 and 50,000 individuals over the last three months. Similarly, at Bellingen Island camp the number of flying-foxes has increased substantially from approximately 25,000 to 40,000 individuals over the last month.

The number of flying-foxes estimated to be roosting at the Gordon Park camp has remained steady over the past three months at around 10,000 individuals, likely reflecting the poor condition of the rainforest canopy at this camp.

Flying-foxes remain absent from Bowraville and Wheatley Street, Bellingen.

GHFF dominated the species composition at occupied camps making up between 80% and 90% of all individuals present.

The number of dependent young GHFF has decreased at occupied camps compared with the levels recorded in the previous monitoring event as many young are now becoming independent from their mothers.

Moderate flowering of Broad-leaved Paperbark, a key diet species for the GHFF, was observed to be currently occurring in the region.

David Andrighetto
Senior Ecologist

References

Eby, P. (2012). *An Assessment of the Flying-fox Camp at Macksville*. Unpublished report to NSW Roads and Maritime Services.

Eby, P. (2013). *A Field Monitoring Program Proposed for the Macksville Flying-fox Roost*. Unpublished report to Sinclair Knight Merz.

GeoLINK. (2017). *Flying-fox Monitoring March 2017: Warrell Creek to Nambucca Heads Pacific Highway Upgrade*. Unpublished report to NSW Roads and Maritime Services.

GeoLINK. (2018). *Flying-fox Monitoring February 2018: Warrell Creek to Nambucca Heads Pacific Highway Upgrade*. Unpublished report to NSW Roads and Maritime Services.

Appendix 5 April 2018 monitoring report.

Flying-fox Monitoring
April 2018

Warrell Creek to Nambucca Heads
Pacific Highway Upgrade

PO Box 119
Lennox Head NSW 2478
T 02 6687 7666

PO Box 1446
Coffs Harbour NSW 2450
T 02 6651 7666

PO Box 1267
Armidale NSW 2350
T 02 6772 0454

PO Box 229
Lismore NSW 2480
T 02 6621 6677

info@geolink.net.au

Prepared for: Roads and Maritime Services

© GeoLINK, 2018

UPR	*Description*	*Date Issued*	*Issued By*
2692-1105	First issue	10/05/2018	David Andrighetto
2692-1113	Second issue	17/05/2018	David Andrighetto

Table of Contents

1. Introduction 1

1.1 Introduction 1

2. Flying-fox Survey 2

2.1 Methodology 2
2.2 Results 3

2.2.1 Roost Footprint 3
2.2.2 Population Estimates 6
2.2.3 Detailed Data 6

2.3 Discussion 9

2.3.1 Population Estimates 9
2.3.2 Species Composition and Demographic Data 10
2.3.3 Phenology of Trees in the Region 10

2.4 Summary and Conclusion 12

Illustrations

Illustration 2.1 Location of Regional Flying-fox Camps 4
Illustration 2.2 Macksville Cemetery Roost Footprint 5

Tables

Table 2.1 Demographic Data of GHFF at the Macksville Cemetery Camp 7
Table 2.2 Demographic Data of GHFF at the Bellingen Island Camp 8

Figures

Figure 2.1 Water level measurements at the site 9
Figure 2.2 Population trends at the site and regional camps over past 12 months 11

1. Introduction

1.1 Introduction

NSW Roads and Maritime Services has been monitoring a Grey-headed Flying-fox (*Pteropus poliocephalus*) (GHFF) camp that was intermittently present within the approved alignment of the Warrell Creek to Nambucca Heads (WC2NH) Pacific Highway upgrade project near Macksville. The camp was located in a patch of swamp sclerophyll forest north of Bald Hill Road (henceforth referred to as 'the site').

GeoLINK has undertaken monitoring at the site on at least a monthly basis since July 2013. Prior to this, irregular monitoring of flying-foxes at the site has been undertaken since the initial establishment of the camp in December 2011 (Eby 2012).

This report details the April 2018 flying-fox monitoring results.

2. Flying-fox Survey

2.1 Methodology

The following GeoLINK personnel undertook fieldwork for the April 2018 flying-fox monitoring:

- Tom Pollard (ecologist).
- Jeremy Clifford (environmental scientist).
- Kale Hardie-Porter (environmental scientist).
- Jacob Sickinger (environmental planner).

Fieldwork followed the methodology developed by Dr Eby for the project. Refer to Eby (2013) for full details of the methodology. A summary of the main procedures used for the monitoring is provided below.

The fieldwork was undertaken on 30 April 2018. The presence of flying-foxes at the site was assessed by undertaking a traverse of the area previously known to support flying-foxes in conjunction with a few sharp handclaps aimed at eliciting a vocal response from any flying-foxes roosting at the site.

When flying-foxes are present at the site, the following data is collected:

- The area of the roost footprint (mapped by GPS).
- Species composition.
- Demographics.
- Reproductive status.
- Behaviour.

When the site is unoccupied and flying-foxes are present at the nearby seasonally-occupied flying-fox camp within two kilometres of the site adjacent to Macksville Cemetery, the abovementioned data is collected here instead. This data provides relevant information on the status of flying-foxes that are camped in the Macksville area.

The water level at the site was measured at GPS location 492866, 6600756 (UTM coordinates, GDA 94, Zone 56). The water level at this location is representative of the average level at the site and is tracked over time to provide information on water level fluctuations that occur at the site.

A dusk exit count survey was undertaken at both the site and the Macksville Cemetery camp to confirm the presence/ absence of flying-foxes and to provide an estimate of the current population at each camp.

Two observers were strategically located for the exit count on a northern and a southern ridge overlooking the site. Specifically, the two observers were located at the following vantage points:

- In a paddock to the north of the swamp sclerophyll forest (off Wedgewood Drive).
- On a prominent ridge to the south (at 41 Bald Hill Road).

Two observers were also located adjacent to the Macksville Cemetery camp at the following vantage points:

- At the Macksville Cemetery gate off Wallace Street (west of the camp).
- Adjacent to the Macksville Golf Course next to the Pacific Highway (east of the camp).

The exit counts extended over approximately 40 minutes from sunset until dark (approximately 5:50 pm to 6:30 pm).

Other regional flying-fox camps at Gordon Park, Nambucca Heads (approximately 12 kilometres north-east of the site), Bowraville (approximately 10.5 kilometres north-west of the site), Bellingen Wheatley Street camp (approximately 30 kilometres north of the site) and Bellingen Island (approximately 31 kilometres north of the site) were also visited and observational comments made. Refer to **Illustration 2.1** for the location of the subject regional camps.

2.2 Results

2.2.1 Roost Footprint

No flying-foxes were recorded roosting at the site in the traverse.

Flying-foxes were observed to be roosting at the Macksville Cemetery camp. The roost extended over an area of approximately 1.7 hectares (refer to **Illustration 2.2**). The roost has shifted further away from the western edge of the paperbark forest when compared with that recorded in the previous monitoring event.

Flying-foxes were not recorded at the Wheatley Street camp in Bellingen or at Bowraville.

Regionally, flying-foxes were observed to be roosting at Bellingen Island and Gordon Park (Nambucca Heads). As was observed in the previous monitoring event (GeoLINK 2018), the extent of the roost footprint at Bellingen Island presently includes many of the mature trees in the old caravan park grounds alongside Dowle Street, however a reduction in roosting in the upper canopy of the emergent fig trees on the island was noted.

At the Gordon Park camp the roost extent has not substantially changed from that recorded in the previous monitoring event, with a general absence of flying-foxes roosting in the upper canopy of the rainforest where only sparse foliage cover (or dead branches) remain.

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: DSA Date: 10/05/2018
Source of base data: Roads and Maritime Services

0 4 km

North

Location of Regional Flying-fox Camps

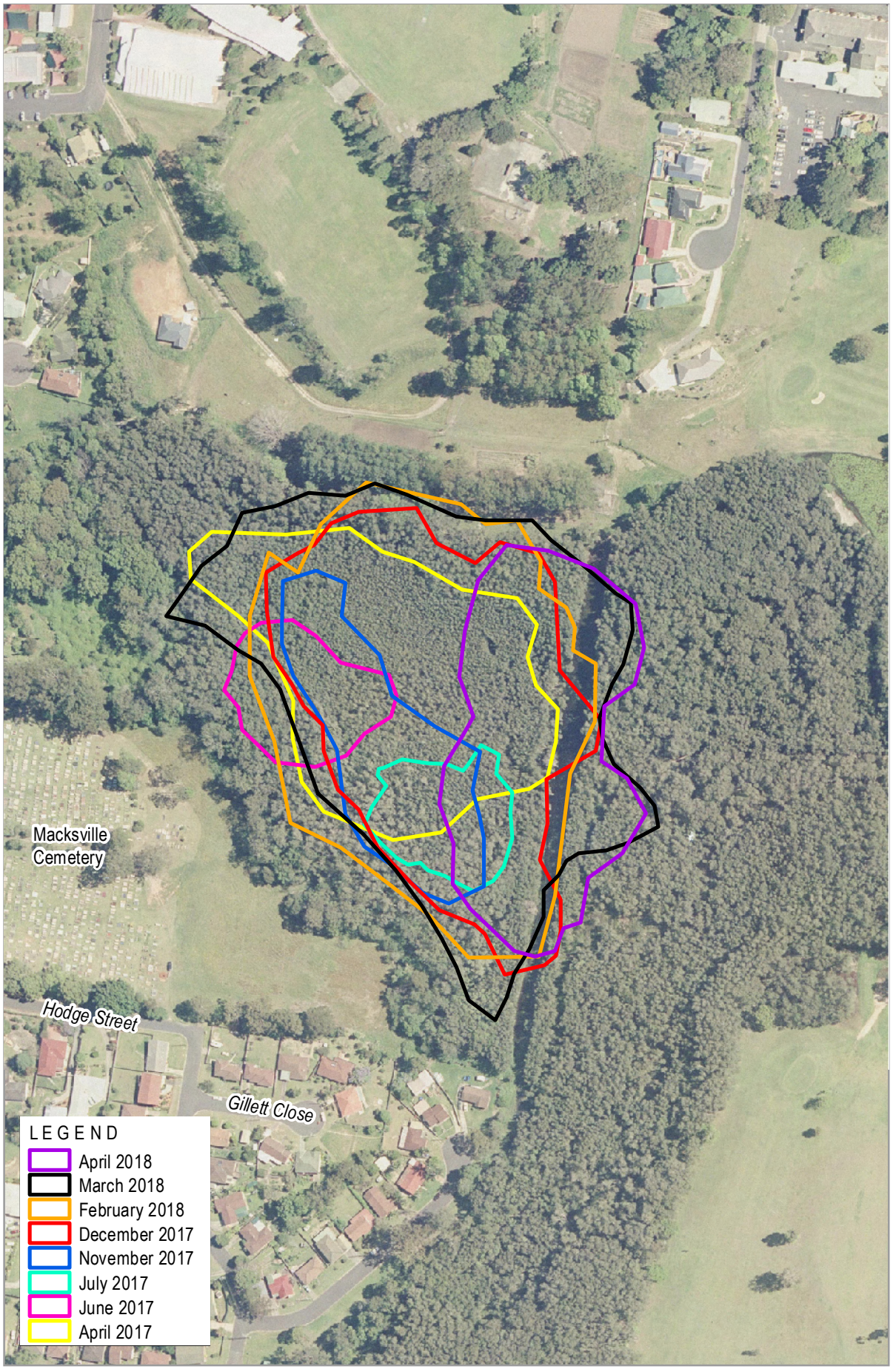
GeoLINK environmental management and design

Flying-fox Monitoring April 2018 - Warrell Creek to Nambucca Heads
Pacific Highway Upgrade
2692-1113

Illustration 2.1

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: DSA Date: 10/05/2018
Source of base data: Roads and Maritime Services



North

0 60

Macksville Cemetery Flying-fox Roost Footprint

GeoLINK environmental management and design

Flying-fox Monitoring April 2018 - Warrell Creek to Nambucca Heads
Pacific Highway Upgrade
2692-1113

Illustration 2.2

2.2.2 Population Estimates

2.2.2.1 Exit Counts

No flying-foxes were observed flying from the site during the exit count.

Approximately 18,000 individuals were recorded exiting the Macksville Cemetery camp in the exit count. The flying-foxes were exiting in two broad streams, one in a westerly direction and another in a south-easterly direction.

2.2.2.2 Direct Counts

With the exception of the Macksville Cemetery camp, no exit counts were conducted at any of the remaining regional camps. However, rough population estimates for these camps based on extrapolation of counts in individual trees and the roost footprint are as follows:

- Gordon Park: approximately 10,000 individuals.
- Bellingen Island: approximately 30,000 individuals.
- Wheatley Street, Bellingen: no individuals recorded.
- Bowraville: no individuals recorded.

2.2.3 Detailed Data

2.2.3.1 Species Composition

The species composition and proportions observed at occupied camps were as follows:

- Macksville Cemetery: 90% GHFF and 10% Black Flying-fox.
- Bellingen Island: 95% GHFF and 5% Black Flying-fox.
- Gordon Park: 90% GHFF and 10% Black Flying-fox.

2.2.3.2 Habitat Characteristics and Demographic Composition

As flying-foxes were not recorded at the site in the current monitoring event, detailed demographic composition data was not collected. This has been the case since April 2014 (excluding a brief return in January 2015). During this period of absence, the Macksville Cemetery camp has been the alternative site for collection of this data.

Both male and female GHFF were present at the Macksville Cemetery camp. The data collected indicated that the proportion of female GHFF present was moderate to high, ranging between 66% and 91% of all individuals at individual demographic point counts (79% average). No dependent young GHFF were present (refer to **Table 2.1**).

Both male and female GHFF were also present at the Bellingen Island camp. Data collected indicated that the proportion of female GHFF present was relatively high, ranging between 77% and 91% of all individuals at individual demographic point counts (82% average). No dependent young GHFF were present (refer to **Table 2.2**).

General observations of the GHFF currently roosting at the Gordon Park camp indicated that males and females were present. No dependent young were observed with the females.

Table 2.1 Demographic Data of GHFF at the Macksville Cemetery Camp

Tree Code	*GPS Location (UTM coordinates GDA94, Zone 56)*	*Tree Species*	*Height (m)*	*DBH (cm)*	*Demographic Ratio (female:male)*	*Presence of Dependant Young (yes/no)*	*% Females with Dependant Young*
MC1	492143, 6601827	Broad-leaved Paperbark	12	20	10:6	No	n/a
MC2	492153, 6601825	Broad-leaved Paperbark	15	30	10:3	No	n/a
MC3	492144, 6601806	Broad-leaved Paperbark	15	30	10:2	No	n/a
MC4	492145, 6601786	Broad-leaved Paperbark	8	20	10:1	No	n/a
MC5	492139, 6601736	Broad-leaved Paperbark	12	20	10:3	No	n/a
MC6	492125, 6601716	Broad-leaved Paperbark	15	30	10:3	No	n/a
MC7	492133, 6601713	Broad-leaved Paperbark	10	20	10:5	No	n/a
MC8	492138, 6601679	Broad-leaved Paperbark	8	15	10:2	No	n/a
MC9	492154, 6601645	Broad-leaved Paperbark	15	30	10:3	No	n/a
MC10	492176, 6601640	Broad-leaved Paperbark	8	20	10:2	No	n/a

Table 2.2 Demographic Data of GHFF at the Bellingen Island Camp

Tree Code	*GPS Location (UTM coordinates GDA94, Zone 56)*	*Tree Species*	*Height (m)*	*DBH (cm)*	*Demographic Ratio (female:male)*	*Presence of Dependant Young (yes/no)*	*% Females with Dependant Young*
BI1	490058, 6631683	Red Cedar	10	80	10:1	No	n/a
BI2	490085, 6631663	Red Cedar	20	150	10:2	No	n/a
BI3	490034, 6631694	Flame Tree	12	80	10:3	No	n/a
BI4	489986, 6631559	Creek Sandpaper Fig	8	40	10:2	No	n/a
BI5	490034, 6631520	Giant Stinging Tree	15	80	10:3	No	n/a
BI6	490062, 6631507	Creek Sandpaper Fig	8	30	2:10 (male dominated 'bachelor tree')	No	n/a
BI7	490093, 6631526	Creek Sandpaper Fig	10	30	10:2	No	n/a
BI8	490085, 6631560	Giant Stinging Tree	12	60	10:2	No	n/a
BI9	490059, 6631609	Creek Sandpaper Fig	8	30	10:3	No	n/a
BI10	490038, 6631638	Creek Sandpaper Fig	8	20	10:2	No	n/a

2.2.3.3 Water Level at the Site

Water level at the site measured at the representative measurement location was approximately 50 cm in depth. This is a minor decrease on the level that was recorded in the previous monitoring event, reflecting a relatively dry April in the area (refer to **Figure 2.1**).

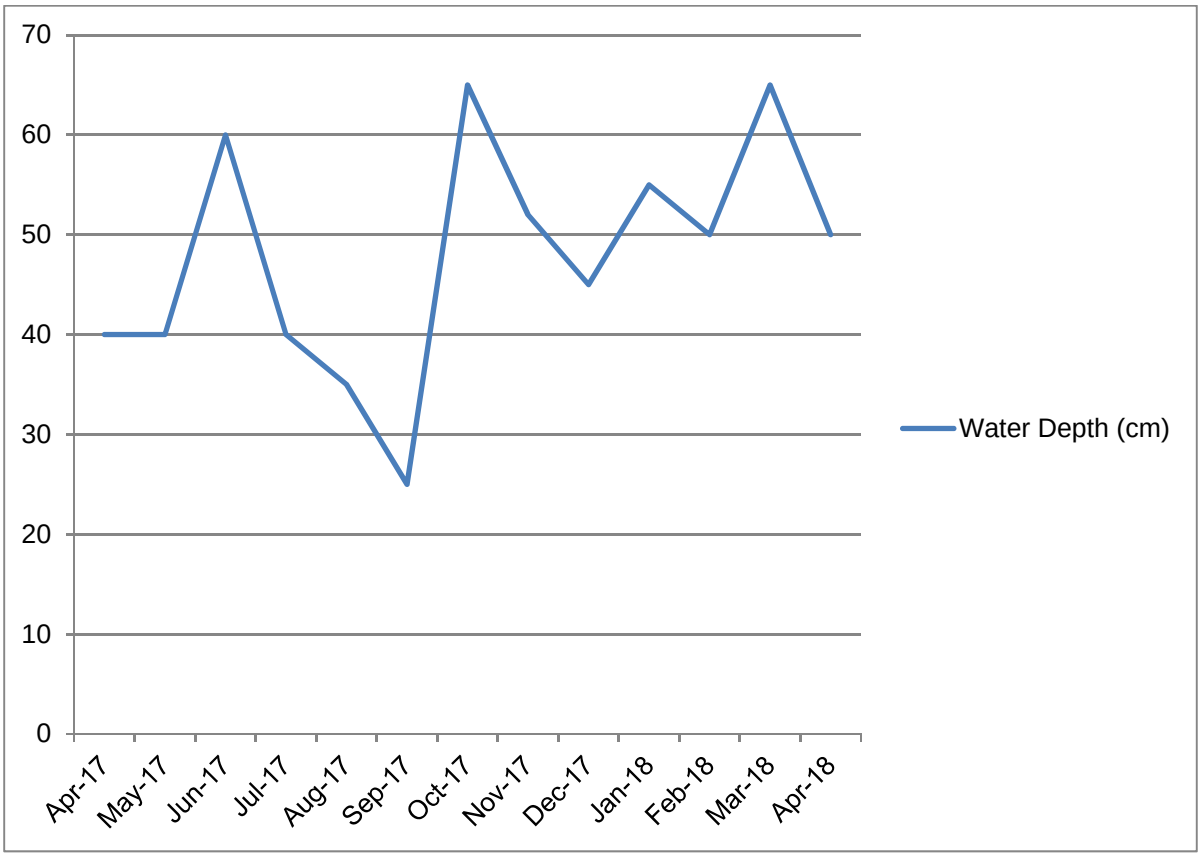


Figure 2.1 Water level measurements at the site

2.3 Discussion

2.3.1 Population Estimates

The trend in flying-fox numbers over the last 12-month period at the site and other monitored regional flying-fox camps is shown in **Figure 2.2**. No flying-foxes were recorded at the site again this month. Flying-foxes have not occupied the site (excluding a brief return in January 2015) since mid-April 2014.

Following a peak in the number of flying-foxes roosting at the Macksville Cemetery camp in March when approximately 45,000 individuals were present, a substantial decrease has now occurred with approximately half this number of flying-foxes currently roosting at this camp. In April 2017 flying-fox numbers were similar with approximately 20,000 individuals present (GeoLINK 2017).

It was estimated that approximately 30,000 flying-foxes were present at the Bellingen Island camp in the current monitoring event. The number of flying-foxes has ranged between 25,000 and 40,000 during the four months since January of this year. In April 2017 the estimated number of flying-foxes roosting at the Bellingen Island camp was only 15,000 (GeoLINK 2017), which is substantially fewer than was recorded in the current monitoring event.

The number of flying-foxes estimated to be roosting at the Gordon Park camp has remained steady over the past four months at around 10,000 individuals. Slightly fewer flying-foxes were present in April 2017, when it was estimated that approximately 7,500 individuals were roosting at this camp (GeoLINK 2017).

No flying-foxes were recorded at Bowraville in the current monitoring event. Flying-foxes have been absent from this site for over 12 months, and were last recorded in December 2016 in low numbers.

As can be seen in the 12-monthly population comparisons (refer to **Figure 2.2**), numbers of flying-foxes at regional camps now appear to be declining after the typical annual summer peak.

2.3.2 Species Composition and Demographic Data

At occupied camps, GHFF dominated the species composition making up between 90% and 95% of all individuals. Similar high proportions have consistently been recorded in previous monitoring events.

Female GHFF dominated the occupied camps in the current monitoring event, with demographic point counts averaging 82% at the Bellingen Island camp and 79% at the Macksville Cemetery camp. Very similar proportions were recorded in the previous monitoring event (GeoLINK 2018).

No dependent young GHFF were recorded at any of the occupied camps in the current monitoring event, in line with the reproductive cycle of this species.

2.3.3 Phenology of Trees in the Region

April/ May bi-monthly flowering of a number of highly productive nectar source trees in the upper North Coast region of NSW includes Coast Banksia (*Banksia integrifolia*), Coastal Blackbutt (*Eucalyptus pilularis*), Swamp Mahogany (*Eucalyptus robusta*), Blue Gum (*Eucalytpus saligna*) and Broad-leaved Paperbark (*Melaleuca quinquenervia*). These are considered key diet species for GHFF in the region (Eby 2012; Eby and Law 2008).

Observations when travelling between regional flying-fox camps recorded moderate flowering of Broad-leaved Paperbark and light flowering of Swamp Mahogany (*Eucalyptus robusta*).

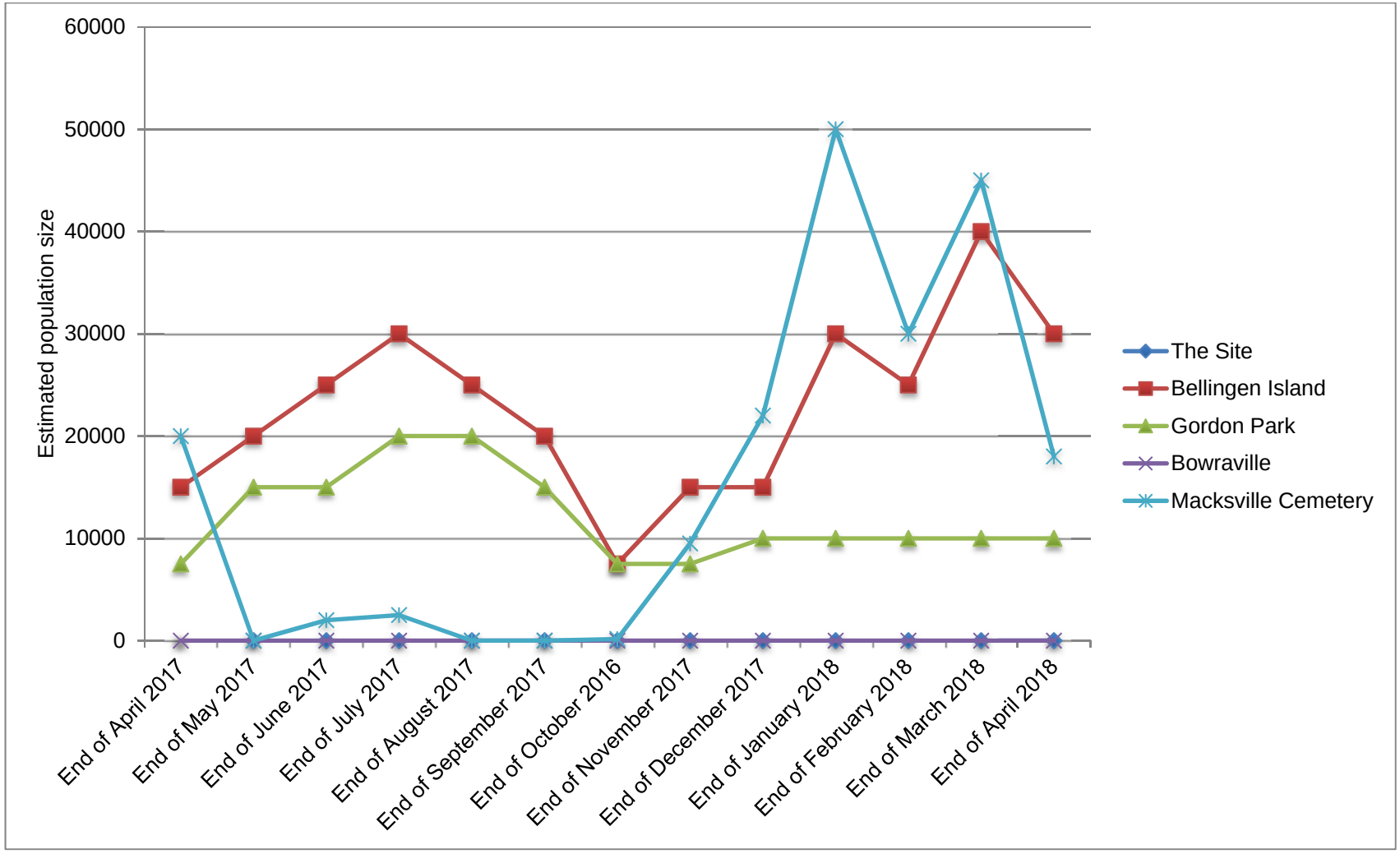


Figure 2.2 Population trends at the site and regional camps over past 12 months

2.4 Summary and Conclusion

The results of the April 2018 flying-fox monitoring indicate that, excluding a brief stopover at the site observed in mid-January 2015, flying-foxes have been absent from the site since April 2014.

Following a peak in the number of flying-foxes roosting at the Macksville Cemetery camp in March when approximately 45,000 individuals were present, a substantial decrease has now occurred with approximately half this number of flying-foxes currently roosting at this camp. Similarly, at Bellingen Island camp the number of flying-foxes has also decreased over the last month. This decrease in GHFF numbers leading into winter is typical following the annual summer peak in numbers.

The number of flying-foxes estimated to be roosting at the Gordon Park camp has remained steady over the past four months at around 10,000 individuals, possibly reflecting the poor condition of the rainforest canopy at this camp.

Flying-foxes remain absent from Bowraville and Wheatley Street, Bellingen.

GHFF dominated the species composition at occupied camps making up between 90% and 95% of all individuals present.

No dependent young GHFF were recorded at any of the occupied camps in the current monitoring event, in line with the reproductive cycle of this species.

Moderate flowering of Broad-leaved Paperbark and light flowering of Swamp Mahogany, both key diet species for the GHFF, was observed to be currently occurring in the region.

David Andrighetto
Senior Ecologist

References

Eby, P. (2012). *An Assessment of the Flying-fox Camp at Macksville*. Unpublished report to NSW Roads and Maritime Services.

Eby, P. (2013). *A Field Monitoring Program Proposed for the Macksville Flying-fox Roost*. Unpublished report to Sinclair Knight Merz.

GeoLINK. (2017). *Flying-fox Monitoring April 2017: Warrell Creek to Nambucca Heads Pacific Highway Upgrade*. Unpublished report to NSW Roads and Maritime Services.

GeoLINK. (2018). *Flying-fox Monitoring March 2018: Warrell Creek to Nambucca Heads Pacific Highway Upgrade*. Unpublished report to NSW Roads and Maritime Services.

Appendix 6 May 2018 monitoring report

Flying-fox Monitoring May 2018

Warrell Creek to Nambucca Heads Pacific Highway Upgrade

PO Box 119
Lennox Head NSW 2478
T 02 6687 7666

PO Box 1446
Coffs Harbour NSW 2450
T 02 6651 7666

PO Box 1267
Armidale NSW 2350
T 02 6772 0454

PO Box 229
Lismore NSW 2480
T 02 6621 6677

info@geolink.net.au

Prepared for: Roads and Maritime Services

© GeoLINK, 2018

UPR	*Description*	*Date Issued*	*Issued By*
2692-1120	First issue	06/06/2018	David Andrighetto

Table of Contents

1. Introduction 1

1.1 Introduction 1

2. Flying-fox Survey 2

2.1 Methodology 2
2.2 Results 3

2.2.1 Roost Footprint 3
2.2.2 Population Estimates 6
2.2.3 Detailed Data 6

2.3 Discussion 9

2.3.1 Population Estimates 9
2.3.2 Species Composition and Demographic Data 10
2.3.3 Phenology of Trees in the Region 10

2.4 Summary and Conclusion 12

Illustrations

Illustration 2.1 Location of Regional Flying-fox Camps 4
Illustration 2.2 Macksville Cemetery Roost Footprint 5

Tables

Table 2.1 Demographic Data of GHFF at the Macksville Cemetery Camp 7
Table 2.2 Demographic Data of GHFF at the Bellingen Island Camp 8

Figures

Figure 2.1 Water level measurements at the site 9
Figure 2.2 Population trends at the site and regional camps over past 12 months 11

1. Introduction

1.1 Introduction

NSW Roads and Maritime Services has been monitoring a Grey-headed Flying-fox (*Pteropus poliocephalus*) (GHFF) camp that was intermittently present within the approved alignment of the Warrell Creek to Nambucca Heads (WC2NH) Pacific Highway upgrade project near Macksville. The camp was located in a patch of swamp sclerophyll forest north of Bald Hill Road (henceforth referred to as 'the site').

GeoLINK has undertaken monitoring at the site on at least a monthly basis since July 2013. Prior to this, irregular monitoring of flying-foxes at the site has been undertaken since the initial establishment of the camp in December 2011 (Eby 2012).

This report details the May 2018 flying-fox monitoring results.

2. Flying-fox Survey

2.1 Methodology

The following GeoLINK personnel undertook fieldwork for the May 2018 flying-fox monitoring:

- Tom Pollard (ecologist).
- Frank Makin (ecologist).
- Jeremy Clifford (environmental scientist).
- Kale Hardie-Porter (environmental scientist).

Fieldwork followed the methodology developed by Dr Eby for the project. Refer to Eby (2013) for full details of the methodology. A summary of the main procedures used for the monitoring is provided below.

The fieldwork was undertaken on 29 May 2018. The presence of flying-foxes at the site was assessed by undertaking a traverse of the area previously known to support flying-foxes in conjunction with a few sharp handclaps aimed at eliciting a vocal response from any flying-foxes roosting at the site.

When flying-foxes are present at the site, the following data is collected:

- The area of the roost footprint (mapped by GPS).
- Species composition.
- Demographics.
- Reproductive status.
- Behaviour.

When the site is unoccupied and flying-foxes are present at the nearby seasonally-occupied flying-fox camp within two kilometres of the site adjacent to Macksville Cemetery, the abovementioned data is collected here instead. This data provides relevant information on the status of flying-foxes that are camped in the Macksville area.

The water level at the site was measured at GPS location 492866, 6600756 (UTM coordinates, GDA 94, Zone 56). The water level at this location is representative of the average level at the site and is tracked over time to provide information on water level fluctuations that occur at the site.

A dusk exit count survey was undertaken at both the site and the Macksville Cemetery camp to confirm the presence/ absence of flying-foxes and to provide an estimate of the current population at each camp.

Two observers were strategically located for the exit count on a northern and a southern ridge overlooking the site. Specifically, the two observers were located at the following vantage points:

- In a paddock to the north of the swamp sclerophyll forest (off Wedgewood Drive).
- On a prominent ridge to the south (at 41 Bald Hill Road).

Two observers were also located adjacent to the Macksville Cemetery camp at the following vantage points:

- At the Macksville Cemetery gate off Wallace Street (west of the camp).
- Adjacent to the Macksville Golf Course next to the Pacific Highway (east of the camp).

The exit counts extended over approximately 40 minutes from sunset until dark (approximately 5:00 pm to 5:40 pm).

Other regional flying-fox camps at Gordon Park, Nambucca Heads (approximately 12 kilometres north-east of the site), Bowraville (approximately 10.5 kilometres north-west of the site), Bellingen Wheatley Street camp (approximately 30 kilometres north of the site) and Bellingen Island (approximately 31 kilometres north of the site) were also visited and observational comments made. Refer to **Illustration 2.1** for the location of the subject regional camps.

2.2 Results

2.2.1 Roost Footprint

No flying-foxes were recorded roosting at the site in the traverse.

Flying-foxes were observed to be roosting at the Macksville Cemetery camp. The roost extended over an area of approximately 0.76 hectares (refer to **Illustration 2.2**). The roost site was located in the southern section of the paperbark forest, between McNeill Place and the Macksville golf course.

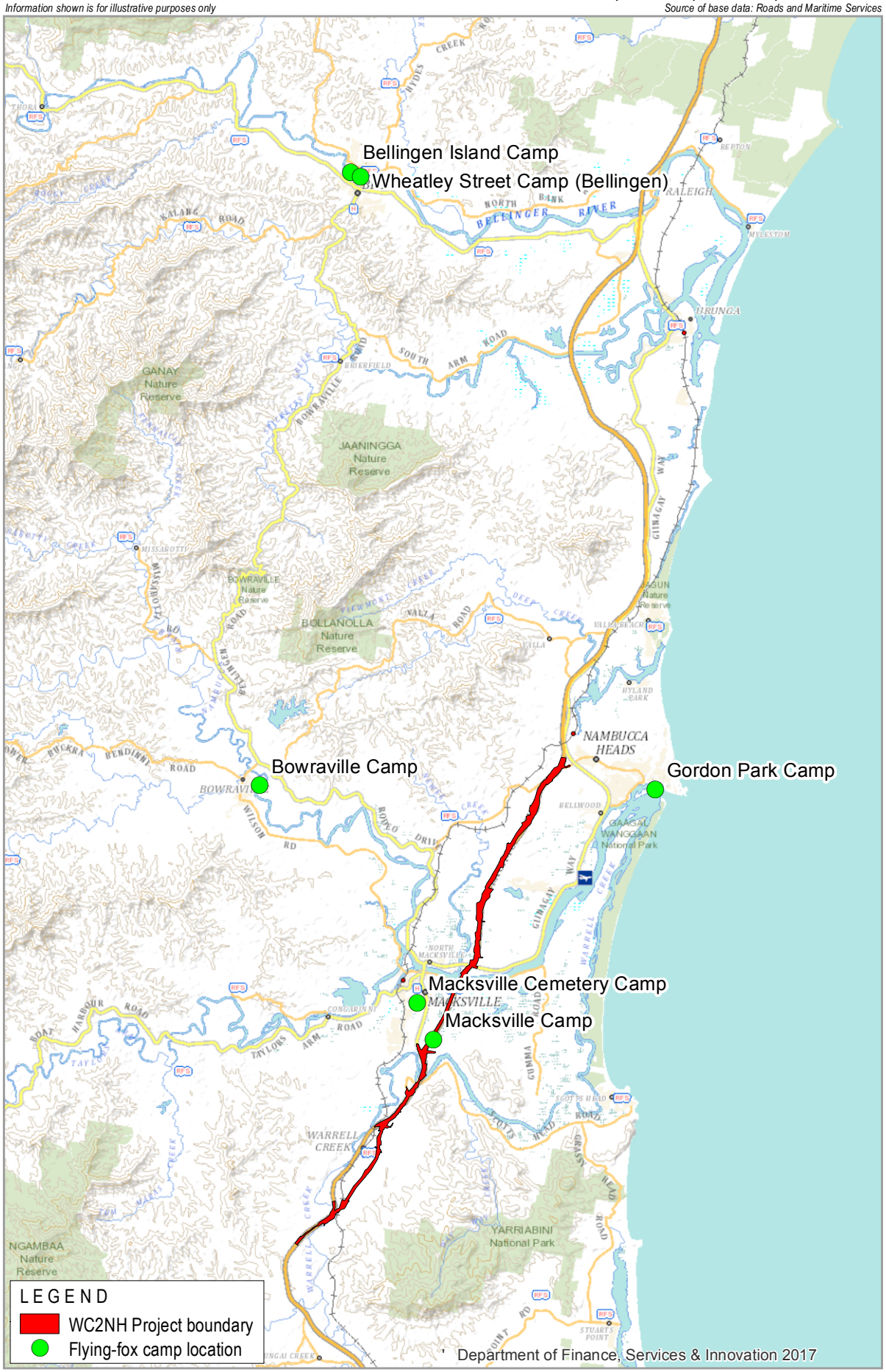
Regionally, flying-foxes were observed to be roosting at Bellingen Island and Gordon Park (Nambucca Heads). As was observed in the previous monitoring event (GeoLINK 2018), the extent of the roost footprint at Bellingen Island included many of the mature trees in the old caravan park grounds alongside Dowle Street (roosting individuals in this part of the roost were observed to be mostly Black Flying-foxes).

At the Gordon Park camp the roost extent covers a larger area than was recorded in the previous monitoring event. In addition, more flying-foxes were observed to be roosting in the upper canopy of the damaged rainforest vegetation.

Flying-foxes were not recorded at the Wheatley Street camp in Bellingen or at Bowraville.

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: DSA Date: 6/06/2018
Source of base data: Roads and Maritime Services



0 4 km

North

Location of Regional Flying-fox Camps

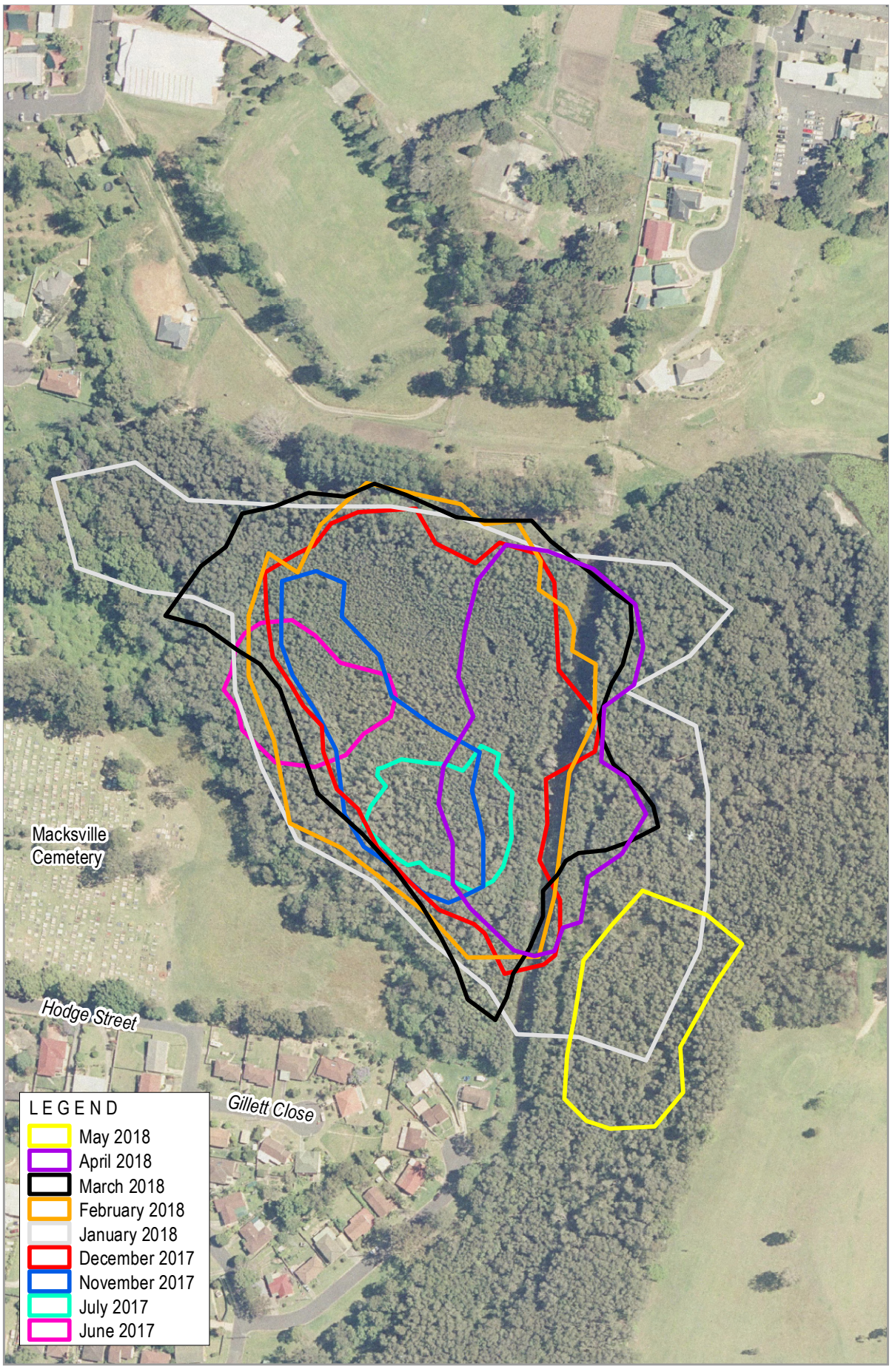
GeoLINK environmental management and design

Flying-fox Monitoring May 2018 - Warrell Creek to Nambucca Heads
Pacific Highway Upgrade
2692-1118

Illustration 2.1

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: DSA Date: 6/06/2018
Source of base data: Roads and Maritime Services



0 60

North

Macksville Cemetery Flying-fox Roost Footprint

GeoLINK environmental management and design

Flying-fox Monitoring May 2018 - Warrell Creek to Nambucca Heads
Pacific Highway Upgrade
2692-1117

Illustration 2.2

2.2.2 Population Estimates

2.2.2.1 Exit Counts

No flying-foxes were observed flying from the site during the exit count.

Approximately 10,500 individuals were recorded exiting the Macksville Cemetery camp in the exit count. The flying-foxes were exiting in two broad streams, one in a westerly direction and another in a south-easterly direction.

2.2.2.2 Direct Counts

With the exception of the Macksville Cemetery camp, no exit counts were conducted at any of the remaining regional camps. However, rough population estimates for these camps based on extrapolation of counts in individual trees and the roost footprint are as follows:

- Gordon Park: approximately 20,000 individuals.
- Bellingen Island: approximately 30,000 individuals.
- Wheatley Street, Bellingen: no individuals recorded.
- Bowraville: no individuals recorded.

2.2.3 Detailed Data

2.2.3.1 Species Composition

The species composition and proportions observed at occupied camps were as follows:

- Macksville Cemetery: 95% GHFF and 5% Black Flying-fox.
- Bellingen Island: 95% GHFF and 5% Black Flying-fox.
- Gordon Park: 90% GHFF and 10% Black Flying-fox.

2.2.3.2 Habitat Characteristics and Demographic Composition

As flying-foxes were not recorded at the site in the current monitoring event, detailed demographic composition data was not collected. This has been the case since April 2014 (excluding a brief return in January 2015). During this period of absence, the Macksville Cemetery camp has been the alternative site for collection of this data.

Both male and female GHFF were present at the Macksville Cemetery camp. The data collected indicated that the proportion of female GHFF present was generally high, ranging between 71% and 100% of all individuals at individual demographic point counts (88% average). No dependent young GHFF were present (refer to **Table 2.1**).

Both male and female GHFF were also present at the Bellingen Island camp. Similar to the Macksville Cemetery camp, data collected indicated that the proportion of female GHFF present was generally high, ranging between 71% and 91% of all individuals at individual demographic point counts (83% average). No dependent young GHFF were present (refer to **Table 2.2**).

General observations of the GHFF currently roosting at the Gordon Park camp indicated that males and females were present. No dependent young were observed with the females.

Table 2.1 Demographic Data of GHFF at the Macksville Cemetery Camp

Tree Code	*GPS Location (UTM coordinates GDA94, Zone 56)*	*Tree Species*	*Height (m)*	*DBH (cm)*	*Demographic Ratio (female:male)*	*Presence of Dependant Young (yes/no)*	*% Females with Dependant Young*
MC1	492200, 6601607	Broad-leaved Paperbark	12	20	10:3	No	n/a
MC2	492202, 6601622	Broad-leaved Paperbark	8	15	10:2	No	n/a
MC3	492219, 6601622	Broad-leaved Paperbark	8	15	10:4	No	n/a
MC4	492221, 6601637	Broad-leaved Paperbark	12	20	10:1	No	n/a
MC5	492224, 6601648	Broad-leaved Paperbark	12	20	10:1	No	n/a
MC6	492237, 6601649	Broad-leaved Paperbark	12	20	10:3	No	n/a
MC7	492245, 6601650	Broad-leaved Paperbark	8	20	10:0	No	n/a
MC8	492254, 6601637	Broad-leaved Paperbark	10	15	10:0	No	n/a
MC9	492252, 6601628	Broad-leaved Paperbark	8	15	10:0	No	n/a
MC10	492256, 6601614	Broad-leaved Paperbark	10	20	10:1	No	n/a

Table 2.2 Demographic Data of GHFF at the Bellingen Island Camp

Tree Code	*GPS Location (UTM coordinates GDA94, Zone 56)*	*Tree Species*	*Height (m)*	*DBH (cm)*	*Demographic Ratio (female:male)*	*Presence of Dependant Young (yes/no)*	*% Females with Dependant Young*
BI1	490087, 6631532	White Booyong	15	100	10:0	No	n/a
BI2	490091, 6631552	Foambark	8	20	10:2	No	n/a
BI3	490083, 6631565	Creek Sandpaper Fig	8	30	10:2	No	n/a
BI4	490074, 6631575	Unknown sp.	8	45	10:2	No	n/a
BI5	490068, 6631585	Creek Sandpaper Fig	15	20	10:1	No	n/a
BI6	490065, 6631604	Moreton Bay Fig	12	80	10:4	No	n/a
BI7	490051, 6631612	Creek Sandpaper Fig	8	30	10:1	No	n/a
BI8	490032, 6631633	Moreton Bay Fig	10	40	10:4	No	n/a
BI9	490013, 6631643	Small-leaved Fig	8	40	10:1	No	n/a
BI10	490003, 6631644	Sandpaper Fig	7	30	10:3	No	n/a

2.2.3.3 Water Level at the Site

Water level at the site measured at the representative measurement location was approximately 40 cm in depth. Water depth continues to decrease at the site in response to ongoing dry weather conditions (refer to **Figure 2.1**).

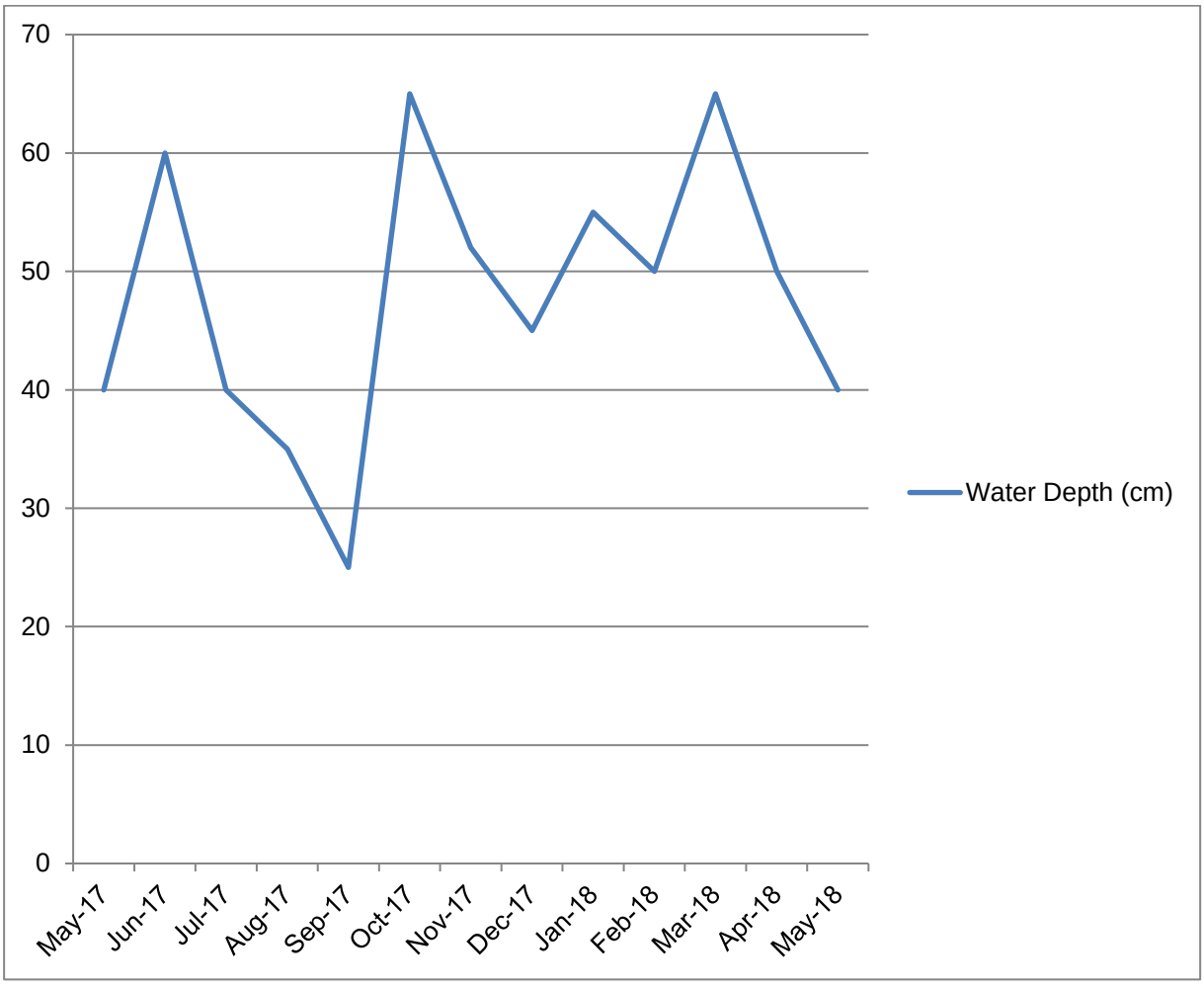


Figure 2.1 Water level measurements at the site

2.3 Discussion

2.3.1 Population Estimates

The trend in flying-fox numbers over the last 12-month period at the site and other monitored regional flying-fox camps is shown in **Figure 2.2**. No flying-foxes were recorded at the site again this month. Flying-foxes have not occupied the site (excluding a brief return in January 2015) since mid-April 2014.

Following a peak in the number of flying-foxes roosting at the Macksville Cemetery camp in March when approximately 45,000 individuals were present, a decrease has occurred to around 10,500 individuals in the current monitoring event. In May 2017, no flying-foxes were recorded roosting at this camp, and very low numbers or an absence was recorded throughout winter until late spring (refer to **Figure 2.2**).

It was estimated that approximately 30,000 flying-foxes were present at the Bellingen Island camp in the current monitoring event, representing no change from the previous monitoring event. The number of flying-foxes has ranged between 25,000 and 40,000 during the five months since January 2018. In May 2017, the estimated number of flying-foxes roosting at the Bellingen Island camp was less at around 20,000 (GeoLINK 2017).

The number of flying-foxes estimated to be roosting at the Gordon Park camp has doubled to around 20,000 individuals, after remaining steady over the previous four months at around 10,000 individuals. Slightly fewer flying-foxes were present a year ago, when it was estimated that approximately 15,000 individuals were roosting at this camp (GeoLINK 2017).

No flying-foxes were recorded at Bowraville in the current monitoring event. Flying-foxes have been absent from this site for over 12 months, and were last recorded in December 2016 in low numbers.

As can be seen in the 12-monthly population comparisons (refer to **Figure 2.2**), there has been a decreasing trend in flying-fox numbers at the Macksville Cemetery camp and Bellingen Island camp since a peak in March 2018. In contrast, no clear trend is evident at Gordon Park, where flying-fox numbers have doubled over the past month.

2.3.2 Species Composition and Demographic Data

At occupied camps, GHFF dominated the species composition making up between 90% and 95% of all individuals. Similar high proportions have consistently been recorded in previous monitoring events.

Female GHFF dominated the occupied camps in the current monitoring event, with demographic point counts averaging 88% at the Macksville Cemetery camp and 83% at the Bellingen Island camp. Similarly, high proportions of female GHFF were recorded in the previous monitoring event (GeoLINK 2018).

No dependent young GHFF were recorded at any of the occupied camps in the current monitoring event, in line with the reproductive cycle of this species. Subadult only groupings of GHFF were evident at both camps, and particularly along the eastern channel at the Bellingen Island camp.

2.3.3 Phenology of Trees in the Region

April/ May bi-monthly flowering of a number of highly productive nectar source trees in the upper North Coast region of NSW includes Coast Banksia (*Banksia integrifolia*), Coastal Blackbutt (*Eucalyptus pilularis*), Swamp Mahogany (*Eucalyptus robusta*), Blue Gum (*Eucalytpus saligna*) and Broad-leaved Paperbark (*Melaleuca quinquenervia*). These are considered key diet species for GHFF in the region (Eby 2012; Eby and Law 2008).

Observations when travelling between regional flying-fox camps recorded light flowering of Swamp Mahogany (*Eucalyptus robusta*).

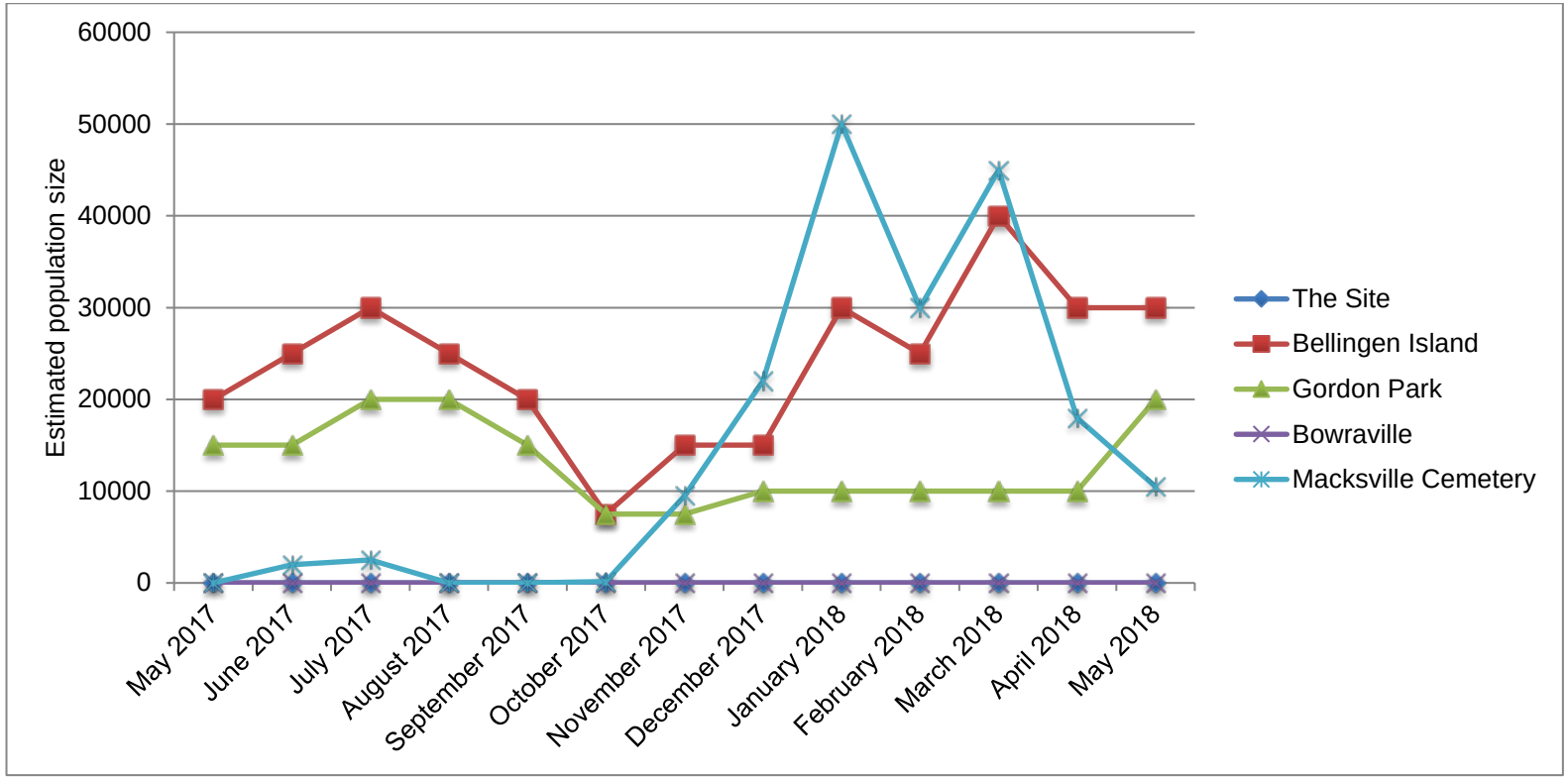


Figure 2.2 Population trends at the site and regional camps over the past 12 months

2.4 Summary and Conclusion

The results of the May 2018 flying-fox monitoring indicate that, excluding a brief stopover at the site observed in mid-January 2015, flying-foxes have been absent from the site since April 2014.

There has been a general decreasing trend in flying-fox numbers at the Macksville Cemetery camp and Bellingen Island camp since a peak in March 2018. In contrast, no clear trend is evident at Gordon Park, where flying-fox numbers have doubled over the past month.

Flying-foxes remain absent from Bowraville and Wheatley Street, Bellingen.

GHFF dominated the species composition at occupied camps making up between 90% and 95% of all individuals present.

No dependent young GHFF were recorded at any of the occupied camps in the current monitoring event, in line with the reproductive cycle of this species.

Light flowering of Swamp Mahogany, a key diet species for the GHFF, was observed to be currently occurring in the region.

David Andrighetto
Senior Ecologist

References

Eby, P. (2012). *An Assessment of the Flying-fox Camp at Macksville*. Unpublished report to NSW Roads and Maritime Services.

Eby, P. (2013). *A Field Monitoring Program Proposed for the Macksville Flying-fox Roost*. Unpublished report to Sinclair Knight Merz.

GeoLINK. (2017). *Flying-fox Monitoring May 2017: Warrell Creek to Nambucca Heads Pacific Highway Upgrade*. Unpublished report to NSW Roads and Maritime Services.

GeoLINK. (2018). *Flying-fox Monitoring April 2018: Warrell Creek to Nambucca Heads Pacific Highway Upgrade*. Unpublished report to NSW Roads and Maritime Services.

Appendix 7 June 2018 monitoring report

Flying-fox Monitoring June 2018

Warrell Creek to Nambucca Heads Pacific Highway Upgrade

PO Box 119
Lennox Head NSW 2478
T 02 6687 7666

PO Box 1446
Coffs Harbour NSW 2450
T 02 6651 7666

PO Box 1267
Armidale NSW 2350
T 02 6772 0454

PO Box 229
Lismore NSW 2480
T 02 6621 6677

info@geolink.net.au

Prepared for: Roads and Maritime Services

© GeoLINK, 2018

UPR	Description	Date Issued	Issued By
2692-1125	First issue	12/07/2018	David Andrighetto

Table of Contents

1. Introduction 1

1.1 Introduction 1

2. Flying-fox Survey 2

2.1 Methodology 2
2.2 Results 3

2.2.1 Roost Footprint 3
2.2.2 Population Estimates 6
2.2.3 Detailed Data 6

2.3 Discussion 9

2.3.1 Population Estimates 9
2.3.2 Species Composition and Demographic Data 10
2.3.3 Phenology of Trees in the Region 10

2.4 Summary and Conclusion 12

Illustrations

Illustration 2.1 Location of Regional Flying-fox Camps 4
Illustration 2.2 Macksville Cemetery Roost Footprint 5

Tables

Table 2.1 Demographic Data of GHFF at the Macksville Cemetery Camp 7
Table 2.2 Demographic Data of GHFF at the Bellingen Island Camp 8

Figures

Figure 2.1 Water level measurements at the site 9
Figure 2.2 Population trends at the site and regional camps over past 12 months 11

1. Introduction

1.1 Introduction

NSW Roads and Maritime Services has been monitoring a Grey-headed Flying-fox (*Pteropus poliocephalus*) (GHFF) camp that was intermittently present within the approved alignment of the Warrell Creek to Nambucca Heads (WC2NH) Pacific Highway upgrade project near Macksville. The camp was located in a patch of swamp sclerophyll forest north of Bald Hill Road (henceforth referred to as 'the site').

GeoLINK has undertaken monitoring at the site on at least a monthly basis since July 2013. Prior to this, irregular monitoring of flying-foxes at the site has been undertaken since the initial establishment of the camp in December 2011 (Eby 2012).

This report details the June 2018 flying-fox monitoring results.

2. Flying-fox Survey

2.1 Methodology

The following GeoLINK personnel undertook fieldwork for the June 2018 flying-fox monitoring:

- Tom Pollard (ecologist).
- Jeremy Clifford (environmental scientist).
- Kale Hardie-Porter (environmental scientist).
- Jacob Sickinger (environmental planner).

Fieldwork followed the methodology developed by Dr Eby for the project. Refer to Eby (2013) for full details of the methodology. A summary of the main procedures used for the monitoring is provided below.

The fieldwork was undertaken on 27 June 2018. The presence of flying-foxes at the site was assessed by undertaking a traverse of the area previously known to support flying-foxes in conjunction with a few sharp handclaps aimed at eliciting a vocal response from any flying-foxes roosting at the site.

When flying-foxes are present at the site, the following data is collected:

- The area of the roost footprint (mapped by GPS).
- Species composition.
- Demographics (avoiding male 'bachelor trees' where possible).
- Reproductive status.
- Behaviour.

When the site is unoccupied and flying-foxes are present at the nearby seasonally-occupied flying-fox camp within two kilometres of the site adjacent to Macksville Cemetery, the abovementioned data is collected here instead. This data provides relevant information on the status of flying-foxes that are camped in the Macksville area.

The water level at the site was measured at GPS location 492866, 6600756 (UTM coordinates, GDA 94, Zone 56). The water level at this location is representative of the average level at the site and is tracked over time to provide information on water level fluctuations that occur at the site.

A dusk exit count survey was undertaken at both the site and the Macksville Cemetery camp to confirm the presence/ absence of flying-foxes and to provide an estimate of the current population at each camp.

Two observers were strategically located for the exit count on a northern and a southern ridge overlooking the site. Specifically, the two observers were located at the following vantage points:

- In a paddock to the north of the swamp sclerophyll forest (off Wedgewood Drive).
- On a prominent ridge to the south (at 41 Bald Hill Road).

Two observers were also located adjacent to the Macksville Cemetery camp at the following vantage points:

- At the Macksville Cemetery gate off Wallace Street (west of the camp).
- Adjacent to the Macksville Golf Course next to the Pacific Highway (east of the camp).

The exit counts extended over approximately 40 minutes from sunset until dark (approximately 4:50 pm to 5:30 pm).

Other regional flying-fox camps at Gordon Park, Nambucca Heads (approximately 12 kilometres north-east of the site), Bowraville (approximately 10.5 kilometres north-west of the site), Bellingen Wheatley Street camp (approximately 30 kilometres north of the site) and Bellingen Island (approximately 31 kilometres north of the site) were also visited and observational comments made. Refer to **Illustration 2.1** for the location of the subject regional camps.

2.2 Results

2.2.1 Roost Footprint

No flying-foxes were recorded roosting at the site in the traverse.

Flying-foxes were observed to be roosting at the Macksville Cemetery camp. The roost extended over an area of approximately 0.66 hectares (refer to **Illustration 2.2**). As was recorded in the previous monitoring event, the flying-fox roost has shifted approximately 200 m further south than is typical and is currently in a narrow section of paperbark swamp forest west of the Macksville golf course near the northern end of McNeill Close.

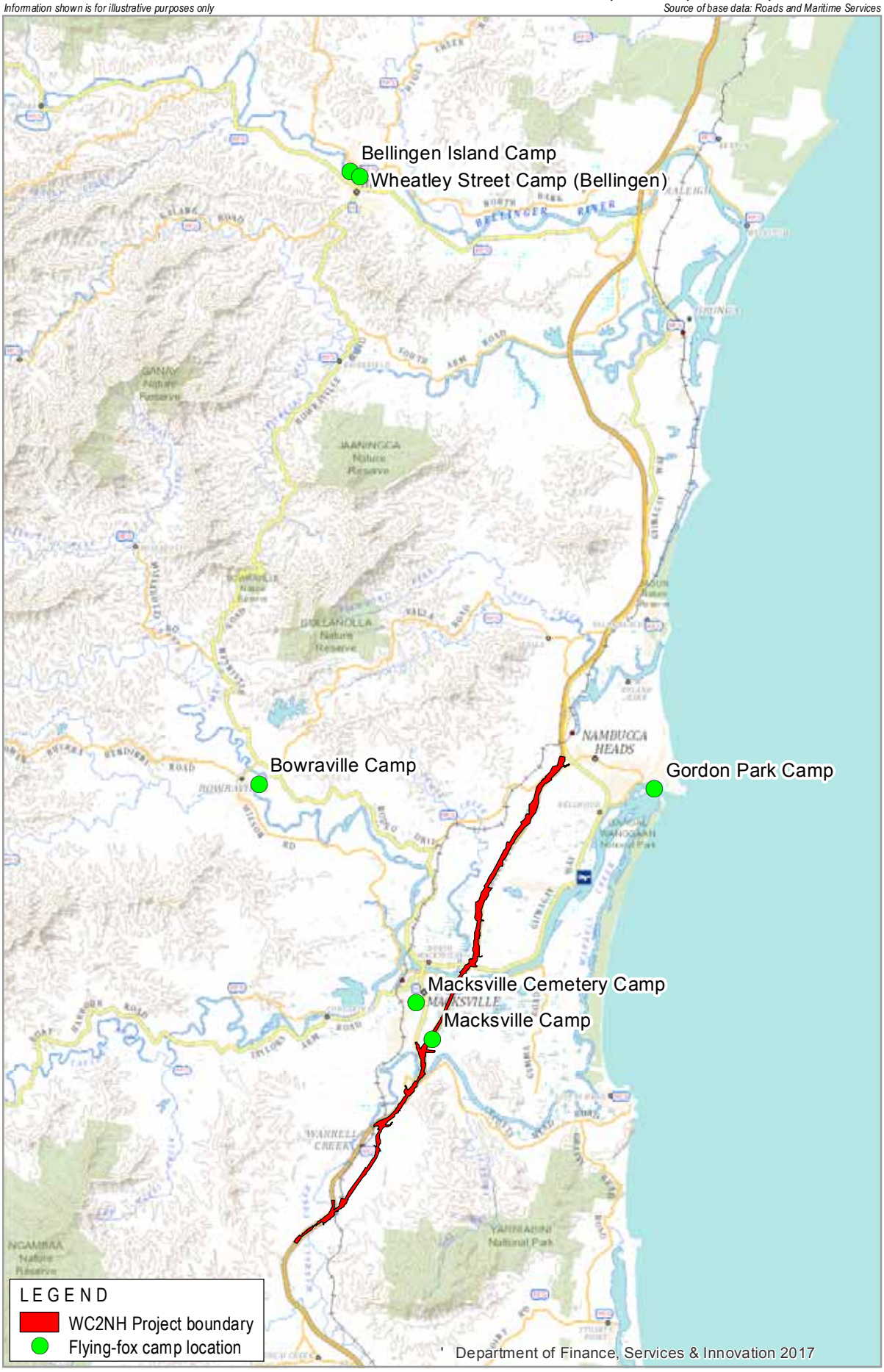
Flying-foxes were not recorded at the Wheatley Street camp in Bellingen or at Bowraville.

Regionally, flying-foxes were observed to be roosting at Bellingen Island and Gordon Park (Nambucca Heads). The extent of the roost footprint at Bellingen Island covered the eastern portion of the island, mostly around the channel between the island and the old caravan park. At the Gordon Park camp the roost extent has not substantially changed from that recorded in the previous monitoring event.

Drawn by: AB Checked by: RE Reviewed by: DSA Date: 12/07/2018

Information shown is for illustrative purposes only

Source of base data: Roads and Maritime Services



North

0 4 km

Location of Regional Flying-fox Camps

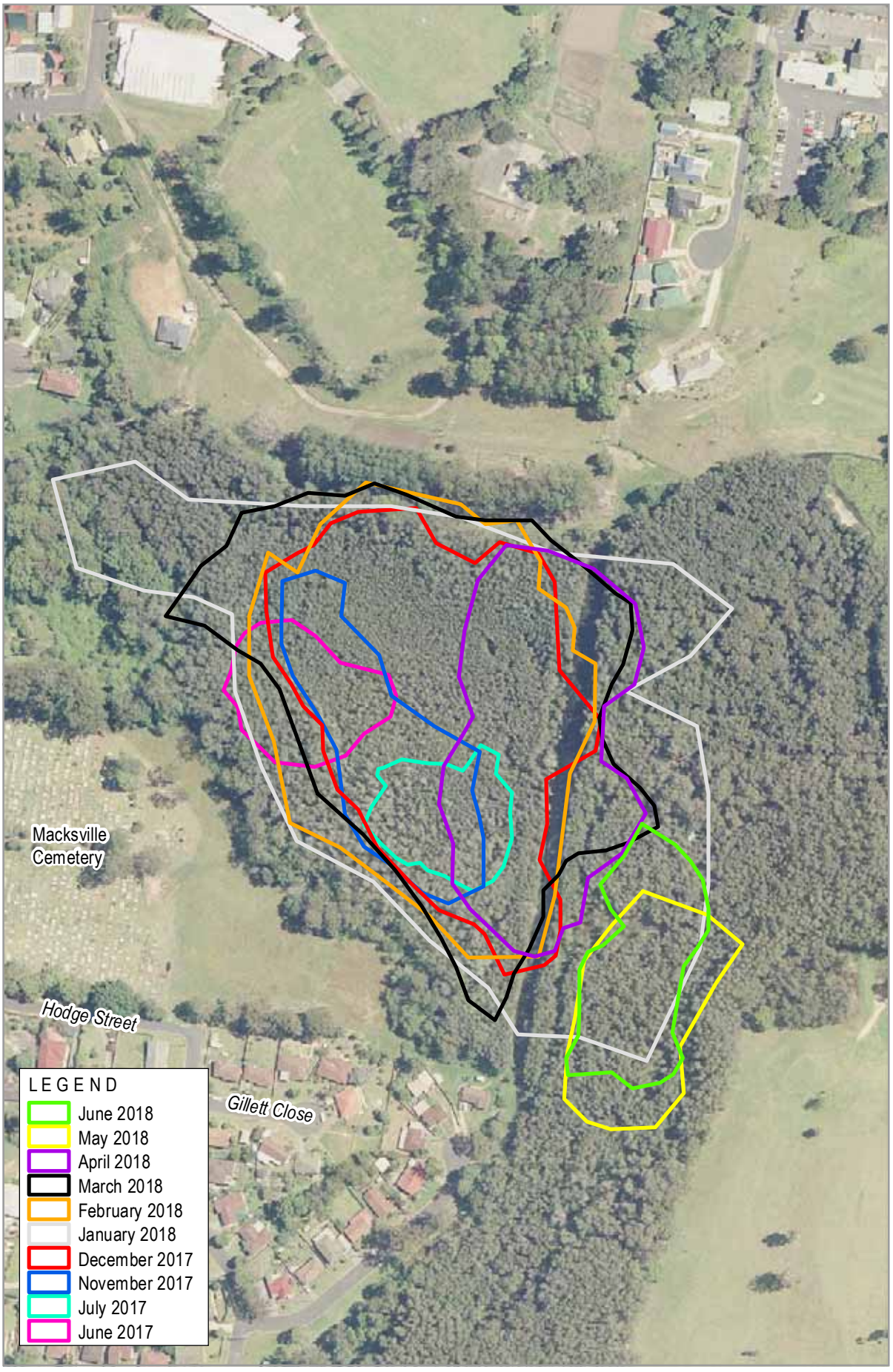
GeoLINK environmental management and design

Flying-fox Monitoring June 2018 - Warrell Creek to Nambucca Heads
Pacific Highway Upgrade
2692-1127

Illustration 2.1

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: DSA Date: 12/07/2018
Source of base data: Roads and Maritime Services



North

0 60

Macksville Cemetery Flying-fox Roost Footprint

GeoLINK environmental management and design

Flying-fox Monitoring June 2018 - Warrell Creek to Nambucca Heads
Pacific Highway Upgrade
2692-1126

Illustration 2.2

2.2.2 Population Estimates

2.2.2.1 Exit Counts

No flying-foxes were observed flying from the site during the exit count.

Approximately 7,500 individuals were recorded exiting the Macksville Cemetery camp in the exit count. The flying-foxes were exiting in two broad streams, one in a westerly direction and another in a south-easterly direction.

2.2.2.2 Direct Counts

With the exception of the Macksville Cemetery camp, no exit counts were conducted at any of the remaining regional camps. However, rough population estimates for these camps based on extrapolation of counts in individual trees and the roost footprint are provided. These flying-fox population estimate results (from this and past monitoring as part of this program) should not be relied on for accuracy or other purposes. Population estimates are provided in line with the Australian Government Department of the Environment and Energy (DEE)/ CSIRO *Monitoring flying-fox Populations* (DEE 2018) categories:

1 = 1 – 499
2 = 500 – 2,499
3 = 2,500 – 9,999
4 = 10,000 – 15,999
5 = 16,000 – 49,999
6 = >50,000.

Regional camp count estimates are as follows:

- Gordon Park: approximately 10,000 individuals (category 4).
- Bellingen Island: approximately 12,500 individuals (category 4).
- Wheatley Street, Bellingen: no individuals recorded.
- Bowraville: no individuals recorded.

2.2.3 Detailed Data

2.2.3.1 Species Composition

The species composition and proportions observed at occupied camps were as follows:

- Macksville Cemetery: 80% GHFF and 20% Black Flying-fox.
- Bellingen Island: 95% GHFF and 5% Black Flying-fox.
- Gordon Park: 90% GHFF and 10% Black Flying-fox.

2.2.3.2 Habitat Characteristics and Demographic Composition

As flying-foxes were not recorded at the site in the current monitoring event, detailed demographic composition data was not collected. This has been the case since April 2014 (excluding a brief return in January 2015). During this period of absence, the Macksville Cemetery camp has been the alternative site for collection of this data.

Both male and female GHFF were present at the Macksville Cemetery camp. The data collected indicated that the proportion of female GHFF present was moderate to high, ranging between 67% and 100% of all individuals at individual demographic point counts (84% average). No dependent young GHFF were present (refer to **Table 2.1**).

Both male and female GHFF were also present at the Bellingen Island camp. Data collected indicated that the proportion of female GHFF present was relatively high, ranging between 77% and 100% of all individuals at individual demographic point counts (91% average). No dependent young GHFF were present (refer to **Table 2.2**).

General observations of the GHFF currently roosting at the Gordon Park camp indicated that males and females were present. No dependent young were observed with the females.

Table 2.1 Demographic Data of GHFF at the Macksville Cemetery Camp

Tree Code	*GPS Location (UTM coordinates GDA94, Zone 56)*	*Tree Species*	*Height (m)*	*DBH (cm)*	*Demographic Ratio (female:male)*	*Presence of Dependant Young (yes/no)*	*% Females with Dependant Young*
MC1	492192, 6601576	Broad-leaved Paperbark	15	30	10:3	No	n/a
MC2	492198, 6601610	Broad-leaved Paperbark	15	20	10:2	No	n/a
MC3	492203, 6601627	Broad-leaved Paperbark	12	30	10:0	No	n/a
MC4	492206, 6601635	Broad-leaved Paperbark	10	20	10:1	No	n/a
MC5	492217, 6601643	Broad-leaved Paperbark	12	30	10:2	No	n/a
MC6	492211, 6601670	Broad-leaved Paperbark	15	30	10:1	No	n/a
MC7	492219, 6601678	Broad-leaved Paperbark	12	20	10:3	No	n/a
MC8	492226, 6601689	Broad-leaved Paperbark	15	30	10:5	No	n/a
MC9	492236, 6601688	Broad-leaved Paperbark	15	20	10:2	No	n/a
MC10	492242, 6601687	Broad-leaved Paperbark	15	30	10:2	No	n/a

Table 2.2 Demographic Data of GHFF at the Bellingen Island Camp

Tree Code	*GPS Location (UTM coordinates GDA94, Zone 56)*	*Tree Species*	*Height (m)*	*DBH (cm)*	*Demographic Ratio (female:male)*	*Presence of Dependant Young (yes/no)*	*% Females with Dependant Young*
BI1	490087, 6631559	Creek Sandpaper Fig	10	30	10:1	No	n/a
BI2	490078, 6631570	Giant Stinging Tree	8	15	10:0	No	n/a
BI3	490064, 6631589	Unidentifiable sp.	15	60	10:2	No	n/a
BI4	490061, 6631595	Creek Sandpaper Fig	8	40	10:0	No	n/a
BI5	490050, 6631597	Creek Sandpaper Fig	8	30	10:1	No	n/a
BI6	490065, 6631604	Moreton Bay Fig	15	120	10:1	No	n/a
BI7	490033, 6631627	Creek Sandpaper Fig	10	30	10:2	No	n/a
BI8	490016, 6631636	Creek Sandpaper Fig	8	40	10:0	No	n/a
BI9	490013, 6631643	Giant Stinging Tree	12	30	10:3	No	n/a
BI10	489991, 6631649	Creek Sandpaper Fig	8	20	10:1	No	n/a

2.2.3.3 Water Level at the Site

Water level at the site measured at the representative measurement location was approximately 40 cm in depth; no change from the level recorded in the previous monitoring event (refer to **Figure 2.1**).

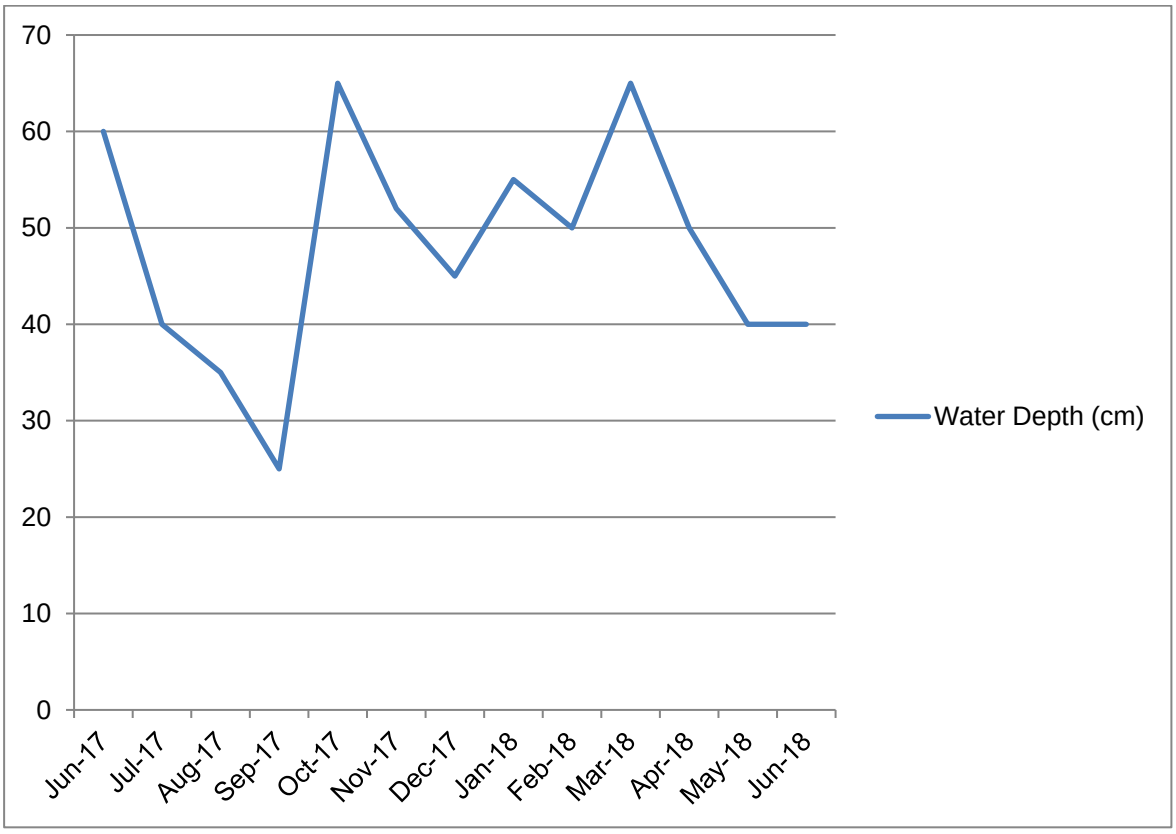


Figure 2.1 Water level measurements at the site

2.3 Discussion

2.3.1 Population Estimates

The trend in flying-fox numbers over the last 12-month period at the site and other monitored regional flying-fox camps is shown in **Figure 2.2**. No flying-foxes were recorded at the site again this month. Flying-foxes have not occupied the site (excluding a brief return in January 2015) since mid-April 2014.

Following a peak in the number of flying-foxes roosting at the Macksville Cemetery camp in March when approximately 45,000 individuals were present, a substantial decrease has been recorded with approximately 7,500 individuals recorded at this camp in the current monitoring event. In June 2017 flying-fox numbers were even lower with approximately 2,000 individuals present (GeoLINK 2017).

It was estimated that approximately 12,500 flying-foxes were present at the Bellingen Island camp in the current monitoring event. A substantial decrease in numbers has been observed from an estimated 30,000 individuals roosting at this camp in the previous monitoring event. In June 2017 the estimated number of flying-foxes roosting at the Bellingen Island camp was substantially higher at approximately 25,000 (GeoLINK 2017).

The number of flying-foxes estimated to be roosting at the Gordon Park camp has remained relatively steady over the past four months at around 10,000 individuals (with the exception of a temporary spike in numbers in May). The estimated number of flying-foxes roosting at this camp was similar in June 2017, when approximately 15,000 individuals were recorded (GeoLINK 2017).

No flying-foxes were recorded at Bowraville in the current monitoring event. Flying-foxes have been absent from this site for over 18 months, and were last recorded in December 2016 in low numbers.

As can be seen in the 12-monthly population comparisons (refer to **Figure 2.2**), numbers of flying-foxes at regional camps now appear to be declining after a summer/ autumn peak.

2.3.2 Species Composition and Demographic Data

At occupied camps, GHFF dominated the species composition making up between 80% and 95% of all individuals. The highest proportion of Black Flying-foxes was recorded at the Macksville Cemetery camp. Similar high proportions of GHFF have consistently been recorded in previous monitoring events.

Female GHFF dominated the occupied camps in the current monitoring event, with demographic point counts averaging 91% at the Bellingen Island camp and 84% at the Macksville Cemetery camp. Similar high proportions of female GHFF were recorded in the previous monitoring event (GeoLINK 2018).

No dependent young GHFF were recorded at any of the occupied camps in the current monitoring event, in line with the reproductive cycle of this species.

2.3.3 Phenology of Trees in the Region

June/ July bi-monthly flowering of a number of highly productive nectar source trees in the upper North Coast region of NSW includes Coast Banksia (*Banksia integrifolia*), Coastal Blackbutt (*Eucalyptus pilularis*), Swamp Mahogany (*Eucalyptus robusta*), Forest Red Gum (*Eucalyptus tereticornis*), and Broad-leaved Paperbark (*Melaleuca quinquenervia*). These are considered key diet species for GHFF in the region (Eby 2012; Eby and Law 2008).

Observations when travelling between regional flying-fox camps recorded light flowering of Forest Red Gum and Grey Ironbark (usually flowers later in the year), and moderate flowering of Broad-leaved Paperbark and Swamp Mahogany (*Eucalyptus robusta*).

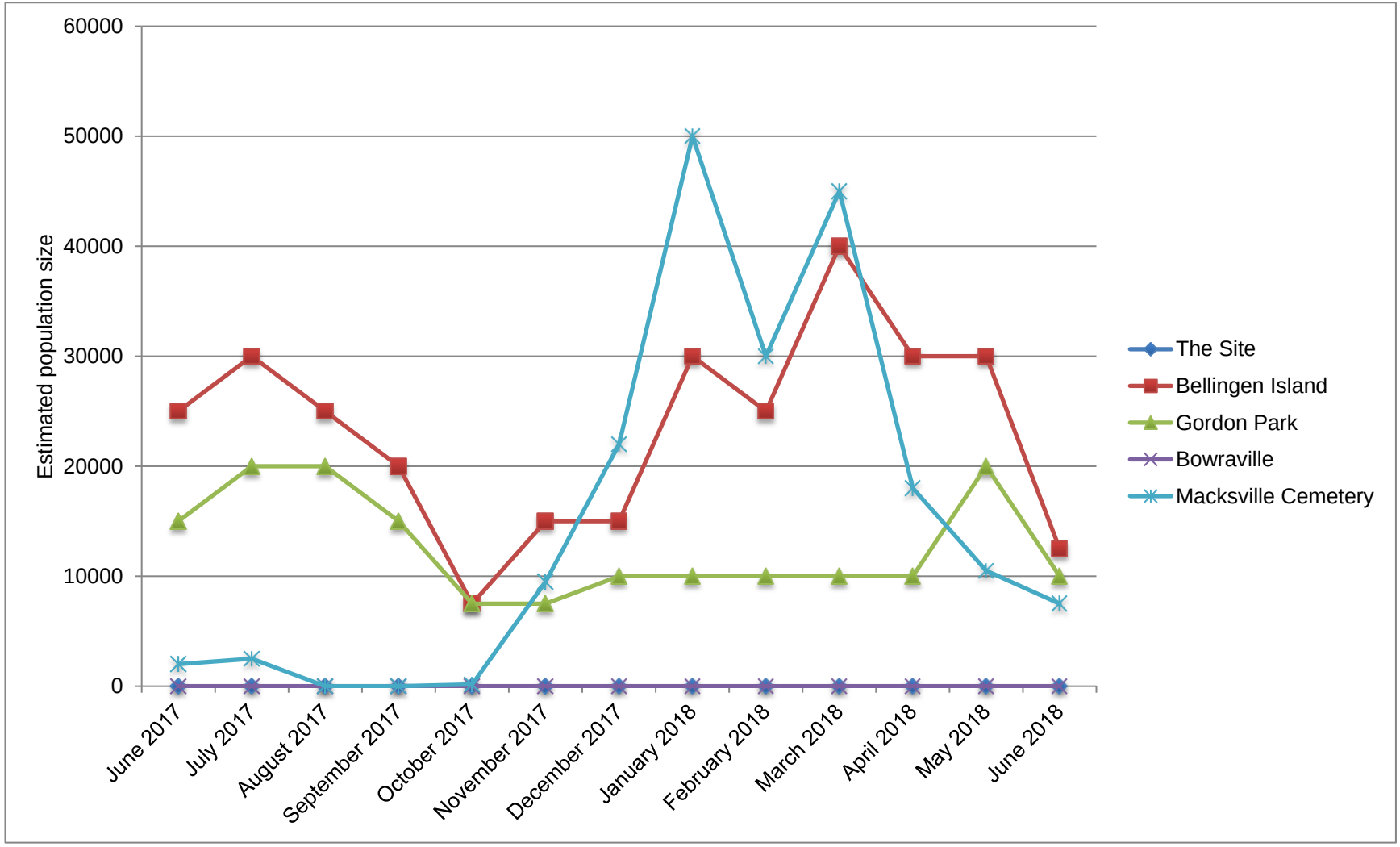


Figure 2.2 Population trends at the site and regional camps over past 12 months

2.4 Summary and Conclusion

The results of the June 2018 flying-fox monitoring indicate that, excluding a brief stopover at the site observed in mid-January 2015, flying-foxes have been absent from the site since April 2014.

There has been a general decreasing trend in flying-fox numbers at the Macksville Cemetery camp and Bellingen Island camp since a peak in March 2018. In contrast, no clear trend is evident at Gordon Park, where flying-fox numbers have remained relatively steady over the past 6 months (excluding a temporary peak in May).

Flying-foxes remain absent from Bowraville and Wheatley Street, Bellingen.

GHFF dominated the species composition at occupied camps making up between 80% and 95% of all individuals present.

Female GHFF dominated the demographic composition at both the Macksville cemetery and Bellingen Island camps, making up between 84% and 91% of all GHFF individuals respectively.

No dependent young GHFF were recorded at any of the occupied camps in the current monitoring event, in line with the reproductive cycle of this species.

Light flowering of Forest Red Gum and Grey Ironbark, and moderate flowering of Swamp Mahogany and Broad-leaved Paperbark was observed to be currently occurring in the region. These are key diet species for the GHFF.

David Andrighetto
Senior Ecologist

References

DEE (2018). *Monitoring Flying-fox Populations*, Australian Government Department of the Environment and Energy, Canberra, viewed 11 July 2018. http://www.environment.gov.au/biodiversity/threatened/species/flying-fox-monitoring/

Eby, P. (2012). *An Assessment of the Flying-fox Camp at Macksville*. Unpublished report to NSW Roads and Maritime Services.

Eby, P. (2013). *A Field Monitoring Program Proposed for the Macksville Flying-fox Roost*. Unpublished report to Sinclair Knight Merz.

GeoLINK. (2017). *Flying-fox Monitoring June 2017: Warrell Creek to Nambucca Heads Pacific Highway Upgrade*. Unpublished report to NSW Roads and Maritime Services.

GeoLINK. (2018). *Flying-fox Monitoring May 2018: Warrell Creek to Nambucca Heads Pacific Highway Upgrade*. Unpublished report to NSW Roads and Maritime Services.

Appendix 8 July 2018 monitoring report

Flying-fox Monitoring
July 2018

Warrell Creek to Nambucca Heads
Pacific Highway Upgrade

PO Box 119
Lennox Head NSW 2478
T 02 6687 7666

PO Box 1446
Coffs Harbour NSW 2450
T 02 6651 7666

PO Box 1267
Armidale NSW 2350
T 02 6772 0454

PO Box 229
Lismore NSW 2480
T 02 6621 6677

info@geolink.net.au

Prepared for: Roads and Maritime Services

© GeoLINK, 2018

UPR	*Description*	*Date Issued*	*Issued By*
2692-1135	First issue	07/08/2018	David Andrighetto

Table of Contents

1. Introduction 1

1.1 Introduction 1

2. Flying-fox Survey 2

2.1 Methodology 2
2.2 Results 3

2.2.1 Roost Footprint 3
2.2.2 Population Estimates 6
2.2.3 Detailed Data 6

2.3 Discussion 10

2.3.1 Population Estimates 10
2.3.2 Species Composition and Demographic Data 11
2.3.3 Phenology of Trees in the Region 11

2.4 Summary and Conclusion 13

Illustrations

Illustration 2.1 Location of Regional Flying-fox Camps 4
Illustration 2.2 Macksville Cemetery Roost Footprint 5

Tables

Table 2.1 Demographic Data of GHFF at the Macksville Cemetery Camp 8
Table 2.2 Demographic Data of GHFF at the Bellingen Island Camp 9

Figures

Figure 2.1 Water level measurements at the site 10
Figure 2.2 Population trends at the site and regional camps over past 12 months 12

1. Introduction

1.1 Introduction

NSW Roads and Maritime Services has been monitoring a Grey-headed Flying-fox (*Pteropus poliocephalus*) (GHFF) camp that was intermittently present within the approved alignment of the Warrell Creek to Nambucca Heads (WC2NH) Pacific Highway upgrade project near Macksville. The camp was located in a patch of swamp sclerophyll forest north of Bald Hill Road (henceforth referred to as 'the site').

GeoLINK has undertaken monitoring at the site on at least a monthly basis since July 2013. Prior to this, irregular monitoring of flying-foxes at the site has been undertaken since the initial establishment of the camp in December 2011 (Eby 2012).

This report details the July 2018 flying-fox monitoring results.

2. Flying-fox Survey

2.1 Methodology

The following GeoLINK personnel undertook fieldwork for the July 2018 flying-fox monitoring:

- Tom Pollard (ecologist).
- Frank Makin (ecologist).
- Jeremy Clifford (environmental scientist).
- Kale Hardie-Porter (environmental scientist).

Fieldwork followed the methodology developed by Dr Eby for the project. Refer to Eby (2013) for full details of the methodology. A summary of the main procedures used for the monitoring is provided below.

The fieldwork was undertaken on 26 July 2018. The presence of flying-foxes at the site was assessed by undertaking a traverse of the area previously known to support flying-foxes in conjunction with a few sharp handclaps aimed at eliciting a vocal response from any flying-foxes roosting at the site.

When flying-foxes are present at the site, the following data is collected:

- The area of the roost footprint (mapped by GPS).
- Species composition.
- Demographics (avoiding male 'bachelor trees' where possible).
- Reproductive status.
- Behaviour.

When the site is unoccupied and flying-foxes are present at the nearby seasonally-occupied flying-fox camp within two kilometres of the site adjacent to Macksville Cemetery, the abovementioned data is collected here instead. This data provides relevant information on the status of flying-foxes that are camped in the Macksville area.

The water level at the site was measured at GPS location 492866, 6600756 (UTM coordinates, GDA 94, Zone 56). The water level at this location is representative of the average level at the site and is tracked over time to provide information on water level fluctuations that occur at the site.

A dusk exit count survey was undertaken at both the site and the Macksville Cemetery camp to confirm the presence/ absence of flying-foxes and to provide an estimate of the current population at each camp.

Two observers were strategically located for the exit count on a northern and a southern ridge overlooking the site. Specifically, the two observers were located at the following vantage points:

- In a paddock to the north of the swamp sclerophyll forest (off Wedgewood Drive).
- On a prominent ridge to the south (at 41 Bald Hill Road).

Two observers were also located adjacent to the Macksville Cemetery camp at the following vantage points:

- At the Macksville Cemetery gate off Wallace Street (west of the camp).
- Adjacent to the Macksville Golf Course next to the Pacific Highway (east of the camp).

The exit counts extended over approximately 45 minutes from sunset until dark (approximately 5:15 pm to 6:00 pm).

Other regional flying-fox camps at Gordon Park, Nambucca Heads (approximately 12 kilometres north-east of the site), Bowraville (approximately 10.5 kilometres north-west of the site), Bellingen Wheatley Street camp (approximately 30 kilometres north of the site) and Bellingen Island (approximately 31 kilometres north of the site) were also visited and observational comments made. Refer to **Illustration 2.1** for the location of the subject regional camps.

2.2 Results

2.2.1 Roost Footprint

No flying-foxes were recorded roosting at the site in the traverse.

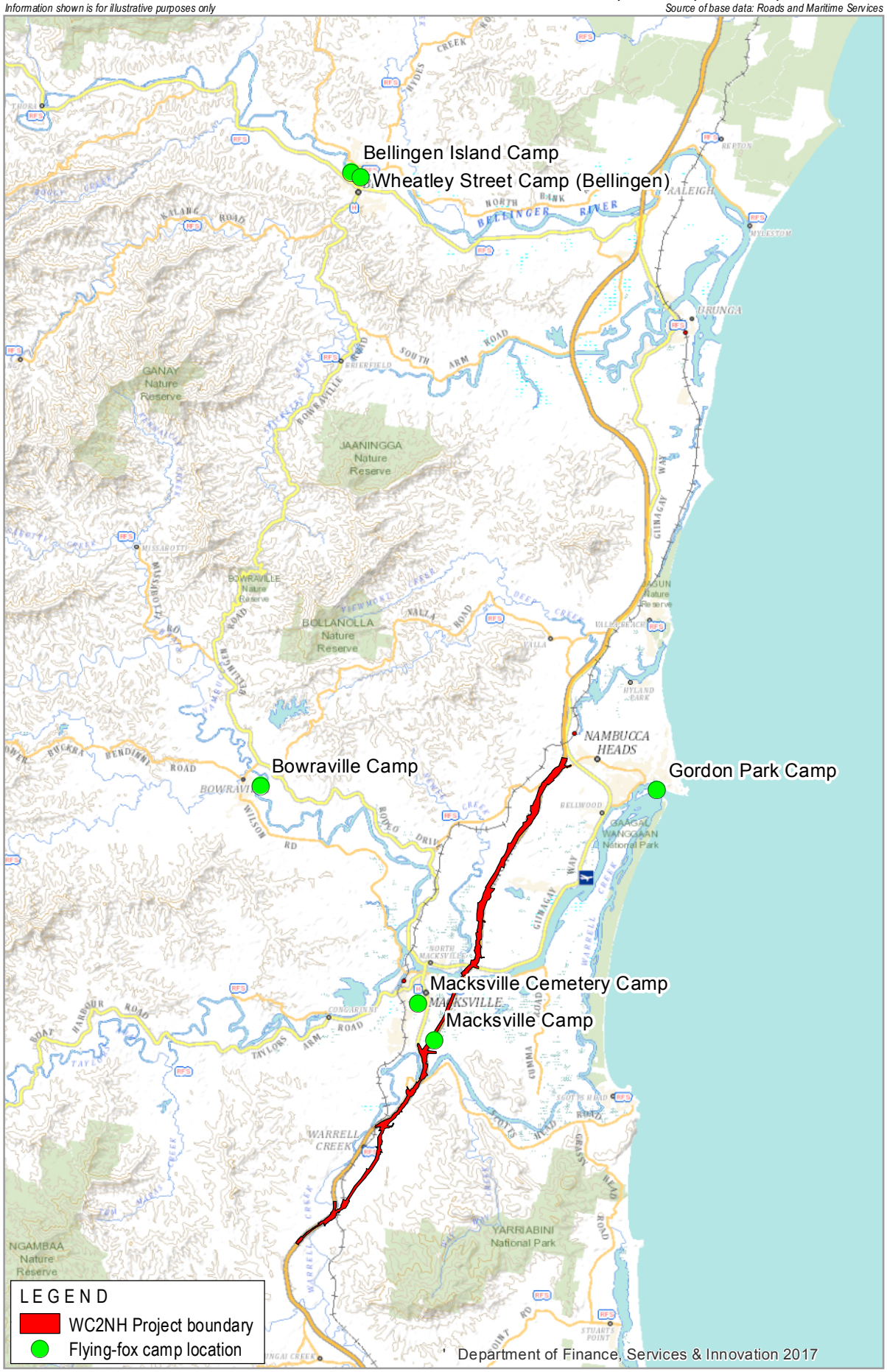
Flying-foxes were observed to be roosting at the Macksville Cemetery camp. The roost extended over an area of approximately 0.30 hectares (refer to **Illustration 2.2**). As has been recorded in the previous two monitoring events, the flying-fox roost is currently located in a narrow section of paperbark swamp forest west of the Macksville golf course near the northern end of McNeill Close.

Flying-foxes were not recorded at the Wheatley Street camp in Bellingen or at Bowraville.

Regionally, flying-foxes were observed to be roosting at Bellingen Island and Gordon Park (Nambucca Heads). The extent of the roost footprint at Bellingen Island was observed to have decreased since the previous monthly monitoring event (GeoLINK 2018), and was only covering the northern section of the channel between the island and the old caravan park in the current monitoring event. At the Gordon Park camp the roost extent has not substantially changed from that recorded in the previous monitoring event, however more Black Flying-foxes appear to be currently roosting in upper canopy, leading to an overall increase in the number of flying-foxes at this camp.

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: DSA Date: 7/08/2018
Source of base data: Roads and Maritime Services



0 4 km

North

Location of Regional Flying-fox Camps

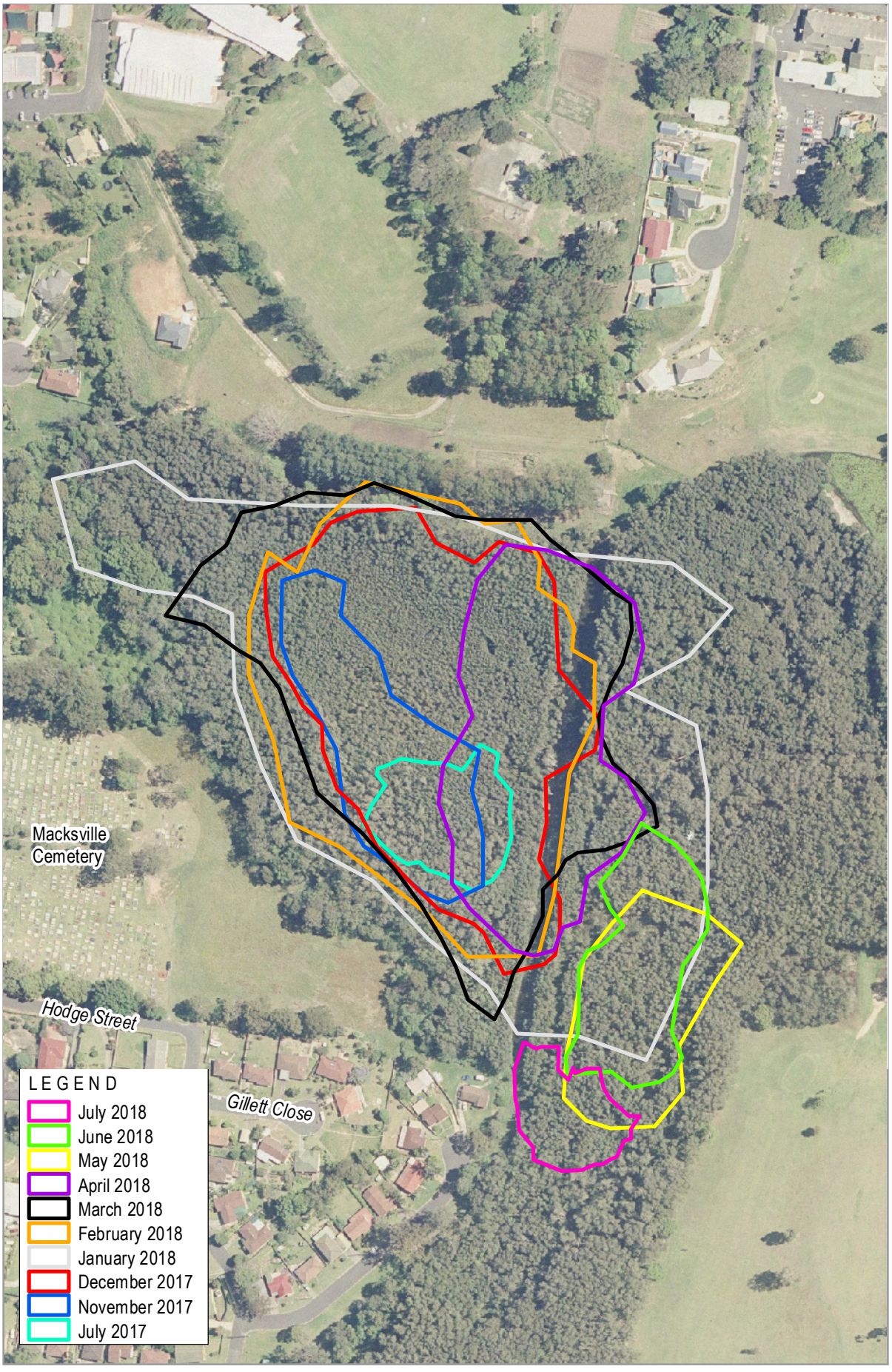
GeoLINK environmental management and design

Flying-fox Monitoring July 2018 - Warrell Creek to Nambucca Heads
Pacific Highway Upgrade
2692-1138

Illustration 2.1

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: DSA Date: 7/08/2018
Source of base data: Roads and Maritime Services



North

0 60

Macksville Cemetery Flying-fox Roost Footprint

GeoLINK environmental management and design

Flying-fox Monitoring July 2018 - Warrell Creek to Nambucca Heads
Pacific Highway Upgrade
2692-1137

Illustration 2.2

2.2.2 Population Estimates

2.2.2.1 Exit Counts

No flying-foxes were observed flying from the site during the exit count.

Approximately 1,000 individuals were recorded exiting the Macksville Cemetery camp in the exit count. The flying-foxes were mostly exiting in a southerly direction.

2.2.2.2 Direct Counts

With the exception of the Macksville Cemetery camp, no exit counts were conducted at any of the remaining regional camps. However, rough population estimates for these camps based on extrapolation of counts in individual trees and the roost footprint are provided. These flying-fox population estimate results (from this and past monitoring as part of this program) should not be relied on for accuracy or other purposes. Population estimates are provided in line with the Australian Government Department of the Environment and Energy (DEE)/ CSIRO *Monitoring flying-fox Populations* (DEE 2018) categories:

1 = 1 – 499
2 = 500 – 2,499
3 = 2,500 – 9,999
4 = 10,000 – 15,999
5 = 16,000 – 49,999
6 = >50,000.

Regional camp count estimates are as follows:

- Gordon Park: approximately 15,000 individuals (category 4).
- Bellingen Island: approximately 7,500 individuals (category 3).
- Wheatley Street, Bellingen: no individuals recorded.
- Bowraville: no individuals recorded.

2.2.3 Detailed Data

2.2.3.1 Species Composition

The species composition and proportions observed at occupied camps were as follows:

- Macksville Cemetery: 70% GHFF and 30% Black Flying-fox.
- Bellingen Island: 95% GHFF and 5% Black Flying-fox.
- Gordon Park: 80% GHFF and 20% Black Flying-fox.

2.2.3.2 Habitat Characteristics and Demographic Composition

As flying-foxes were not recorded at the site in the current monitoring event, detailed demographic composition data was not collected. This has been the case since April 2014 (excluding a brief return in January 2015). During this period of absence, the Macksville Cemetery camp has been the alternative site for collection of this data.

Both male and female GHFF were present at the Macksville Cemetery camp. Data could only be successfully collected from six demographic point counts, as the small number of flying-foxes present were easily disturbed and were changing roosting position frequently. The data collected indicated that the proportion of female GHFF present was moderate to high, ranging between 77% and 100% of all individuals at individual demographic point counts (89% average). No dependent young GHFF were present (refer to **Table 2.1**).

Both male and female GHFF were also present at the Bellingen Island camp. Data collected indicated that the proportion of female GHFF present was relatively high, ranging between 71% and 100% of all individuals at individual demographic point counts (85% average). No dependent young GHFF were present (refer to

Table 2.2).

General observations of the GHFF currently roosting at the Gordon Park camp indicated that males and females were present. No dependent young were observed with the females.

Table 2.1 Demographic Data of GHFF at the Macksville Cemetery Camp

Tree Code	*GPS Location (UTM coordinates GDA94, Zone 56)*	*Tree Species*	*Height (m)*	*DBH (cm)*	*Demographic Ratio (female:male)*	*Presence of Dependant Young (yes/no)*	*% Females with Dependant Young*
MC1	492164, 6601572	Broad-leaved Paperbark	12	20	10:0	No	n/a
MC2	492161, 6601558	Broad-leaved Paperbark	10	25	10:0	No	n/a
MC3	492163, 6601551	Broad-leaved Paperbark	12	30	10:2	No	n/a
MC4	492169, 6601538	Broad-leaved Paperbark	12	20	10:3	No	n/a
MC5	492174, 6601525	Broad-leaved Paperbark	12	20	10:1	No	n/a
MC6	492193, 6601524	Broad-leaved Paperbark	15	30	10:2	No	n/a
MC7	No data recorded	No data recorded	No data recorded	No data recorded	No data recorded	No data recorded	No data recorded
MC8	“	“	“	“	“	“	“
MC9	“	“	“	“	“	“	“
MC10	“	“	“	“	“	“	“

Table 2.2 Demographic Data of GHFF at the Bellingen Island Camp

Tree Code	*GPS Location (UTM coordinates GDA94, Zone 56)*	*Tree Species*	*Height (m)*	*DBH (cm)*	*Demographic Ratio (female:male)*	*Presence of Dependant Young (yes/no)*	*% Females with Dependant Young*
BI1	490047, 6631633	Moreton Bay Fig (*Ficus macrophylla*)	15	100	All males - 'bachelor tree'	No	n/a
BI2	490035, 6631624	White Aspen (*Acronychia oblongifolia*)	12	20/20 (multiple trunks	10:3	No	n/a
BI3	490044, 6631618	Unidentified sp.	12	20	10:1	No	n/a
BI4	490038, 6631627	Dead tree	10	40	10:0	No	n/a
BI5	490035, 6631630	Moreton Bay Fig (*Ficus macrophylla*)	8	40	10:4	No	n/a
BI6	490005, 6631648	Moreton Bay Fig (*Ficus macrophylla*)	12	90	10:2	No	n/a
BI7	490017, 6631633	Giant Stinging Tree (*Dendrocnide excelsa*)	12	30	10:2	No	n/a
BI8	490029, 6631612	Giant Stinging Tree (*Dendrocnide excelsa*)	10	90	10:4	No	n/a
BI9	490041, 6631615	Creek Sandpaper Fig (*Ficus coronata*)	10	20	10:0	No	n/a
BI10	490057, 6631615	C Creek Sandpaper Fig (*Ficus coronata*)	10	20	10:2	No	n/a

2.2.3.3 Water Level at the Site

Water level at the site measured at the representative measurement location was approximately 45 cm in depth; similar to the level recorded in the previous monitoring event (refer to **Figure 2.1**).

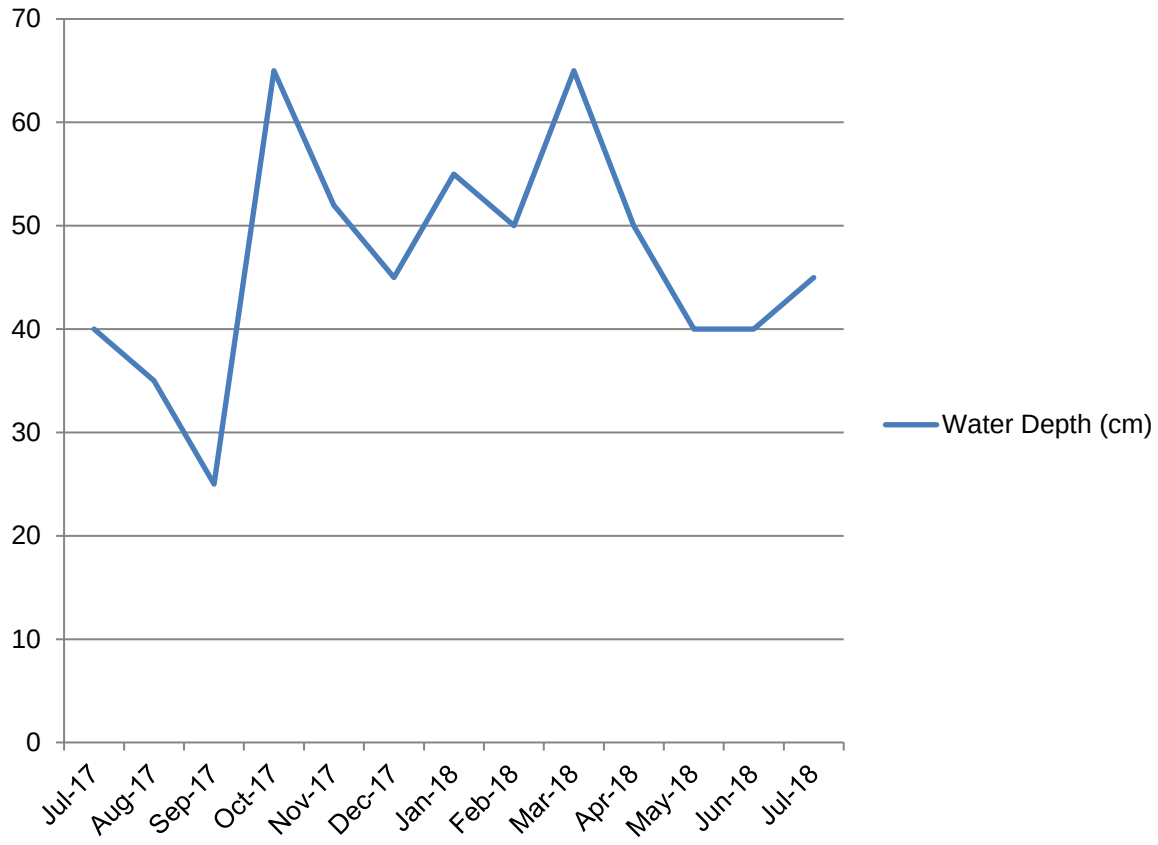


Figure 2.1 Water level measurements at the site

2.3 Discussion

2.3.1 Population Estimates

The following discussion refers to the following Australian Government Department of the Environment and Energy (DEE)/ CSIRO *Monitoring flying-fox Populations* (DEE 2018) categories:

1 = 1 – 499
2 = 500 – 2,499
3 = 2,500 – 9,999
4 = 10,000 – 15,999
5 = 16,000 – 49,999
6 = >50,000.

The trend in flying-fox numbers over the last 12-month period at the site and other monitored regional flying-fox camps is shown in **Figure 2.2**. No flying-foxes were recorded at the site again this month. Flying-foxes have not occupied the site (excluding a brief return in January 2015) since mid-April 2014.

Since a peak in the number of flying-foxes roosting at the Macksville Cemetery camp in March 2018 when approximately 45,000 individuals were present (category 5), a steady decrease in numbers has been recorded. The current monitoring event recorded only 1,000 flying-foxes (category 2), the lowest number since October 2017. In July 2017 flying-fox numbers were at a similar level, with approximately 2,500 individuals present (category 3; GeoLINK 2017).

At Bellingen Island it was estimated that approximately 7,500 flying-foxes (category 3) were present in the current monitoring event. A steep decrease in numbers has been observed at this camp over the past four months following a peak of around 40,000 individuals (category 5) roosting at this camp in March 2018 (refer to **Figure 2.2**).

The number of flying-foxes at the Gordon Park camp has remained relatively steady over the past eight months, estimated at between 10,000 and 15,000 individuals (category 4) with the exception of a temporary spike in numbers in May 2018 to category 5 levels.

No flying-foxes were recorded at Bowraville in the current monitoring event. Flying-foxes have been absent from this site for over 18 months, and were last recorded in December 2016 in low numbers.

As can be seen in the 12-monthly population comparisons (refer to **Figure 2.2**), numbers of flying-foxes at regional camps are generally decreasing (with the exception of the Gordon Park camp following a summer/ autumn peak.

2.3.2 Species Composition and Demographic Data

At occupied camps, GHFF dominated the species composition making up between 70% and 95% of all individuals. Similar high proportions of GHFF have consistently been recorded in previous monitoring events. The highest proportion of Black Flying-foxes was recorded at the Macksville Cemetery camp.

Female GHFF dominated the occupied camps in the current monitoring event, with demographic point counts averaging 85% at the Bellingen Island camp and 89% at the Macksville Cemetery camp. Similar high proportions of female GHFF were recorded in the previous monitoring event (GeoLINK 2018).

No dependent young GHFF were recorded at any of the occupied camps in the current monitoring event, in line with the reproductive cycle of this species.

2.3.3 Phenology of Trees in the Region

June/ July bi-monthly flowering of a number of highly productive nectar source trees in the upper North Coast region of NSW includes Coast Banksia (*Banksia integrifolia*), Coastal Blackbutt (*Eucalyptus pilularis*), Swamp Mahogany (*Eucalyptus robusta*), Forest Red Gum (*Eucalyptus tereticornis*), and Broad-leaved Paperbark (*Melaleuca quinquenervia*). These are considered key diet species for GHFF in the region (Eby 2012; Eby and Law 2008).

Observations when travelling between regional flying-fox camps recorded light to moderate flowering of Forest Red Gum, light flowering of Grey Ironbark. The moderate flowering of Broad-leaved Paperbark that was recorded in the previous monitoring event has now ended.

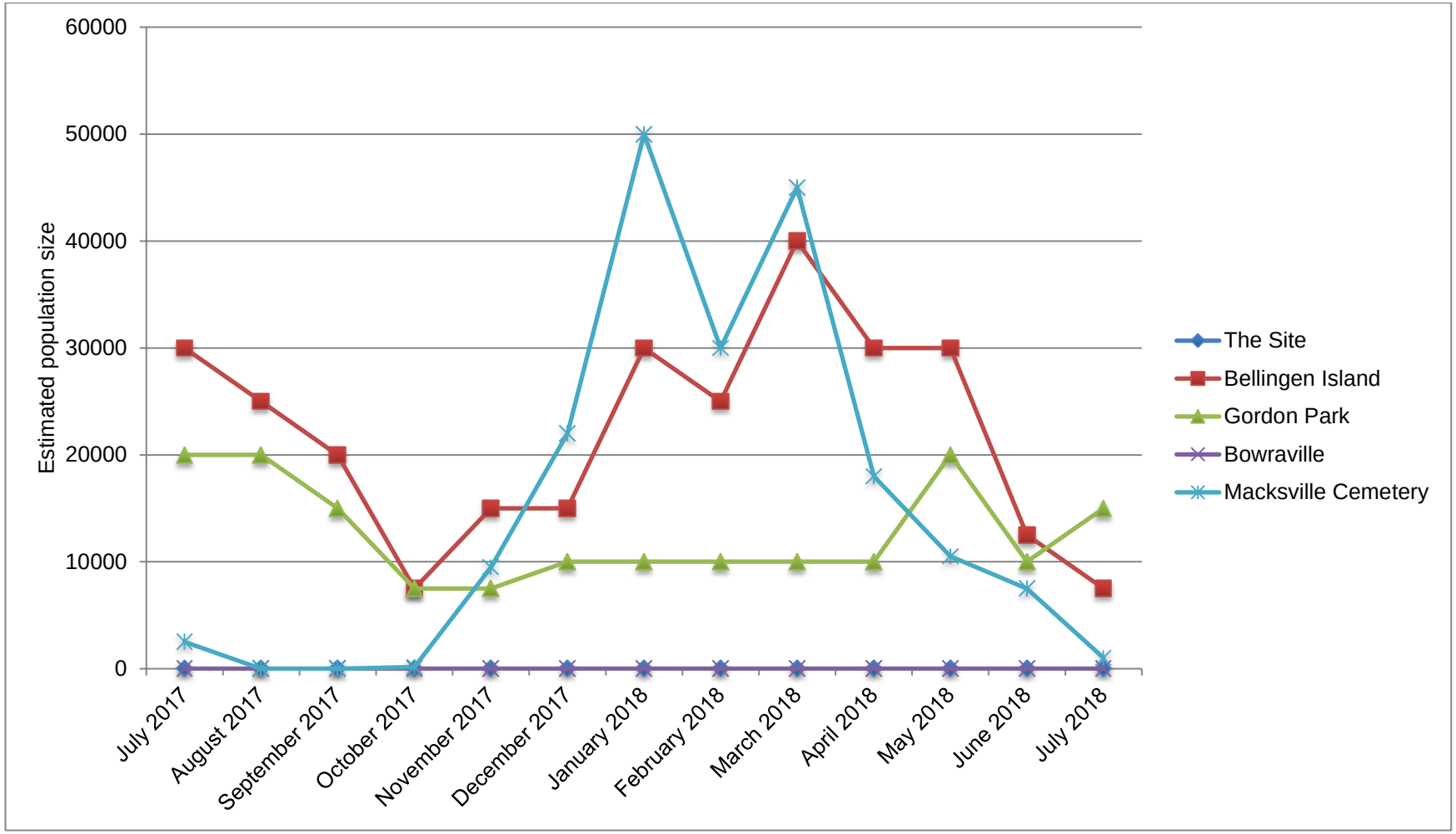


Figure 2.2 Population trends at the site and regional camps over past 12 months

2.4 Summary and Conclusion

The results of the July 2018 flying-fox monitoring indicate that, excluding a brief stopover at the site observed in mid-January 2015, flying-foxes have been absent from the site since April 2014.

There has been a general decreasing trend in flying-fox numbers at the Macksville Cemetery camp and Bellingen Island camp since a peak in March 2018. In contrast, no clear trend is evident at Gordon Park, where flying-fox numbers have remained relatively steady over the past 8 months (excluding a temporary peak in May).

Flying-foxes remain absent from Bowraville and Wheatley Street, Bellingen.

GHFF dominated the species composition at occupied camps making up between 70% and 95% of all individuals present.

Female GHFF dominated the demographic composition at both the Bellingen Island and Macksville cemetery camps, making up between 85% and 89% of all GHFF individuals respectively.

No dependent young GHFF were recorded at any of the occupied camps in the current monitoring event, in line with the reproductive cycle of this species.

Light to moderate flowering of Forest Red Gum and moderate flowering of Grey Ironbark was observed to be currently occurring in the region. Flowering of Broad-leaved Paperbark has now generally ended in the region. These are all key diet species for the GHFF.

David Andrighetto
Senior Ecologist

References

DEE (2018). *Monitoring Flying-fox Populations*, Australian Government Department of the Environment and Energy, Canberra, viewed 11 July 2018. http://www.environment.gov.au/biodiversity/threatened/species/flying-fox-monitoring/

Eby, P. (2012). *An Assessment of the Flying-fox Camp at Macksville*. Unpublished report to NSW Roads and Maritime Services.

Eby, P. (2013). *A Field Monitoring Program Proposed for the Macksville Flying-fox Roost*. Unpublished report to Sinclair Knight Merz.

GeoLINK. (2017). *Flying-fox Monitoring July 2017: Warrell Creek to Nambucca Heads Pacific Highway Upgrade*. Unpublished report to NSW Roads and Maritime Services.

GeoLINK. (2018). *Flying-fox Monitoring June 2018: Warrell Creek to Nambucca Heads Pacific Highway Upgrade*. Unpublished report to NSW Roads and Maritime Services.

Appendix 9 August 2018 monitoring report

Flying-fox Monitoring August 2018

Warrell Creek to Nambucca Heads Pacific Highway Upgrade

PO Box 119
Lennox Head NSW 2478
T 02 6687 7666

PO Box 1446
Coffs Harbour NSW 2450
T 02 6651 7666

PO Box 1267
Armidale NSW 2350
T 02 6772 0454

PO Box 229
Lismore NSW 2480
T 02 6621 6677

info@geolink.net.au

Prepared for: Roads and Maritime Services

© GeoLINK, 2018

UPR	*Description*	*Date Issued*	*Issued By*
2692-1139	First issue	14/09/2018	David Andrighetto

Table of Contents

1. Introduction 1

1.1 Introduction 1

2. Flying-fox Survey 2

2.1 Methodology 2
2.2 Results 3

2.2.1 Roost Footprint 3
2.2.2 Population Estimates 5
2.2.3 Detailed Data 5

2.3 Discussion 8

2.3.1 Population Estimates 8
2.3.2 Species Composition and Demographic Data 9
2.3.3 Phenology of Trees in the Region 9

2.4 Summary and Conclusion 11

Illustrations

Illustration 2.1 Location of Regional Flying-fox Camps 4

Tables

Table 2.1 Demographic Data of GHFF at the Bellingen Island Camp 7

Figures

Figure 2.1 Water Level Measurements at the Site 8
Figure 2.2 Population Trends at the Site and Regional Camps Over Past 12 Months 10

1. Introduction

1.1 Introduction

NSW Roads and Maritime Services has been monitoring a Grey-headed Flying-fox (*Pteropus poliocephalus*) (GHFF) camp that was intermittently present within the approved alignment of the Warrell Creek to Nambucca Heads (WC2NH) Pacific Highway upgrade project near Macksville. The camp was located in a patch of swamp sclerophyll forest north of Bald Hill Road (henceforth referred to as 'the site').

GeoLINK has undertaken monitoring at the site on at least a monthly basis since July 2013. Prior to this, irregular monitoring of flying-foxes at the site has been undertaken since the initial establishment of the camp in December 2011 (Eby 2012).

This report details the August 2018 flying-fox monitoring results.

2. Flying-fox Survey

2.1 Methodology

The following GeoLINK personnel undertook fieldwork for the August 2018 flying-fox monitoring:

- Tom Pollard (ecologist).
- Frank Makin (ecologist).
- Jeremy Clifford (environmental scientist).
- Kale Hardie-Porter (environmental scientist).

Fieldwork followed the methodology developed by Dr Eby for the project. Refer to Eby (2013) for full details of the methodology. A summary of the main procedures used for the monitoring is provided below.

The fieldwork was undertaken on 30 August 2018. The presence of flying-foxes at the site was assessed by undertaking a traverse of the area previously known to support flying-foxes in conjunction with a few sharp handclaps aimed at eliciting a vocal response from any flying-foxes roosting at the site.

When flying-foxes are present at the site, the following data is collected:

- The area of the roost footprint (mapped by GPS).
- Species composition.
- Demographics (avoiding male 'bachelor trees' where possible).
- Reproductive status.
- Behaviour.

When the site is unoccupied and flying-foxes are present at the nearby seasonally-occupied flying-fox camp within two kilometres of the site adjacent to Macksville Cemetery, the abovementioned data is collected here instead. This data provides relevant information on the status of flying-foxes that are camped in the Macksville area.

The water level at the site was measured at GPS location 492866, 6600756 (UTM coordinates, GDA 94, Zone 56). The water level at this location is representative of the average level at the site and is tracked over time to provide information on water level fluctuations that occur at the site.

A dusk exit count survey was undertaken at both the site and the Macksville Cemetery camp to confirm the presence/ absence of flying-foxes and to provide an estimate of the current population at each camp.

Two observers were strategically located for the exit count on a northern and a southern ridge overlooking the site. Specifically, the two observers were located at the following vantage points:

- In a paddock to the north of the swamp sclerophyll forest (off Wedgewood Drive).
- On a prominent ridge to the south (at 41 Bald Hill Road).

Two observers were also located adjacent to the Macksville Cemetery camp at the following vantage points:

- At the Macksville Cemetery gate off Wallace Street (west of the camp).
- Adjacent to the Macksville Golf Course next to the Pacific Highway (east of the camp).

The exit counts extended over approximately 45 minutes from sunset until dark (approximately 5:40 pm to 6:25 pm).

Other regional flying-fox camps at Gordon Park, Nambucca Heads (approximately 12 kilometres north-east of the site), Bowraville (approximately 10.5 kilometres north-west of the site), Bellingen Wheatley Street camp (approximately 30 kilometres north of the site) and Bellingen Island (approximately 31 kilometres north of the site) were also visited and observational comments made. Refer to **Illustration 2.1** for the location of the subject regional camps.

2.2 Results

2.2.1 Roost Footprint

No flying-foxes were recorded roosting at the site in the traverse.

No flying-foxes were observed to be roosting at the Macksville Cemetery camp. Nor were there any flying-foxes recorded at the Wheatley Street camp in Bellingen or at the Bowraville camp.

Regionally, flying-foxes were observed to be roosting at the Bellingen Island camp and Gordon Park camp (Nambucca Heads). The extent of the roost footprint at both of these camps was generally similar to that recorded in the previous monthly monitoring event (GeoLINK 2018).

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: DSA Date: 7/08/2018
Source of base data: Roads and Maritime Services

0 4 km

North

Location of Regional Flying-fox Camps

GeoLINK environmental management and design

Flying-fox Monitoring August 2018 - Warrell Creek to Nambucca Heads Pacific Highway Upgrade
2692-1138

Illustration 2.1

2.2.2 Population Estimates

2.2.2.1 Exit Counts

No flying-foxes were observed flying from either the site or the Macksville Cemetery camp during the exit count.

2.2.2.2 Direct Counts

With the exception of the Macksville Cemetery camp, no exit counts were conducted at any of the remaining regional camps. However, rough population estimates for these camps based on extrapolation of counts in individual trees and the roost footprint are provided. These flying-fox population estimate results (from this and past monitoring as part of this program) should not be relied on for accuracy or other purposes. Population estimates are provided in line with the Australian Government Department of the Environment and Energy (DEE)/ CSIRO *Monitoring flying-fox Populations* (DEE 2018) categories:

1 = 1 – 499
2 = 500 – 2,499
3 = 2,500 – 9,999
4 = 10,000 – 15,999
5 = 16,000 – 49,999
6 = >50,000.

Regional camp count estimates are as follows:

- Gordon Park: approximately 15,000 individuals (category 4).
- Bellingen Island: approximately 10,000 individuals (category 4).
- Wheatley Street, Bellingen: no individuals recorded.
- Bowraville: no individuals recorded.

2.2.3 Detailed Data

2.2.3.1 Species Composition

The species composition and proportions observed at occupied camps were as follows:

- Bellingen Island: 90% GHFF and 10% Black Flying-fox.
- Gordon Park: 80% GHFF and 20% Black Flying-fox.

2.2.3.2 Habitat Characteristics and Demographic Composition

As flying-foxes were not recorded at the site in the current monitoring event, detailed demographic composition data was not collected. This has been the case since April 2014 (excluding a brief return in January 2015). During this period of absence, the Macksville Cemetery camp has been the alternative site for collection of this data. However, flying-foxes were also not present at the Macksville Cemetery camp in the current monitoring event and therefore detailed demographic composition data was therefore not collected for this alternative site.

Both male and female GHFF were present at the Bellingen Island camp. Data collected indicated that the proportion of female GHFF present was variable, ranging between 59% and 100% of all individuals at individual demographic point counts (77% average). No dependent young GHFF were present (refer to **Table 2.1).**

General observations of the GHFF currently roosting at the Gordon Park camp indicated that males and females were present. No dependent young were observed with the females.

Table 2.1 Demographic Data of GHFF at the Bellingen Island Camp

Tree Code	*GPS Location (UTM coordinates GDA94, Zone 56)*	*Tree Species*	*Height (m)*	*DBH (cm)*	*Demographic Ratio (female:male)*	*Presence of Dependant Young (yes/no)*	*% Females with Dependant Young*
BI1	490035, 6631612	Unidentified sp.	8	15	10:5	No	n/a
BI2	490017, 6631609	Creek Sandpaper Fig (*Ficus coronata*)	8	15	10:2	No	n/a
BI3	490005, 6631621	Creek Sandpaper Fig (*Ficus coronata*)	10	20	10:6	No	n/a
BI4	490051, 6631624	Creek Sandpaper Fig (*Ficus coronata*)	8	15	10:4	No	n/a
BI5	490054, 6631624	Giant Stinging Tree (*Dendrocnide excelsa*)	15	40	10:0	No	n/a
BI6	490060, 6631618	Creek Sandpaper Fig (*Ficus coronata*)	12	20	10:7	No	n/a
BI7	490069, 6631630	Unidentified sp.	10	25	10:1	No	n/a
BI8	490054, 6631639	Moreton Bay Fig (*Ficus macrophylla*)	15	100	10:7	No	n/a
BI9	490035, 6631639	Unidentified sp.	12	20	10:1	No	n/a
BI10	490011, 6631648	Creek Sandpaper Fig (*Ficus coronata*)	10	20	10:2	No	n/a

2.2.3.3 Water Level at the Site

Water level at the site measured at the representative measurement location was approximately 45 cm in depth; similar to the level recorded in the previous monitoring event (refer to **Figure 2.1**).

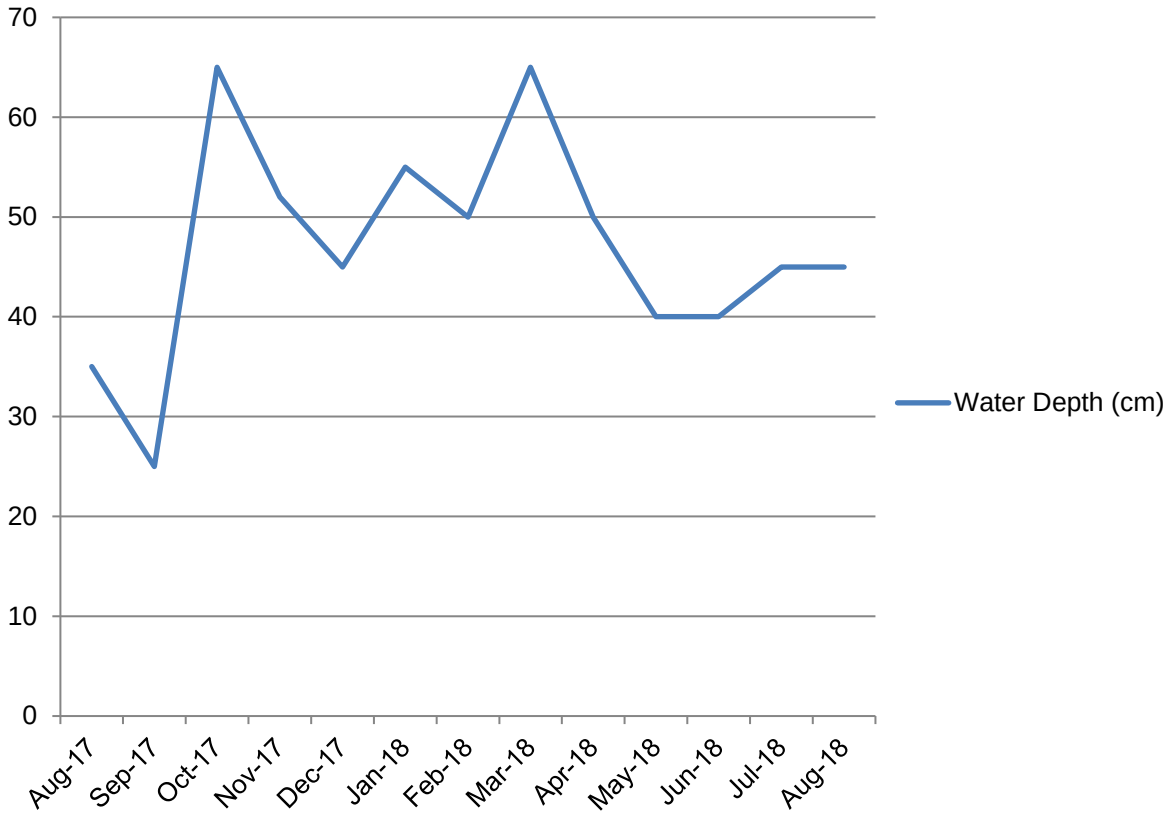


Figure 2.1 Water Level Measurements at the Site

2.3 Discussion

2.3.1 Population Estimates

The following discussion refers to the following Australian Government Department of the Environment and Energy (DEE)/ CSIRO *Monitoring flying-fox Populations* (DEE 2018) categories (refer to **Section 2.2.2.2**).

The trend in flying-fox numbers over the last 12-month period at the site and other monitored regional flying-fox camps is shown in **Figure 2.2**. No flying-foxes were recorded at the site again this month. Flying-foxes have not occupied the site (excluding a brief return in January 2015) since mid-April 2014.

Since a peak in the number of flying-foxes roosting at the Macksville Cemetery camp in March 2018 when approximately 45,000 individuals were present (category 5), a steady decrease in numbers has been recorded down to zero flying-foxes in the current monitoring event. This is consistent with the monitoring results from 2017, when flying-foxes were absent from this camp over the August to October period (refer to **Figure 2.2**).

At the Bellingen Island camp it was estimated that approximately 10,000 flying-foxes (category 4) were present. A similar number of flying-foxes were recorded in the previous monitoring event. The number of flying-foxes at both the Bellingen Island and Gordon Park camps in August 2017 was higher than that estimated in the current monitoring event (category 5; GeoLINK 2017), possibly indicating that key foraging resources were more readily available locally at that time of year in 2017 (refer to **Figure 2.2**).

The number of flying-foxes at the Gordon Park camp has remained relatively steady over the past nine months, estimated at between 10,000 and 15,000 individuals (category 4) with the exception of a temporary spike in numbers in May 2018 to category 5 levels.

No flying-foxes were recorded at Bowraville in the current monitoring event. Flying-foxes have been absent from this site for over 18 months, and were last recorded in December 2016 in low numbers.

As can be seen in the 12-monthly population comparisons (refer to **Figure 2.2**), numbers of flying-foxes at occupied regional camps is now at relatively low to moderate levels following a summer/ autumn peak.

2.3.2 Species Composition and Demographic Data

At occupied camps, GHFF dominated the species composition making up between 80% and 90% of all individuals. Similar high proportions of GHFF have consistently been recorded in previous monitoring events.

The proportion of female GHFF decreased from 85% to 77% at the Bellingen Island camp over the last month (GeoLINK 2018). Despite this minor decrease, female GHFF nonetheless strongly dominated the demographic composition.

No dependent young GHFF were recorded at any of the occupied camps in the current monitoring event, in line with the reproductive cycle of this species.

2.3.3 Phenology of Trees in the Region

August/ September bi-monthly flowering of a number of highly productive nectar source trees in the upper North Coast region of NSW includes Coast Banksia (*Banksia integrifolia*), Coastal Blackbutt (*Eucalyptus pilularis*), Narrow-leaved Red Gum (*Eucalyptus seeana*), Grey Ironbark (*Eucalyptus siderophloia*) and Forest Red Gum (*Eucalyptus tereticornis*). These are considered key diet species for GHFF in the region (Eby 2012; Eby and Law 2008).

Observations when travelling between regional flying-fox camps recorded moderate flowering of Coast Banksia, Forest Red Gum and Grey Ironbark.

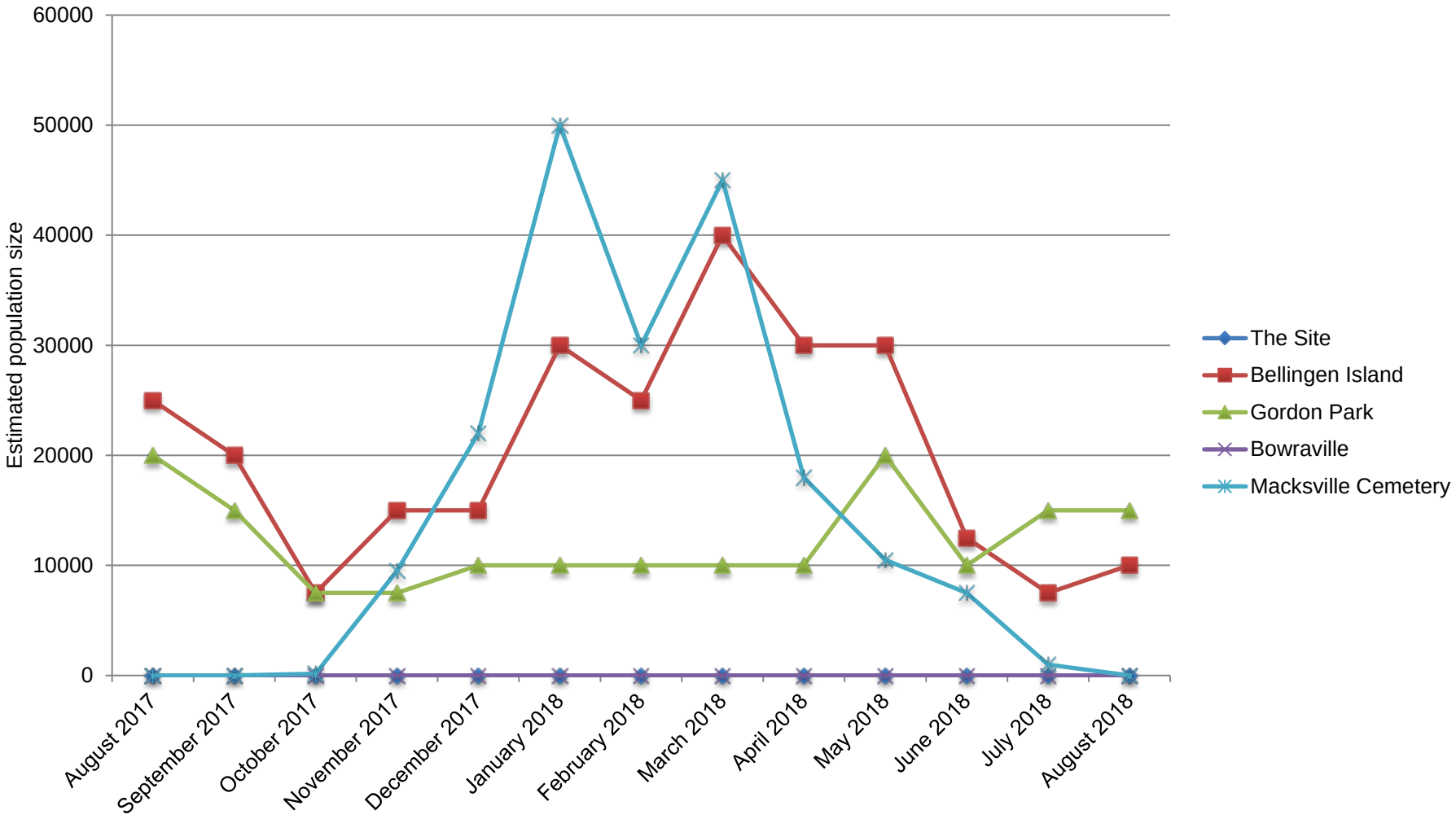


Figure 2.2 Population Trends at the Site and Regional Camps Over Past 12 Months

2.4 Summary and Conclusion

The results of the August 2018 flying-fox monitoring indicate that, excluding a brief stopover at the site observed in mid-January 2015, flying-foxes have been absent from the site since April 2014. Flying-foxes were also absent from the Macksville Cemetery, Bowraville, and Wheatley Street camps.

Only the Bellingen Island and Gordon Park camps were occupied. The number of flying-foxes at these occupied regional camps is now at relatively low to moderate levels following a summer/ autumn peak. GHFF dominated the species composition at occupied camps at between 80% and 90% of all individuals present. The proportion of female GHFF remains relatively high. No dependent young GHFF were recorded at any of the occupied camps in the current monitoring event, in line with the reproductive cycle of this species.

Moderate flowering of Coast Banksia, Forest Red Gum and Grey Ironbark was observed to be currently occurring in the region. These are all key diet species for the GHFF.

David Andrighetto
Senior Ecologist

References

DEE (2018). *Monitoring Flying-fox Populations*, Australian Government Department of the Environment and Energy, Canberra, viewed 11 July 2018. http://www.environment.gov.au/biodiversity/threatened/species/flying-fox-monitoring/

Eby, P. (2012). *An Assessment of the Flying-fox Camp at Macksville*. Unpublished report to NSW Roads and Maritime Services.

Eby, P. (2013). *A Field Monitoring Program Proposed for the Macksville Flying-fox Roost*. Unpublished report to Sinclair Knight Merz.

GeoLINK. (2017). *Flying-fox Monitoring August 2017: Warrell Creek to Nambucca Heads Pacific Highway Upgrade*. Unpublished report to NSW Roads and Maritime Services.

GeoLINK. (2018). *Flying-fox Monitoring July 2018: Warrell Creek to Nambucca Heads Pacific Highway Upgrade*. Unpublished report to NSW Roads and Maritime Services.

Appendix 10 September 2018 monitoring report

Flying-fox Monitoring September 2018

Warrell Creek to Nambucca Heads Pacific Highway Upgrade

PO Box 119
Lennox Head NSW 2478
T 02 6687 7666

PO Box 1446
Coffs Harbour NSW 2450
T 02 6651 7666

PO Box 1267
Armidale NSW 2350
T 02 6772 0454

PO Box 229
Lismore NSW 2480
T 02 6621 6677

info@geolink.net.au

Prepared for: Roads and Maritime Services

© GeoLINK, 2018

UPR	*Description*	*Date Issued*	*Issued By*
2692-1143	First issue	03/10/2018	David Andrighetto

Table of Contents

1. Introduction 1

1.1 Introduction 1

2. Flying-fox Survey 2

2.1 Methodology 2
2.2 Results 3

2.2.1 Roost Footprint 3
2.2.2 Population Estimates 6
2.2.3 Detailed Data 6

2.3 Discussion 9

2.3.1 Population Estimates 9
2.3.2 Species Composition and Demographic Data 10
2.3.3 Phenology of Trees in the Region 10

2.4 Summary and Conclusion 12

Illustrations

Illustration 2.1 Location of Regional Flying-fox Camps 4
Illustration 2.2 – Macksville Cemetary Flying-fox Roost Footprint 5

Tables

Table 2.1 Demographic Data of GHFF at the Macksville Cemetery Camp 7
Table 2.2 Demographic Data of GHFF at the Bellingen Island Camp 8

Figures

Figure 2.1 Water Level Measurements at the Site 9
Figure 2.2 Population Trends at the Site and Regional Camps Over Past 12 Months 11

1. Introduction

1.1 Introduction

NSW Roads and Maritime Services has been monitoring a Grey-headed Flying-fox (*Pteropus poliocephalus*) (GHFF) camp that was intermittently present within the approved alignment of the Warrell Creek to Nambucca Heads (WC2NH) Pacific Highway upgrade project near Macksville. The camp was located in a patch of swamp sclerophyll forest north of Bald Hill Road (henceforth referred to as 'the site').

GeoLINK has undertaken monitoring at the site on at least a monthly basis since July 2013. Prior to this, irregular monitoring of flying-foxes at the site has been undertaken since the initial establishment of the camp in December 2011 (Eby 2012).

This report details the September 2018 flying-fox monitoring results.

2. Flying-fox Survey

2.1 Methodology

The following GeoLINK personnel undertook fieldwork for the September 2018 flying-fox monitoring:

- Jessica O'Leary (ecologist).
- Frank Makin (ecologist).
- Jeremy Clifford (environmental scientist).
- Kale Hardie-Porter (environmental scientist).

Fieldwork followed the methodology developed by Dr Eby for the project. Refer to Eby (2013) for full details of the methodology. A summary of the main procedures used for the monitoring is provided below.

The fieldwork was undertaken on 25 September 2018. The presence of flying-foxes at the site was assessed by undertaking a traverse of the area previously known to support flying-foxes in conjunction with a few sharp handclaps aimed at eliciting a vocal response from any flying-foxes roosting at the site.

When flying-foxes are present at the site, the following data is collected:

- The area of the roost footprint (mapped by GPS).
- Species composition.
- Demographics (avoiding male 'bachelor trees' where possible).
- Reproductive status.
- Behaviour.

When the site is unoccupied and flying-foxes are present at the nearby seasonally-occupied flying-fox camp within two kilometres of the site adjacent to Macksville Cemetery, the abovementioned data is collected here instead. This data provides relevant information on the status of flying-foxes that are camped in the Macksville area.

The water level at the site was measured at GPS location 492866, 6600756 (UTM coordinates, GDA 94, Zone 56). The water level at this location is representative of the average level at the site and is tracked over time to provide information on water level fluctuations that occur at the site.

A dusk exit count survey was undertaken at both the site and the Macksville Cemetery camp to confirm the presence/ absence of flying-foxes and to provide an estimate of the current population at each camp.

Two observers were strategically located for the exit count on a northern and a southern ridge overlooking the site, as follows:

- In a paddock to the north of the swamp sclerophyll forest (off Wedgewood Drive).
- On a prominent ridge to the south (at 41 Bald Hill Road).

Two observers were also located adjacent to the Macksville Cemetery camp at the following vantage points:

- At the Macksville Cemetery gate off Wallace Street (west of the camp).
- Adjacent to the Macksville Golf Course next to the Pacific Highway (east of the camp).

The exit counts extended over approximately 45 minutes from sunset until dark (approximately 5:50 pm to 6:35 pm).

Other regional flying-fox camps at Gordon Park, Nambucca Heads (approximately 12 kilometres north-east of the site), Bowraville (approximately 10.5 kilometres north-west of the site), Bellingen Wheatley Street camp (approximately 30 kilometres north of the site) and Bellingen Island (approximately 31 kilometres north of the site) were also visited and observational comments made. Refer to **Illustration 2.1** for the location of the subject regional camps.

2.2 Results

2.2.1 Roost Footprint

No flying-foxes were recorded roosting at the site in the traverse.

Flying-foxes were observed to be roosting at the Macksville Cemetery camp. The roost extended over an area of approximately 0.39 hectares (refer to **Illustration 2.2**). The flying-fox roost is currently located in a narrow section of paperbark swamp forest west of the Macksville golf course near the northern end of McNeill Close.

No flying-foxes were observed at the Wheatley Street camp in Bellingen or at the Bowraville camp.

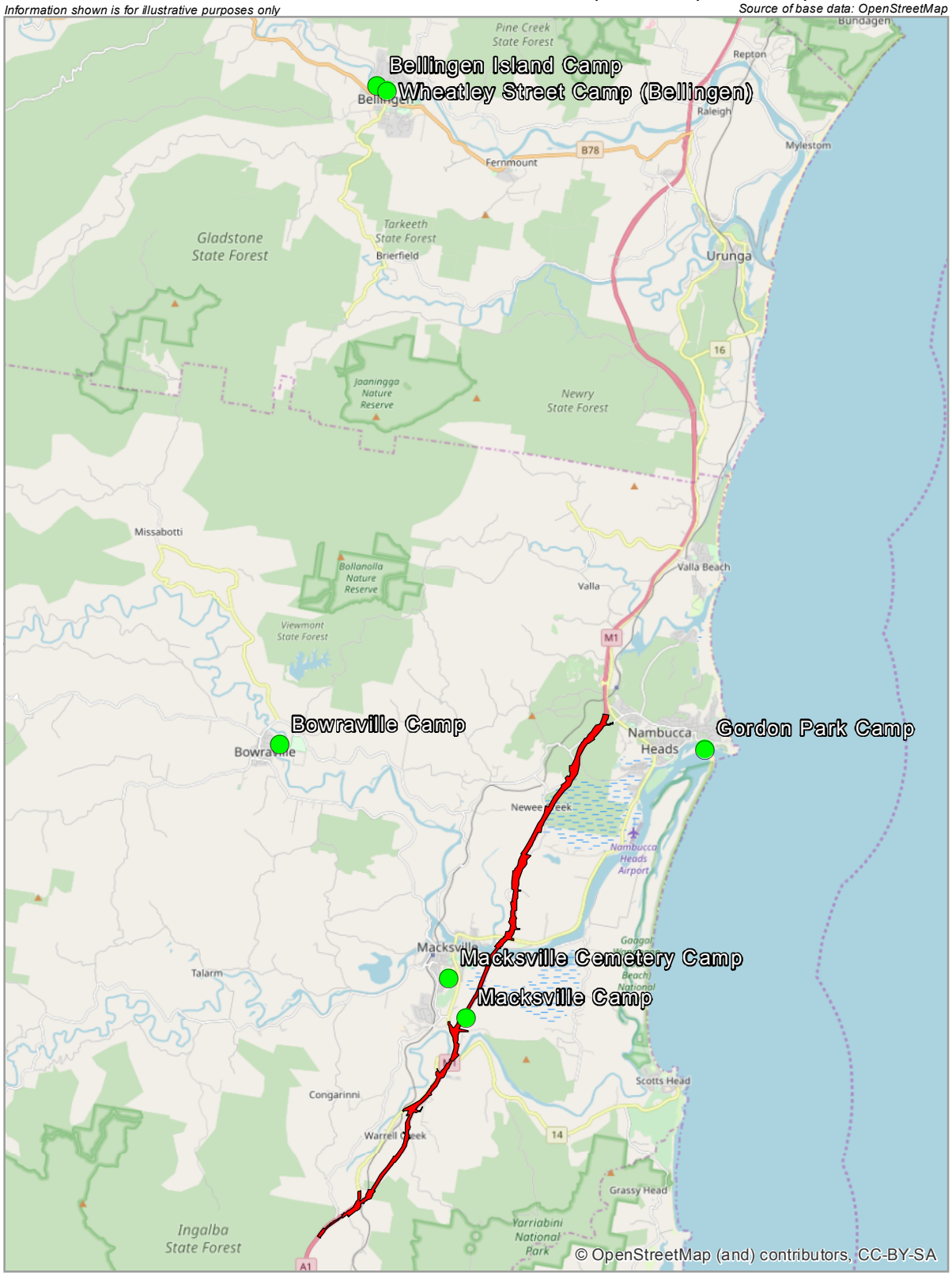
Regionally, flying-foxes were observed to be roosting at the Bellingen Island camp and Gordon Park camp (Nambucca Heads). The extent of the roost footprint at both of these camps was generally similar to that recorded in the previous monthly monitoring event (GeoLINK 2018).

Regionally, flying-foxes were observed to be roosting at Bellingen Island and Gordon Park (Nambucca Heads). The extent of the roost footprint at Bellingen Island was observed to have increased since the previous monthly monitoring event (GeoLINK 2018), this month covering a broader area of the island including the north and southern edges of the island vegetation. At the Gordon Park camp, the roost extent has not substantially changed from that recorded in the previous monitoring event.

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 27/09/2018

Information shown is for illustrative purposes only

Source of base data: OpenStreetMap



LEGEND

- WC2NH Project boundary
- Flying-fox camp location

0 4 Km

Location of Regional Flying-fox Camps

GeoLINK environmental management and design

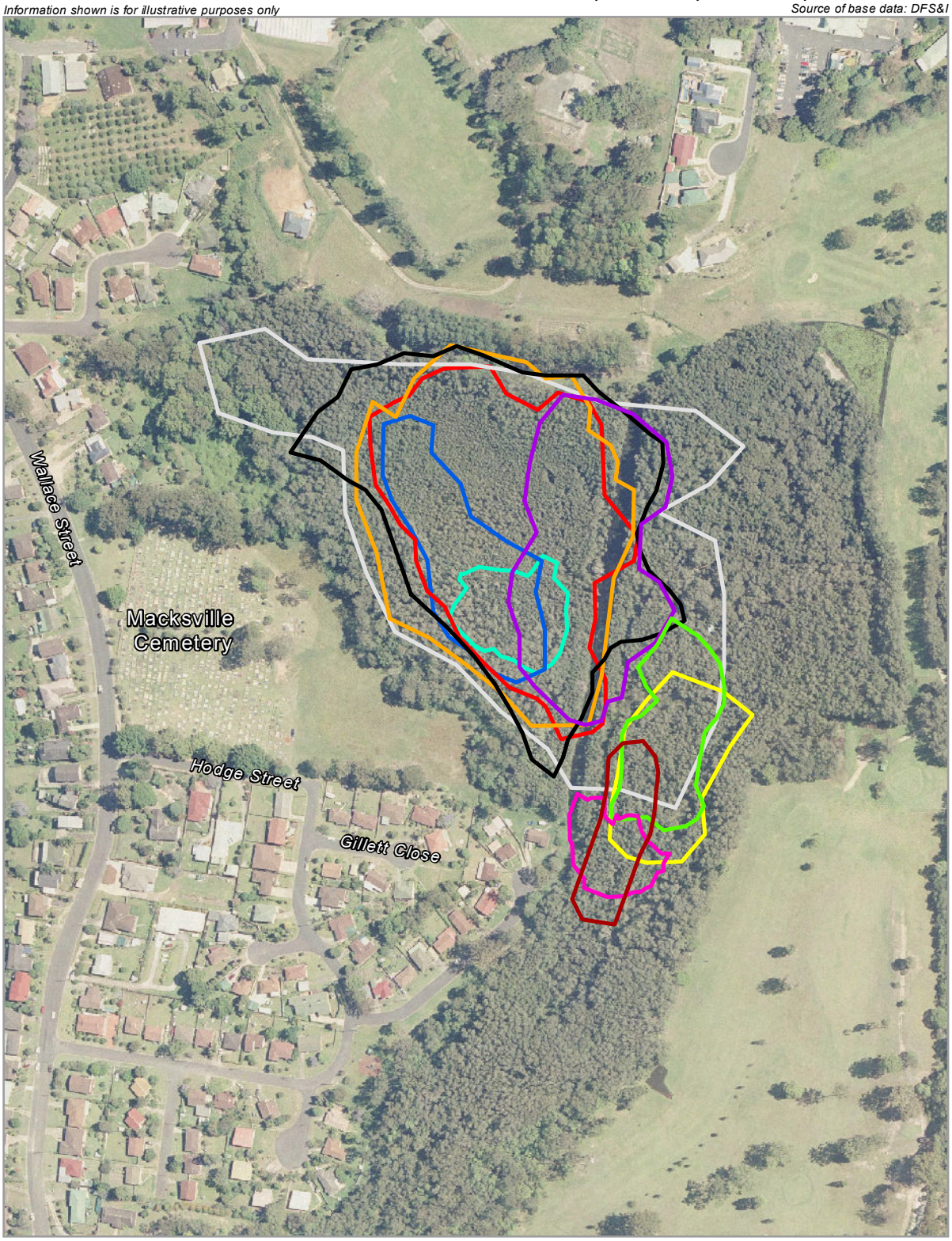
Flying-fox Monitoring September 2018 - Warrell Creek to Nambucca Heads Pacific Highway Upgrade
2692-1144

Illustration 2.1

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 27/09/2018

Information shown is for illustrative purposes only

Source of base data: DFS&I



LEGEND

- September 2018
- July 2018
- June 2018
- May 2018
- April 2018
- March 2018
- February 2018
- January 2018
- December 2017
- November 2017
- July 2017

0 80

Macksville Cemetery Flying-fox Roost Footprint

GeoLINK environmental management and design

Flying-fox Monitoring September 2018 - Warrell Creek to Nambucca Heads
Pacific Highway Upgrade
2692-1145

Illustration 2.2

2.2.2 Population Estimates

2.2.2.1 Exit Counts

No flying-foxes were observed flying from the site during the exit count.

Approximately 2,334 individuals were recorded exiting the Macksville Cemetery camp in the exit count. The flying-foxes were mostly exiting in a westerly direction.

2.2.2.2 Direct Counts

With the exception of the Macksville Cemetery camp, no exit counts were conducted at any of the remaining regional camps. However, rough population estimates for these camps based on extrapolation of counts in individual trees and the roost footprint are provided. These flying-fox population estimate results (from this and past monitoring as part of this program) should not be relied on for accuracy or other purposes. Population estimates are provided in line with the Australian Government Department of the Environment and Energy (DEE)/ CSIRO *Monitoring flying-fox Populations* (DEE 2018) categories:

1 = 1 – 499
2 = 500 – 2,499
3 = 2,500 – 9,999
4 = 10,000 – 15,999
5 = 16,000 – 49,999
6 = >50,000.

Regional camp count estimates are as follows:

- Gordon Park: approximately 15,000 individuals (category 4).
- Bellingen Island: approximately 15,000 individuals (category 4).
- Wheatley Street, Bellingen: no individuals recorded.
- Bowraville: no individuals recorded.

2.2.3 Detailed Data

2.2.3.1 Species Composition

The species composition and proportions observed at occupied camps were as follows:

- Macksville Cemetery: 95% GHFF and 5% Black Flying-fox.
- Bellingen Island: 95% GHFF and 5% Black Flying-fox.
- Gordon Park: 90% GHFF and 10% Black Flying-fox.

2.2.3.2 Habitat Characteristics and Demographic Composition

As flying-foxes were not recorded at the site in the current monitoring event, detailed demographic composition data was not collected. This has been the case since April 2014 (excluding a brief return in January 2015). During this period of absence, the Macksville Cemetery camp has been the alternative site for collection of this data.

Both male and female GHFF were present at the Macksville Cemetery camp. Data could only be successfully collected from four demographic point counts, as the small number of flying-foxes present were easily disturbed and were changing roosting position frequently. The data collected indicated that the proportion of female GHFF present was moderate to high, ranging between 66% and 83.3% of all individuals at individual demographic point counts (74.4% average). No dependent young GHFF were present (refer to **Table 2.1**).

Both male and female GHFF were present at the Bellingen Island camp. Data collected indicated that the proportion of female GHFF present was variable, ranging between 58% and 91% of all individuals at eight individual demographic point counts (70.5% average). *Note: Ten females were unable to be found at two point counts, most likely due to the harem bring surrounded by bachelor groups/ trees. Their values excluded from the female ratio counts.* No dependent young GHFF were present (refer to **Table 2.2**).

General observations of the GHFF currently roosting at the Gordon Park camp indicated that males and females were present. No dependent young were observed with the females.

Table 2.1 Demographic Data of GHFF at the Macksville Cemetery Camp

Tree Code	*GPS Location (UTM coordinates GDA94, Zone 56)*	*Tree Species*	*Height (m)*	*DBH (cm)*	*Demographic Ratio (female:male)*	*Presence of Dependant Young (yes/no)*	*% Females with Dependant Young*
MC1	492198, 6601613	Broad-leaved Paperbark	12	20	10:2	No	n/a
MC2	492191, 6601600	Broad-leaved Paperbark	12	25	10:5	No	n/a
MC3	492191, 6601585	Broad-leaved Paperbark	12	25	10:3	No	n/a
MC4	492184, 6601561	Broad-leaved Paperbark	12	20	10:4	No	n/a

Table 2.2 Demographic Data of GHFF at the Bellingen Island Camp

Tree Code	*GPS Location (UTM coordinates GDA94, Zone 56)*	*Tree Species*	*Height (m)*	*DBH (cm)*	*Demographic Ratio (female:male)*	*Presence of Dependant Young (yes/no)*	*% Females with Dependant Young*
BI1	490035, 6631612	Unidentified sp.	10	15	10:5	No	n/a
BI2	490017, 6631609	Giant Stinging Tree (*Dendrocnide excelsa*)	10	40	10:5	No	n/a
BI3	490005, 6631621	Creek Sandpaper Fig (*Ficus coronata*)	10	20	7:10*	No	n/a
BI4	490051, 6631624	Creek Sandpaper Fig (*Ficus coronata*)	8	15	4:10*	No	n/a
BI5	490054, 6631624	Creek Sandpaper Fig (*Ficus coronata*)	10	7	10:7	No	n/a
BI6	490060, 6631618	Red Cedar (*Toona ciliata*)	12	20	10:6	No	n/a
BI7	490069, 6631630	Creek Sandpaper Fig (*Ficus coronata*)	10	20	10:5	No	n/a
BI8	490054, 6631639	Creek Sandpaper Fig (*Ficus coronata*)	12	25	10:3	No	n/a
BI9	490035, 6631639	Giant Stinging Tree (*Dendrocnide excelsa*)	25	70	10:3	No	n/a
BI10	490011, 6631648	Moreton Bay Fig (*Ficus macrophylla*)	8	40	10:1	No	n/a

** denotes trees where occurrences of females was limited and surrounded by bachelor male groups.*

2.2.3.3 Water Level at the Site

Water level at the site measured at the representative measurement location was approximately 50 cm in depth; similar to the level recorded in the previous monitoring event (refer to **Figure 2.1**).

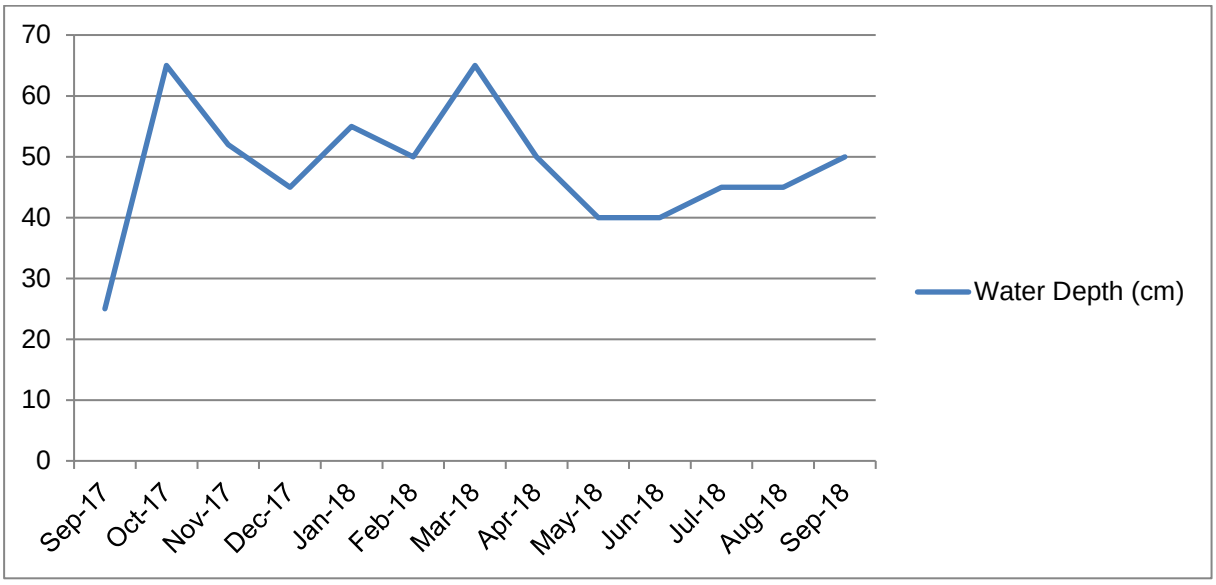


Figure 2.1 Water Level Measurements at the Site

2.3 Discussion

2.3.1 Population Estimates

The following discussion refers to the following Australian Government Department of the Environment and Energy (DEE)/ CSIRO *Monitoring flying-fox Populations* (DEE 2018) categories (refer to **Section 2.2.2.2**). The trend in flying-fox numbers over the last 12-month period at the site and other monitored regional flying-fox camps is shown in **Figure 2.2**. No flying-foxes were recorded at the site again this month. Flying-foxes have not occupied the site (excluding a brief return in January 2015) since mid-April 2014.

Since a peak in the number of flying-foxes roosting at the Macksville Cemetery camp in March 2018 when approximately 45,000 individuals were present (category 5), a steady decrease in numbers was recorded down to zero in August 2018. The current monitoring event has shown a return of relatively small numbers of flying-fox to the camp. The seasonal trend of summer/ autumn peaks and late autumn to spring reductions (including periodic absences) in the camp population has been consistently observed throughout the monitoring program; though the durations and the exact timing of the peak and reductions has varied slightly.

At the Bellingen Island camp it was estimated that approximately 15,000 flying-foxes (category 4) were present. This represents an increase in numbers of flying-foxes since the August monitoring event when an estimated 10,000 flying-foxes were recorded. Bellingen Island numbers are slightly lower than that estimated same time last year (GeoLINK 2017).

The number of flying-foxes at the Gordon Park camp has remained relatively steady over the past nine months, estimated at between 10,000 and 15,000 individuals (category 4) with the exception of a temporary spike in numbers in May 2018 to category 5 levels.

No flying-foxes were recorded at Bowraville in the current monitoring event. Flying-foxes have been absent from this site for over 18 months, and were last recorded in December 2016 in low numbers.

As can be seen in the 12-monthly population comparisons (refer to **Figure 2.2**), numbers of flying-foxes at occupied regional camps is now at relatively low to moderate levels following a summer/ autumn peak.

2.3.2 Species Composition and Demographic Data

At occupied camps, GHFF dominated the species composition making up between 90% and 95% of all individuals. Similar high proportions of GHFF have consistently been recorded in previous monitoring events.

The proportion of female GHFF decreased from 77% to 70.5% at the Bellingen Island camp over the last month (GeoLINK 2018). Despite this minor decrease, female GHFF nonetheless strongly dominated the demographic composition.

No dependent young GHFF were recorded at any of the occupied camps in the current monitoring event, in line with the reproductive cycle of this species. Young are likely to be seen during the next monitoring event in late October 2018.

2.3.3 Phenology of Trees in the Region

August/ September bi-monthly flowering of a number of highly productive nectar source trees in the upper North Coast region of NSW includes Coast Banksia (*Banksia integrifolia*), Coastal Blackbutt (*Eucalyptus pilularis*), Narrow-leaved Red Gum (*Eucalyptus seeana*), Grey Ironbark (*Eucalyptus siderophloia*) and Forest Red Gum (*Eucalyptus tereticornis*). These are considered key diet species for GHFF in the region (Eby 2012; Eby and Law 2008).

Observations when travelling between regional flying-fox camps recorded moderate flowering of Coast Banksia, Forest Red Gum and Grey Ironbark. Tallowwood is also in flower locally.

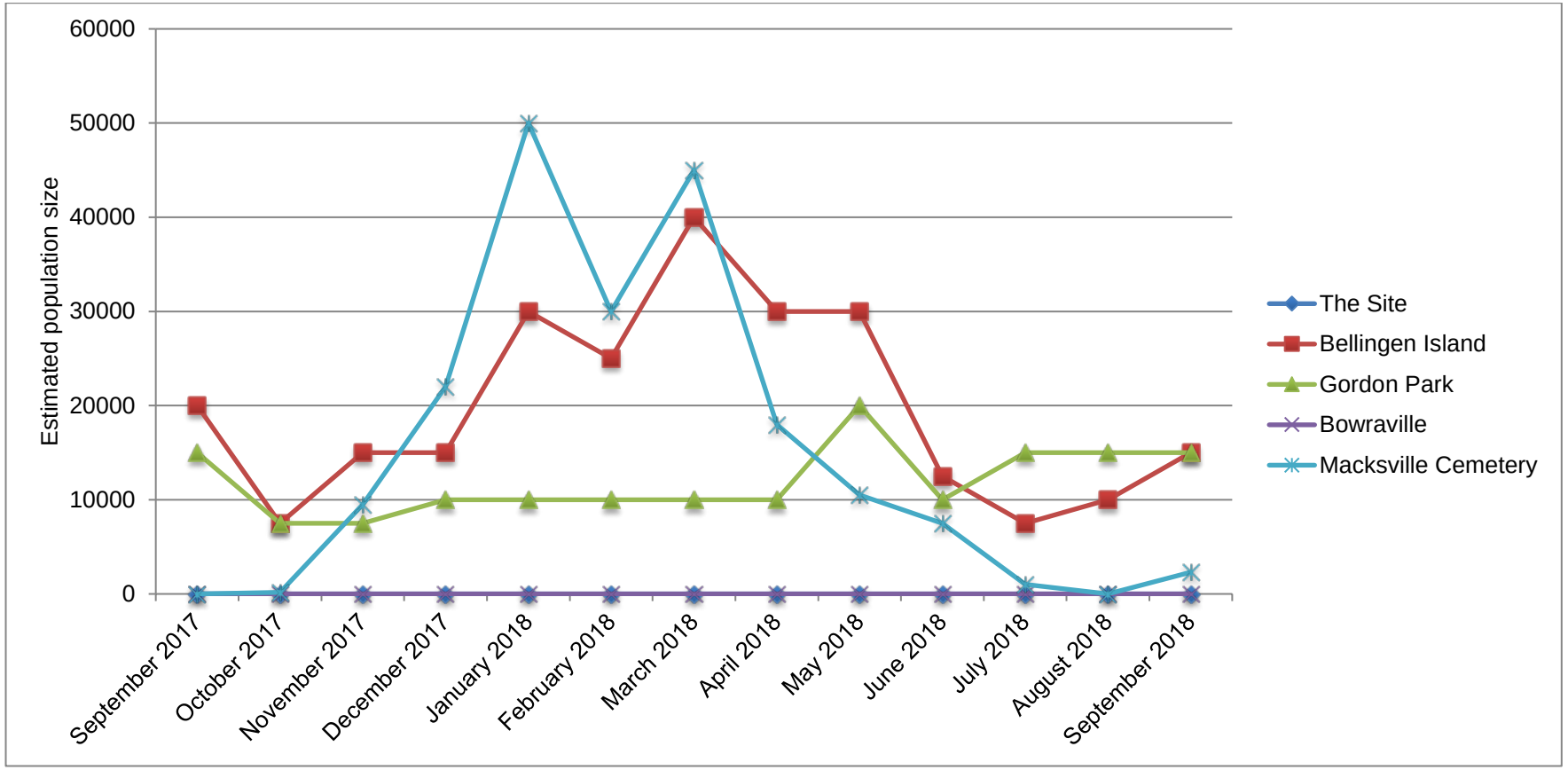


Figure 2.2 Population Trends at the Site and Regional Camps Over Past 12 Months

2.4 Summary and Conclusion

The results of the September 2018 flying-fox monitoring indicate that, excluding a brief stopover at the site observed in mid-January 2015, flying-foxes have been absent from the site since April 2014. Flying-foxes were also absent from the Bowraville and Wheatley Street camps.

Bellingen Island, Gordon Park and Macksville Cemetery camps were occupied. The number of flying-foxes at these occupied regional camps is now at relatively low to moderate levels following a summer/ autumn peak.

GHFF dominated the species composition at occupied camps at between 90% and 95% of all individuals present. The proportion of female GHFF remains relatively high. No dependent young GHFF were recorded at any of the occupied camps in the current monitoring event, in line with the reproductive cycle of this species.

Moderate flowering of Coast Banksia, Forest Red Gum and Grey Ironbark was observed to be currently occurring in the region. These are all key diet species for the GHFF.

David Andrighetto
Senior Ecologist

References

DEE (2018). *Monitoring Flying-fox Populations*, Australian Government Department of the Environment and Energy, Canberra, viewed 11 July 2018. http://www.environment.gov.au/biodiversity/threatened/species/flying-fox-monitoring/

Eby, P. (2012). *An Assessment of the Flying-fox Camp at Macksville*. Unpublished report to NSW Roads and Maritime Services.

Eby, P. (2013). *A Field Monitoring Program Proposed for the Macksville Flying-fox Roost*. Unpublished report to Sinclair Knight Merz.

GeoLINK. (2017). *Flying-fox Monitoring September 2017: Warrell Creek to Nambucca Heads Pacific Highway Upgrade*. Unpublished report to NSW Roads and Maritime Services.

GeoLINK. (2018). *Flying-fox Monitoring August 2018: Warrell Creek to Nambucca Heads Pacific Highway Upgrade*. Unpublished report to NSW Roads and Maritime Services.

Appendix 11 October 2018 monitoring report

Flying-fox Monitoring
October 2018

Warrell Creek to Nambucca Heads
Pacific Highway Upgrade

PO Box 119
Lennox Head NSW 2478
T 02 6687 7666

PO Box 1446
Coffs Harbour NSW 2450
T 02 6651 7666

PO Box 1267
Armidale NSW 2350
T 02 6772 0454

PO Box 229
Lismore NSW 2480
T 02 6621 6677

info@geolink.net.au

Prepared for: Roads and Maritime Services

© GeoLINK, 2018

UPR	*Description*	*Date Issued*	*Issued By*
2692-1150	First issue	13/11/2018	David Andrighetto

Table of Contents

1. Introduction 1

1.1 Introduction 1

2. Flying-fox Survey 2

2.1 Methodology 2
2.2 Results 3
2.2.1 Roost Footprint 3
2.2.2 Population Estimates 6
2.2.3 Detailed Data 6
2.3 Discussion 9
2.3.1 Population Estimates 9
2.3.2 Species Composition and Demographic Data 10
2.3.3 Phenology of Trees in the Region 10
2.4 Summary and Conclusion 12

Illustrations

Illustration 2.1 Location of Regional Flying-fox Camps 4
Illustration 2.2 Macksville Cemetery Flying-fox Roost Footprint 5

Tables

Table 2.1 Demographic Data of GHFF at the Macksville Cemetery Camp 7
Table 2.2 Demographic Data of GHFF at the Bellingen Island Camp 8

Figures

Figure 2.1 Water Level Measurements at the Site 9
Figure 2.2 Population Trends at the Site and Regional Camps Over Past 12 Months 11

1. Introduction

1.1 Introduction

NSW Roads and Maritime Services has been monitoring a Grey-headed Flying-fox (*Pteropus poliocephalus*) (GHFF) camp that was intermittently present within the approved alignment of the Warrell Creek to Nambucca Heads (WC2NH) Pacific Highway upgrade project near Macksville. The camp was located in a patch of swamp sclerophyll forest north of Bald Hill Road (henceforth referred to as 'the site').

GeoLINK has undertaken monitoring at the site on at least a monthly basis since July 2013. Prior to this, irregular monitoring of flying-foxes at the site has been undertaken since the initial establishment of the camp in December 2011 (Eby 2012).

This report details the October 2018 flying-fox monitoring results.

2. Flying-fox Survey

2.1 Methodology

The following GeoLINK personnel undertook fieldwork for the October 2018 flying-fox monitoring:

- Jessica O'Leary (ecologist)
- Frank Makin (ecologist)
- Jeremy Clifford (environmental scientist)
- Kale Hardie-Porter (environmental scientist).

Fieldwork followed the methodology developed by Dr Eby for the project. Refer to Eby (2013) for full details of the methodology. A summary of the main procedures used for the monitoring is provided below.

The fieldwork was undertaken on 30 October 2018. The presence of flying-foxes at the site was assessed by undertaking a traverse of the area previously known to support flying-foxes in conjunction with a few sharp handclaps aimed at eliciting a vocal response from any flying-foxes roosting at the site.

When flying-foxes are present at the site, the following data is collected:

- The area of the roost footprint (mapped by GPS)
- Species composition
- Demographics (avoiding male 'bachelor trees' where possible)
- Reproductive status
- Behaviour.

When the site is unoccupied, and flying-foxes are present at the nearby seasonally-occupied flying-fox camp within two kilometres of the site adjacent to Macksville Cemetery, the abovementioned data is collected here instead. This data provides relevant information on the status of flying-foxes that are camped in the Macksville area.

The water level at the site was measured at GPS location 492866, 6600756 (UTM coordinates, GDA 94, Zone 56). The water level at this location is representative of the average level at the site and is tracked over time to provide information on water level fluctuations that occur at the site.

A dusk exit count survey was undertaken at both the site and the Macksville Cemetery camp to confirm the presence/ absence of flying-foxes and to provide an estimate of the current population at each camp.

Two observers were strategically located for the exit count on a northern and a southern ridge overlooking the site, as follows:

- In a paddock to the north of the swamp sclerophyll forest (off Wedgewood Drive)
- On a prominent ridge to the south (at 41 Bald Hill Road).

Two observers were also located adjacent to the Macksville Cemetery camp at the following vantage points:

- At the Macksville Cemetery gate off Wallace Street (west of the camp)
- Adjacent to the Macksville Golf Course next to the Pacific Highway (east of the camp).

The exit counts extended over approximately 45 minutes from sunset until dark (approximately 7:00 pm to 7:45 pm).

Other regional flying-fox camps at Gordon Park, Nambucca Heads (approximately 12 kilometres north-east of the site), Bowraville (approximately 10.5 kilometres north-west of the site), Bellingen Wheatley Street camp (approximately 30 kilometres north of the site) and Bellingen Island (approximately 31 kilometres north of the site) were also visited and observational comments made. Refer to **Illustration 2.1** for the location of the subject regional camps.

2.2 Results

2.2.1 Roost Footprint

No flying-foxes were recorded roosting at the site in the traverse.

Flying-foxes were observed to be roosting at the Macksville Cemetery camp. The roost extended over an area of approximately 1.91 hectares (refer to **Illustration 2.2**). The flying-fox roost is currently located in a section of paperbark swamp forest west of the Macksville golf course near the northern end of McNeill Close.

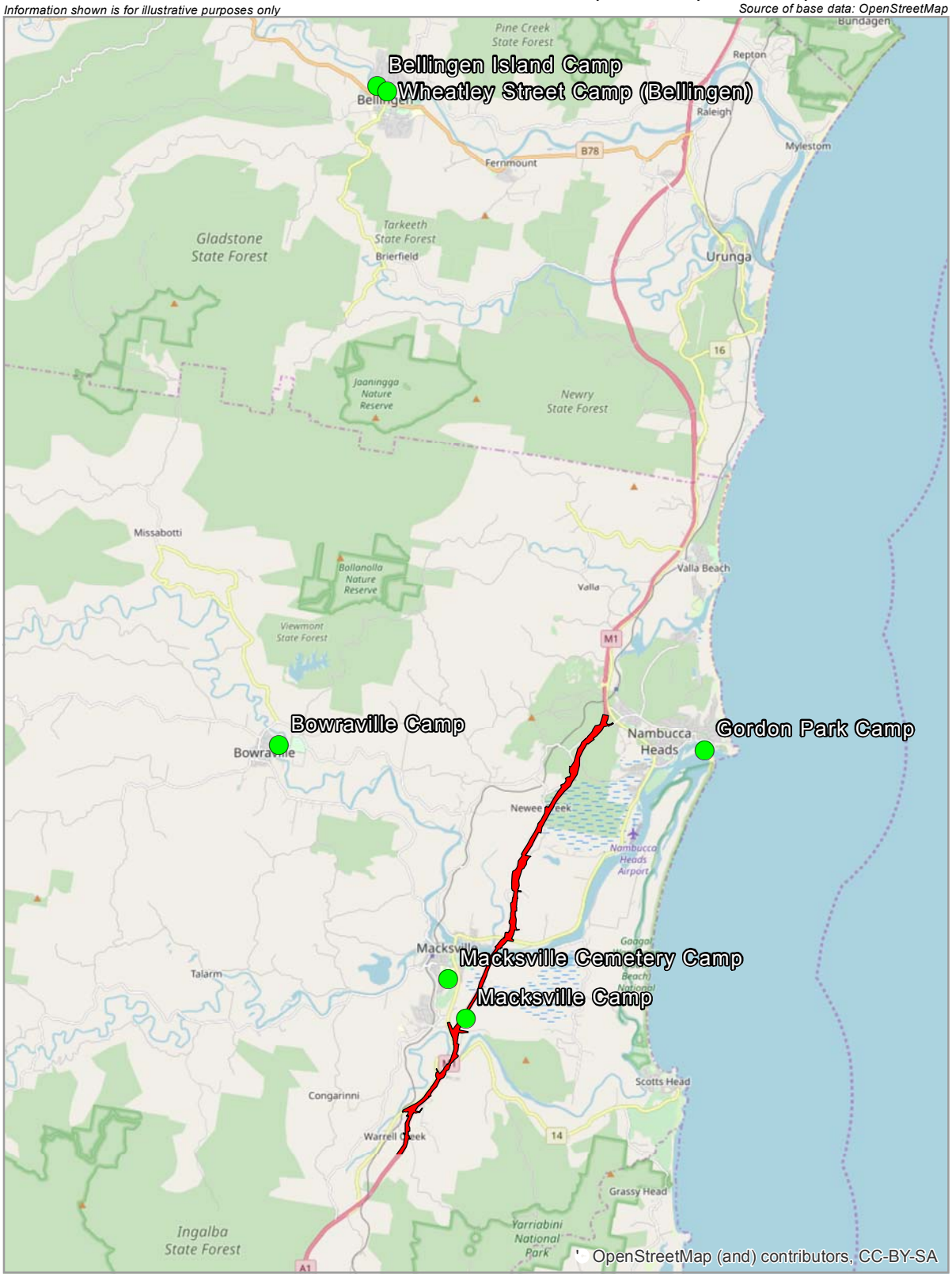
Regionally, flying-foxes were observed to be roosting at Bellingen Island and Gordon Park (Nambucca Heads). The extent of the roost footprint at Bellingen Island was observed to have increased since the previous monthly monitoring event (GeoLINK 2018), this month covering a broader area of the island including the north and southern edges of the island vegetation. At the Gordon Park camp, the roost extent has not substantially changed from that recorded in the previous monitoring event even with significantly less numbers of bats occupying the camp.

No flying-foxes were observed at the Wheatley Street camp in Bellingen or at the Bowraville camp.

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 06/11/2018

Information shown is for illustrative purposes only

Source of base data: OpenStreetMap



LEGEND

- WC2NH Project boundary
- Flying-fox camp location

0 4 Km

Location of Regional Flying-fox Camps

GeoLINK environmental management and design

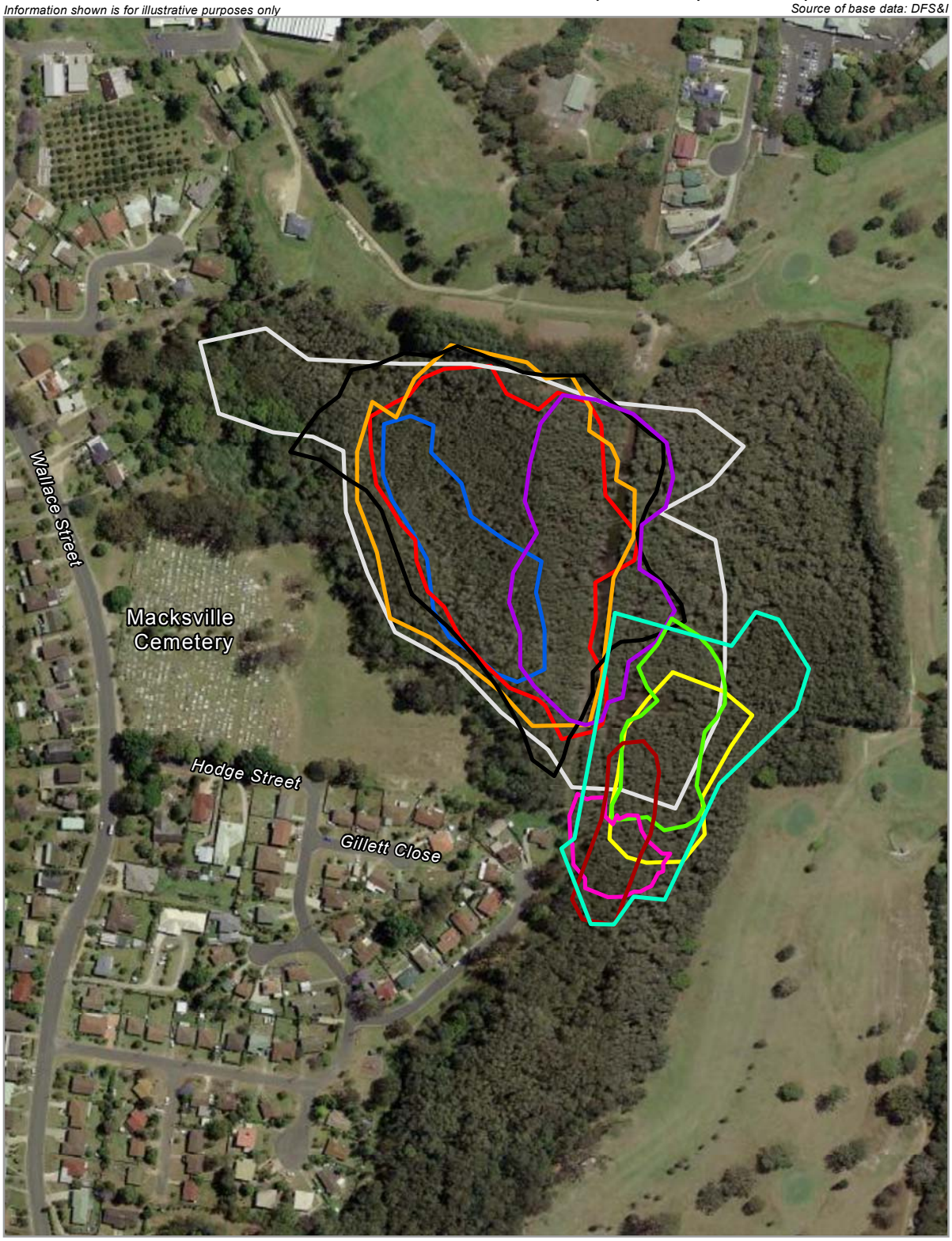
Flying-fox Monitoring October 2018 - Warrell Creek to Nambucca Heads Pacific Highway Upgrade
2692-1152

Illustration 2.1

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 06/11/2018

Information shown is for illustrative purposes only

Source of base data: DFS&I



LEGEND

- October 2018
- September 2018
- July 2018
- June 2018
- May 2018
- April 2018
- March 2018
- February 2018
- January 2018
- December 2017
- November 2017

0 80

Macksville Cemetery Flying-fox Roost Footprint

GeoLINK environmental management and design

Flying-fox Monitoring October 2018 - Warrell Creek to Nambucca Heads
Pacific Highway Upgrade
2692-1151

Illustration 2.2

2.2.2 Population Estimates

2.2.2.1 Exit Counts

No flying-foxes were observed flying from the site during the exit count.

Approximately 10,300 individuals were recorded exiting the Macksville Cemetery camp in the exit count. Approximately 7,600 flying-foxes were observed exiting the camp in a western direction with the remaining numbers exiting in north-east and south-east streams. Due to the direction of the streams and giving consideration of observed flying-fox densities and the roost footprint; it is likely that the exit count result underestimated the number of flying-foxes at the camp.

2.2.2.2 Direct Counts

With the exception of the Macksville Cemetery camp, no exit counts were conducted at any of the remaining regional camps. However, rough population estimates for these camps based on extrapolation of counts in individual trees and the roost footprint are provided. These flying-fox population estimate results (from this and past monitoring as part of this program) should not be relied on for accuracy or other purposes. Population estimates are provided in line with the Australian Government Department of the Environment and Energy (DEE)/ CSIRO *Monitoring flying-fox Populations* (DEE 2018) categories:

1 = 1 – 499
2 = 500 – 2,499
3 = 2,500 – 9,999
4 = 10,000 – 15,999
5 = 16,000 – 49,999
6 = >50,000.

Regional camp count estimates are as follows:

- Gordon Park: approximately 7,500 individuals (category 3)
- Bellingen Island: approximately 20,000 individuals (category 5)
- Wheatley Street, Bellingen: no individuals recorded
- Bowraville: no individuals recorded.

2.2.3 Detailed Data

2.2.3.1 Species Composition

The species composition and proportions observed at occupied camps were as follows:

- Macksville Cemetery: 95% GHFF and 5% Black Flying-fox
- Bellingen Island: 95% GHFF and 5% Black Flying-fox
- Gordon Park: 95% GHFF and 5% Black Flying-fox.

2.2.3.2 Habitat Characteristics and Demographic Composition

As flying-foxes were not recorded at the site in the current monitoring event, detailed demographic composition data was not collected. This has been the case since April 2014 (excluding a brief return in January 2015). Due to this absence, the Macksville Cemetery camp has been the alternative site for collection of this data.

Both male and female GHFF were present at the Macksville Cemetery camp. Data collected in demographic point counts (which excluded bachelor male roost trees) indicated that the proportion of female GHFF present was generally high and ranged from 71% to 90% (average 81%) of all individuals (refer to **Table 2.1**). The percentage of females with dependent young GHFF at demographic point counts averaged 70% (ranging between 50% and 90%).

Both male and female GHFF were present at the Bellingen Island camp. Data collected in demographic point counts indicated that the proportion of female GHFF present was generally high and ranged from 71% to 83% (average 77%) of all individuals. The percentage of females with dependent young GHFF at demographic point counts averaged 66% (ranging between 50% and 90%) (refer to **Table 2.2**).

General observations of the GHFF currently roosting at the Gordon Park camp indicated that males and females were present as well as females with dependent young.

Table 2.1 Demographic Data of GHFF at the Macksville Cemetery Camp

Tree Code	*GPS Location (UTM coordinates GDA94, Zone 56)*	*Tree Species*	*Height (m)*	*DBH (cm)*	*Demographic Ratio (female:male)*	*Presence of Dependant Young (yes/no)*	*% Females with Dependant Young*
MC1	492198, 6601613	Broad-leaved Paperbark (*Melaleuca quinquenervia*)	12	20	10:2	Yes	60
MC2	492191, 6601600	Broad-leaved Paperbark	12	25	10:1	Yes	90
MC3	492191, 6601585	Broad-leaved Paperbark	12	15	10:3	Yes	80
MC4	492184, 6601561	Broad-leaved Paperbark	12	20	10:4	Yes	80
MC5	492199, 6601620	Broad-leaved Paperbark	12	25	10:3	Yes	50
MC6	492311, 6601664	Broad-leaved Paperbark	12	10	10:2	Yes	60
MC7	492272, 6601626	Broad-leaved Paperbark	12	20	10:2	Yes	80
MC8	492251, 6601594	Broad-leaved Paperbark	12	20	10:1	Yes	50
MC9	492237, 6601562	Broad-leaved Paperbark	12	15	10:2	Yes	80
MC10	492219, 6601530	Broad-leaved Paperbark	12	20	10:3	Yes	70

Table 2.2 Demographic Data of GHFF at the Bellingen Island Camp

Tree Code	*GPS Location (UTM coordinates GDA94, Zone 56)*	*Tree Species*	*Height (m)*	*DBH (cm)*	*Demographic Ratio (female:male)*	*Presence of Dependant Young (yes/no)*	*% Females with Dependant Young*
BI1	490035, 6631612	Creek Sandpaper Fig (*Ficus coronata*)	10	20	10:2	Yes	60
BI2	490017, 6631609	Creek Sandpaper Fig	10	35	10:4	Yes	70
BI3	490005, 6631621	Giant Stinging Tree (*Dendrocnide excelsa*)	18	10	10:4	Yes	60
BI4	490051, 6631624	Giant Stinging Tree	18	80	10:2	Yes	60
BI5	490054, 6631624	Giant Stinging Tree	15	70	10:3	Yes	60
BI6	490060, 6631618	Creek Sandpaper Fig	14	20	10:3	Yes	50
BI7	490069, 6631630	Creek Sandpaper Fig	12	25	10:2	Yes	80
BI8	490054, 6631639	Giant Stinging Tree	15	40	10:2	Yes	70
BI9	490035, 6631639	Giant Stinging Tree	13	40	10:3	Yes	60
BI10	490011, 6631648	Moreton Bay Fig (*Ficus macrophylla*)	10	40	10:3	Yes	90

2.2.3.3 Water Level at the Site

Water level at the site measured at the representative measurement location was approximately 55 cm in depth; a slight increase to the level recorded in the previous monitoring event (refer to **Figure 2.1**).

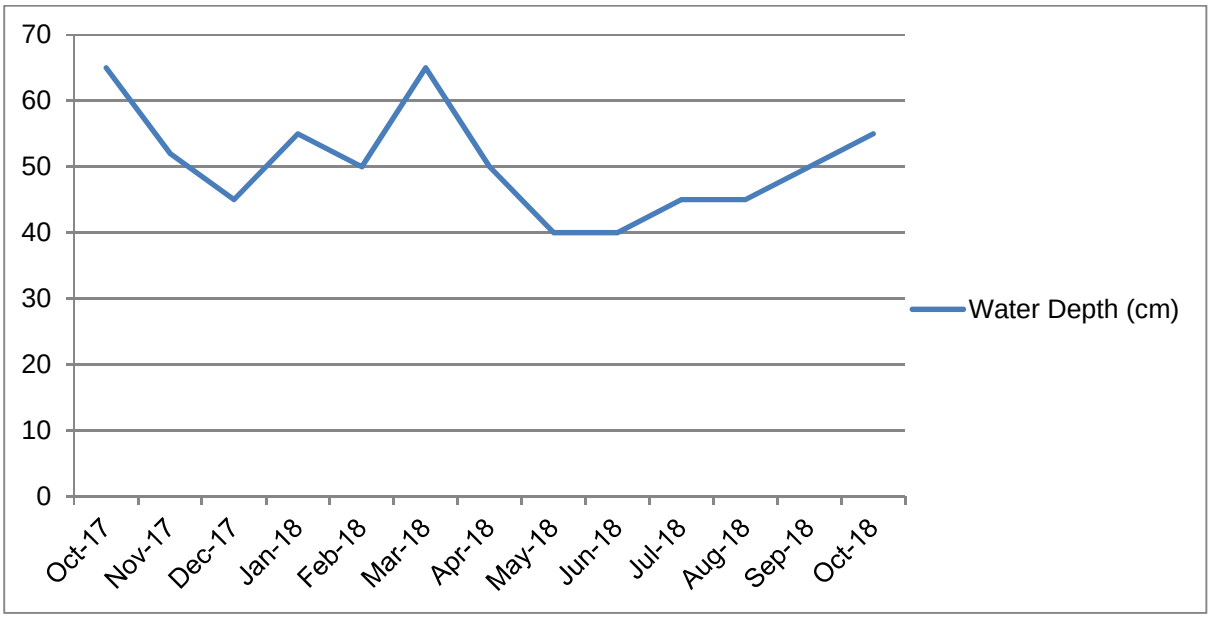


Figure 2.1 Water Level Measurements at the Site

2.3 Discussion

2.3.1 Population Estimates

The following discussion refers to the Australian Government Department of the Environment and Energy (DEE)/ CSIRO *Monitoring flying-fox Populations* (DEE 2018) categories (refer to **Section 2.2.2.2**). The trend in flying-fox numbers over the last 12-month period at the site and other monitored regional flying-fox camps is shown in **Figure 2.2**. No flying-foxes were recorded at the site again this month. Flying-foxes have not occupied the site (excluding a brief return in January 2015) since mid-April 2014.

Since a peak in the number of flying-foxes roosting at the Macksville Cemetery camp in March 2018 when approximately 45,000 individuals were present (category 5), a steady decrease in numbers was recorded down to zero in August 2018. The current monitoring event has shown a return of relatively small-moderate numbers of flying-foxes to the camp. The seasonal trend of summer/ autumn peaks and late autumn to spring reductions (including periodic absences) in the camp population has been consistently observed throughout the monitoring program; though the durations and the exact timing of the peaks and reductions has varied slightly.

At the Bellingen Island camp it was estimated that approximately 20,000 flying-foxes (category 5) were present. This represents an increase in numbers compared to the September 2018 monitoring where 15,000 flying-foxes were recorded. This month the general footprint of the roost was the same however the bats were positioned more sparsely throughout the camp. Bellingen Island numbers are higher than numbers recorded during October 2017 where an estimated 7,500 flying-foxes were recorded (GeoLINK 2017).

The number of flying-foxes at the Gordon Park camp has decreased since last month to 7,500 during October 2018. This observation is consistent with the same time during 2016 and 2017 where 7,500 flying-foxes were recorded during October. During May 2018 numbers spiked to 20,000 (category 5), then between May 2018 and September 2018 the flying-fox numbers have remained relatively steady at between 10,000 and 15,000 individuals (category 4).

No flying-foxes were recorded at Bowraville in the current monitoring event. Flying-foxes have been absent from this site for nearly two years and were last recorded in December 2016 in low numbers.

2.3.2 Species Composition and Demographic Data

At occupied camps, GHFF dominated the species composition making up approximately 95% of all individuals. Similar high proportions of GHFF have consistently been recorded in previous monitoring events. Female flying-foxes dominated the demographic composition at both the Macksville Cemetery and Bellingen Island camps (81% and 77% of individuals excluding bachelor male groups respectively).

The October 2018 monitoring recorded that female GHFF had given birth since the September 2018 monitoring event, with moderate levels of females supporting dependent young at both the Macksville Cemetery (70%) and Bellingen Island camps (66%).

2.3.3 Phenology of Trees in the Region

October flowering of highly productive nectar source trees in the upper North Coast region of NSW includes Narrow-leaved Red Gum (*Eucalyptus seeana*), Grey Ironbark (*E. siderophloia* – coastal lowlands and foothills and ranges), Forest Red Gum (*E. tereticornis* – inland low and altitude and high altitude), Black Bean (*Castanospermum australe*) and Silky Oak (*Grevillea robusta*). These plants are considered key diet species for GHFF in the region (Eby 2012; Eby and Law 2008).

Observations when travelling between regional flying-fox camps indicated that light flowering of Grey Ironbark and moderate flowering of Silky Oak is currently occurring. Tallowwood (*Eucalyptus microcorys*) is also in flower locally.

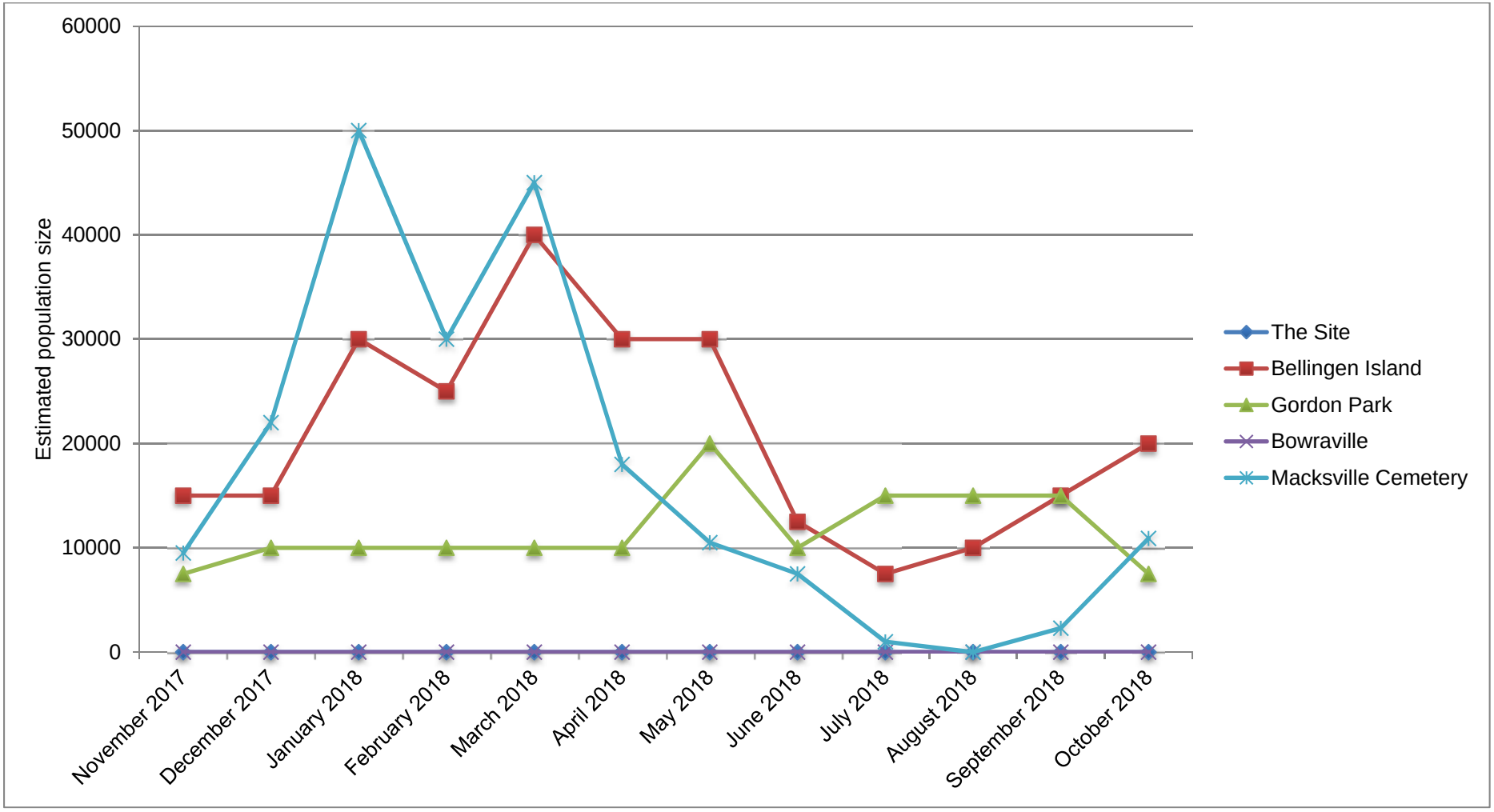


Figure 2.2 Population Trends at the Site and Regional Camps Over Past 12 Months

2.4 Summary and Conclusion

The results of the October 2018 flying-fox monitoring indicate that, excluding a brief stopover at the site observed in mid-January 2015, flying-foxes have been absent from the site since April 2014. Flying-foxes were also absent from the Bowraville and Wheatley Street camps.

Bellingen Island, Gordon Park and Macksville Cemetery camps were occupied. The number of flying-foxes at these occupied regional camps is now at relatively low to moderate levels. Flying-fox numbers are expected to increase over the coming months in line with the historical trends that show summer/ autumn peaks.

GHFF dominated the species composition at occupied camps at approximately 95% of all individuals present. The proportion of female GHFF remains relatively high. Dependent young GHFF were present at a moderate level within occupied camps in the current monitoring event.

Flowering of Grey Ironbark and Silky Oak, key diet species for the GHFF, is currently occurring in the region.

David Andrighetto
Ecologist

References

DEE (2018). *Monitoring Flying-fox Populations*, Australian Government Department of the Environment and Energy, Canberra, viewed 11 July 2018. http://www.environment.gov.au/biodiversity/threatened/species/flying-fox-monitoring/

Eby, P. (2012). *An Assessment of the Flying-fox Camp at Macksville*. Unpublished report to NSW Roads and Maritime Services.

Eby, P. (2013). *A Field Monitoring Program Proposed for the Macksville Flying-fox Roost*. Unpublished report to Sinclair Knight Merz.

GeoLINK. (2017). *Flying-fox Monitoring October 2017: Warrell Creek to Nambucca Heads Pacific Highway Upgrade*. Unpublished report to NSW Roads and Maritime Services.

GeoLINK. (2018). *Flying-fox Monitoring September 2018: Warrell Creek to Nambucca Heads Pacific Highway Upgrade*. Unpublished report to NSW Roads and Maritime Services.

Appendix 12 November 2018 monitoring report

Flying-fox Monitoring November 2018

Warrell Creek to Nambucca Heads Pacific Highway Upgrade

PO Box 119
Lennox Head NSW 2478
T 02 6687 7666

PO Box 1446
Coffs Harbour NSW 2450
T 02 6651 7666

PO Box 1267
Armidale NSW 2350
T 02 6772 0454

PO Box 229
Lismore NSW 2480
T 02 6621 6677

info@geolink.net.au

Prepared for: Roads and Maritime Services

© GeoLINK, 2018

UPR	Description	Date Issued	Issued By
2692-1157	First issue	11/12/2018	David Andrighetto

Table of Contents

1. Introduction 1

1.1 Introduction 1

2. Flying-fox Survey 2

2.1 Methodology 2
2.2 Results 3

2.2.1 Roost Footprint 3
2.2.2 Population Estimates 6
2.2.3 Detailed Data 6

2.3 Discussion 10

2.3.1 Population Estimates 10
2.3.2 Species Composition and Demographic Data 10
2.3.3 Phenology of Trees in the Region 11

2.4 Summary and Conclusion 13

Illustrations

Illustration 2.1 Location of Regional Flying-fox Camps 4
Illustration 2.2 Macksville Cemetery Flying-fox Roost Footprint 5

Tables

Table 2.1 Demographic Data of GHFF at the Macksville Cemetery Camp 7
Table 2.2 Demographic Data of GHFF at the Bellingen Island Camp 9

Figures

Figure 2.1 Water Level Measurements at the Site 9
Figure 2.2 Population Trends at the Site and Regional Camps Over Past 12 Months 12

1. Introduction

1.1 Introduction

NSW Roads and Maritime Services has been monitoring a Grey-headed Flying-fox (*Pteropus poliocephalus*) (GHFF) camp that was intermittently present within the approved alignment of the Warrell Creek to Nambucca Heads (WC2NH) Pacific Highway upgrade project near Macksville. The camp was located in a patch of swamp sclerophyll forest north of Bald Hill Road (henceforth referred to as 'the site').

GeoLINK has undertaken monitoring at the site on at least a monthly basis since July 2013. Prior to this, irregular monitoring of flying-foxes at the site has been undertaken since the initial establishment of the camp in December 2011 (Eby 2012). This report details the November 2018 flying-fox monitoring results which was the final monitoring event for the WC2NH project.

2. Flying-fox Survey

2.1 Methodology

The following GeoLINK personnel undertook fieldwork for the November 2018 flying-fox monitoring:

- Jessica O'Leary (ecologist).
- Frank Makin (ecologist).
- Jeremy Clifford (environmental scientist).
- Kale Hardie-Porter (environmental scientist).

Fieldwork followed the methodology developed by Dr Eby for the project. Refer to Eby (2013) for full details of the methodology. A summary of the main procedures used for the monitoring is provided below.

The fieldwork was undertaken on 28 November 2018. The presence of flying-foxes at the site was assessed by undertaking a traverse of the area previously known to support flying-foxes in conjunction with a few sharp handclaps aimed at eliciting a vocal response from any flying-foxes roosting at the site.

When flying-foxes are present at the site, the following data is collected:

- The area of the roost footprint (mapped by GPS).
- Species composition.
- Demographics (avoiding male 'bachelor trees' where possible).
- Reproductive status.
- Behaviour.

When the site is unoccupied, and flying-foxes are present at the nearby seasonally-occupied flying-fox camp within two kilometres of the site adjacent to Macksville Cemetery, the abovementioned data is collected here instead. This data provides relevant information on the status of flying-foxes that are camped in the Macksville area.

The water level at the site was measured at GPS location 492866, 6600756 (UTM coordinates, GDA 94, Zone 56). The water level at this location is representative of the average level at the site and tracked over time to provide information on water level fluctuations that occur at the site.

A dusk exit count survey was undertaken at both the site and the Macksville Cemetery camp to confirm the presence/ absence of flying-foxes and to provide an estimate of the current population at each camp.

Two observers were strategically located for the exit count on a northern and a southern ridge overlooking the site, as follows:

- In a paddock to the north of the swamp sclerophyll forest (off Wedgewood Drive).
- On a prominent ridge to the south (at 41 Bald Hill Road).

Two observers were also located adjacent to the Macksville Cemetery camp at the following vantage points:

- At the Macksville Cemetery gate off Wallace Street (west of the camp).
- Adjacent to the Macksville Golf Course next to the Pacific Highway (east of the camp).

The exit counts extended over approximately 50 minutes from sunset until dark (approximately 7:30 pm to 8:20 pm).

Other regional flying-fox camps at Gordon Park Nambucca Heads (approximately 12 kilometres north-east of the site), Bowraville (approximately 10.5 kilometres north-west of the site), Bellingen Wheatley Street camp (approximately 30 kilometres north of the site) and Bellingen Island (approximately 31 kilometres north of the site) were also visited and observational comments made. Refer to **Illustration 2.1** for the location of the subject regional camps.

2.2 Results

2.2.1 Roost Footprint

No flying-foxes were recorded roosting at the site in the traverse.

Flying-foxes were observed to be roosting at the Macksville Cemetery camp. The roost extended over an area of approximately 5.19 hectares (refer to **Illustration 2.2**). The flying-fox roost was located in a section of paperbark swamp forest west of the Macksville golf course near the northern end of McNeill Close.

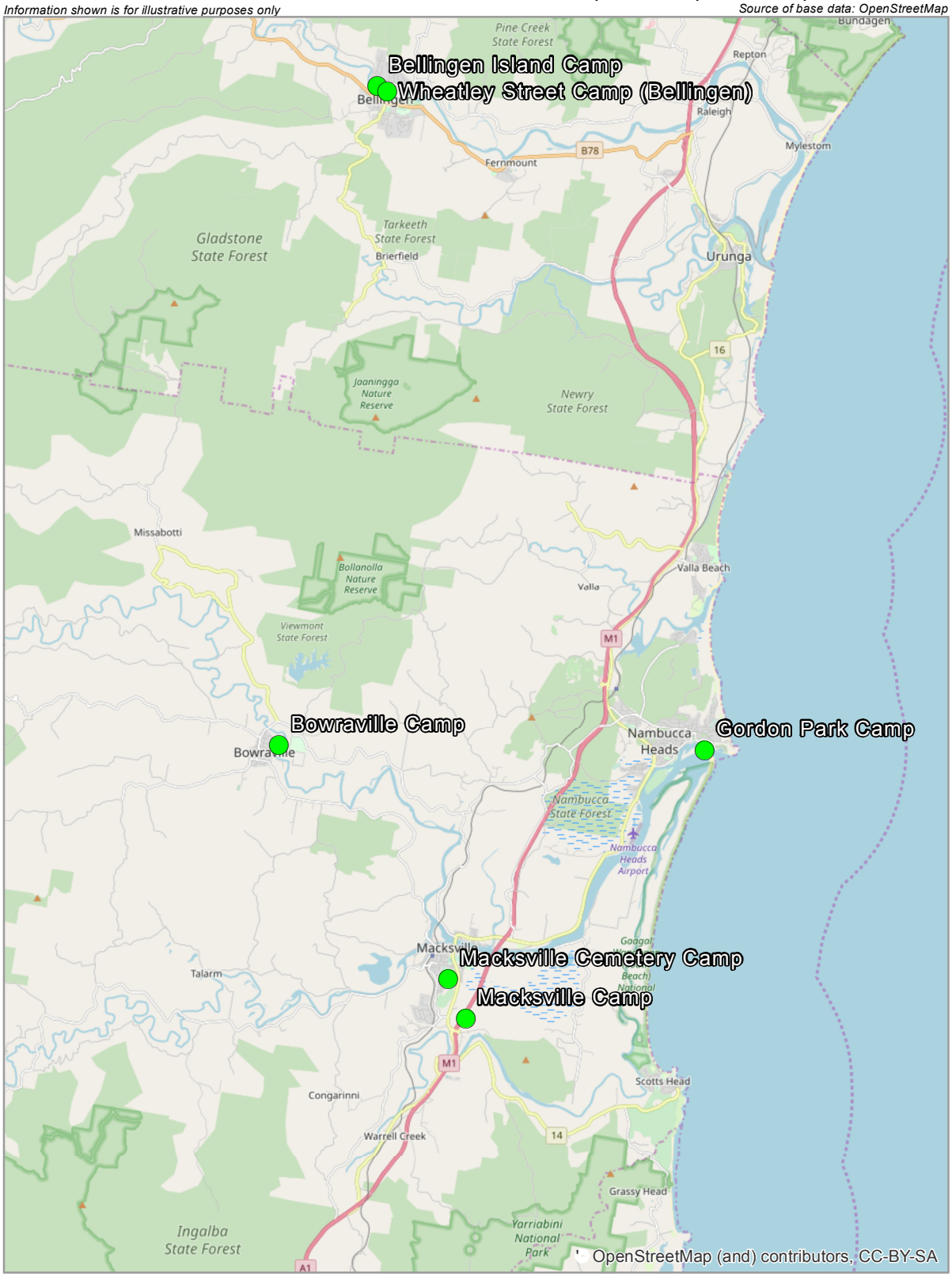
Regionally, flying-foxes were observed to be roosting at Bellingen Island and Gordon Park (Nambucca Heads). The extent of the roost footprint at Bellingen Island was similar to the previous monthly monitoring event (GeoLINK 2018), where the roost covered the central area of the island including the north and southern edges of the island's vegetation. At the Gordon Park camp, the roost footprint has substantially decreased from that recorded in the previous monitoring event with significantly less numbers of bats occupying the camp. The roost footprint was centralised to the lower gully area of Gordon Park

No flying-foxes were observed at the Wheatley Street camp in Bellingen or at the Bowraville camp.

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 05/12/2018

Information shown is for illustrative purposes only

Source of base data: OpenStreetMap



LEGEND

WC2NH Project boundary

Flying-fox camp location

0 4 Km

Location of Regional Flying-fox Camps

GeoLINK environmental management and design

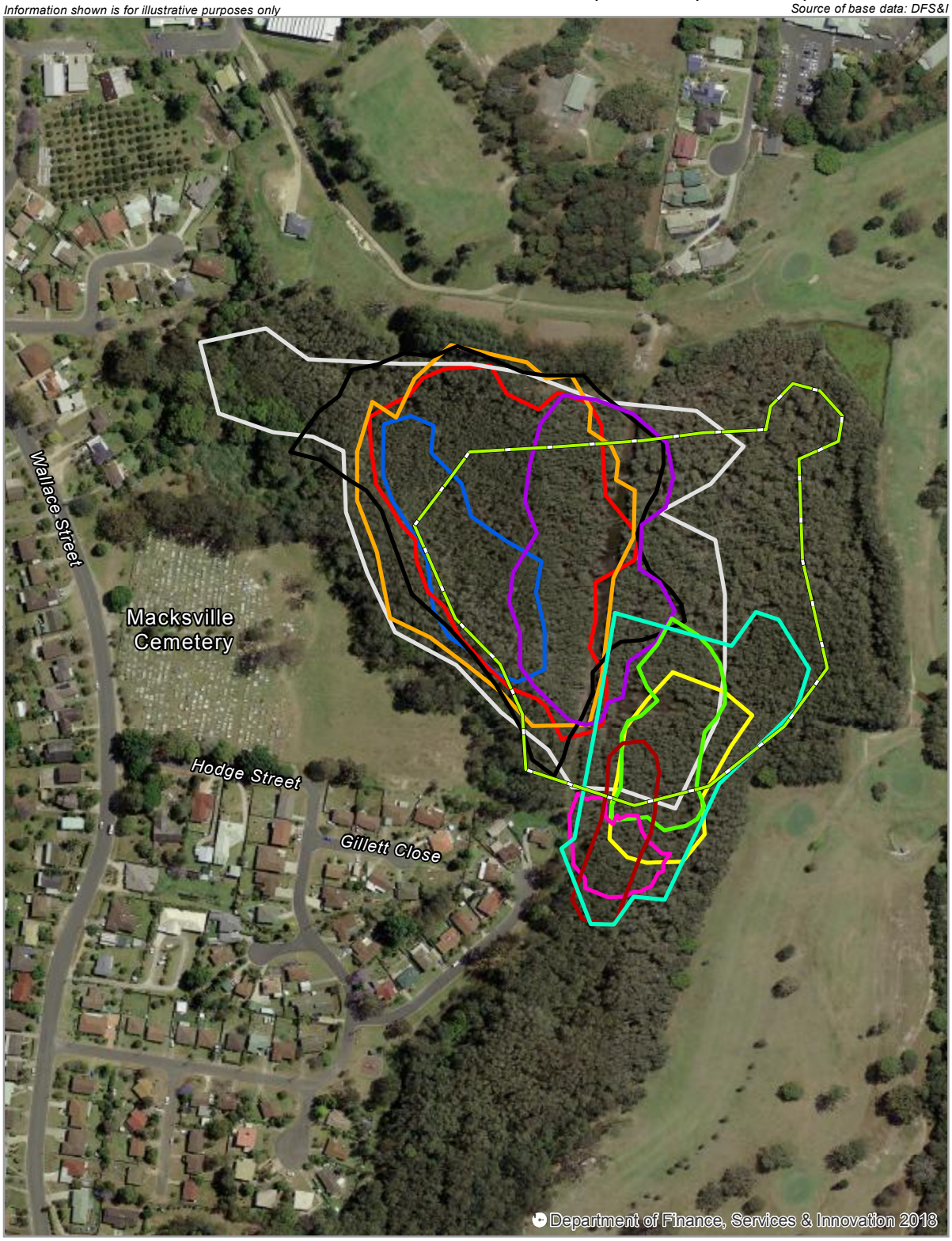
Flying-fox Monitoring November 2018 - Warrell Creek to Nambucca Heads Pacific Highway Upgrade
2692-1158

Illustration 2.1

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 05/12/2018

Information shown is for illustrative purposes only

Source of base data: DFS&I



LEGEND

- November 2018
- October 2018
- September 2018
- July 2018
- June 2018
- May 2018
- April 2018
- March 2018
- February 2018
- January 2018
- December 2017
- November 2017

0 80

Macksville Cemetery Flying-fox Roost Footprint

GeoLINK environmental management and design

Flying-fox Monitoring November 2018 - Warrell Creek to Nambucca Heads Illustration 2.2
Pacific Highway Upgrade
2692-1159

2.2.2 Population Estimates

2.2.2.1 Exit Counts

No flying-foxes were observed flying from the site during the exit count.

Approximately 40,800 flying-foxes were recorded exiting the Macksville Cemetery camp in the exit count. Approximately 31,800 (80%) were observed exiting the camp in a western direction with the remaining numbers exiting in south-west (15%) and north-east (5%) streams.

2.2.2.2 Direct Counts

With the exception of the Macksville Cemetery camp, no exit counts were conducted at any of the remaining regional camps. However, rough population estimates for these camps based on extrapolation of counts in individual trees and the roost footprint are provided. These flying-fox population estimate results (from this and past monitoring as part of this program) should not be relied on for accuracy or other purposes. Population estimates are provided in line with the Australian Government Department of the Environment and Energy (DEE)/ CSIRO *Monitoring flying-fox Populations* (DEE 2018) categories:

1 = 1 – 499
2 = 500 – 2,499
3 = 2,500 – 9,999
4 = 10,000 – 15,999
5 = 16,000 – 49,999
6 = >50,000.

Regional camp count estimates are as follows:

- Gordon Park: approximately 3,000 individuals (category 3).
- Bellingen Island: approximately 5,000 individuals (category 3).
- Wheatley Street, Bellingen: no individuals recorded.
- Bowraville: no individuals recorded.

2.2.3 Detailed Data

2.2.3.1 Species Composition

The species composition and proportions observed at occupied camps were as follows:

- Macksville Cemetery: 90% GHFF and 10% Black Flying-fox.
- Bellingen Island: 95% GHFF and 5% Black Flying-fox.
- Gordon Park: 95% GHFF and 5% Black Flying-fox.

2.2.3.2 Habitat Characteristics and Demographic Composition

As flying-foxes were not recorded at the site in the current monitoring event, detailed demographic composition data was not collected. This has been the case since April 2014 (excluding a brief return in January 2015). Due to this absence, the Macksville Cemetery camp has been the alternative site for collection of this data.

Both male and female GHFF were present at the Macksville Cemetery camp. Data collected in demographic point counts (which excluded bachelor male roost trees) indicated that the proportion of female GHFF present was generally high and ranged from 67% to 100% (average 90%) of all individuals (refer to **Table 2.1**). The percentage of females with dependent young GHFF at demographic point counts averaged 74% (ranging between 0% and 100%). One group did not record any females with dependant young, while between 60% and 100% of females at the remaining nine point count groups supported dependant young.

Both male and female GHFF were present at the Bellingen Island camp. Data could only be successfully collected from five demographic point counts, as the small number of flying-foxes present were roosting high in the canopy in areas of dense canopy cover that was impeding view. Data collected in demographic point counts indicated that the proportion of female GHFF present was generally high and ranged from 67% to 91% (average 76%) of all individuals. The percentage of females with dependent young GHFF at demographic point counts averaged 56% (ranging between 50% and 60%) (refer to **Table 2.2**).

General observations of the GHFF currently roosting at the Gordon Park camp indicated that males and females were present as well as females with dependent young.

Table 2.1 Demographic Data of GHFF at the Macksville Cemetery Camp

Tree Code	*GPS Location (UTM coordinates GDA94, Zone 56)*	*Tree Species*	*Height (m)*	*DBH (cm)*	*Demographic Ratio (female:male)*	*Presence of Dependant Young (yes/no)*	*% Females with Dependant Young*
MC1	492301, 6601860	Broad-leaved Paperbark (*Melaleuca quinquenervia*)	12	15	10:5	No	n/a
MC2	492199, 6601547	Broad-leaved Paperbark	12	20	10:1	Yes	80
MC3	492194, 6601545	Broad-leaved Paperbark	12	15	10:0	Yes	70
MC4	492200, 6601560	Broad-leaved Paperbark	12	25	10:3	Yes	60
MC5	492179, 6601565	Broad-leaved Paperbark	12	15	10:1	Yes	60
MC6	492181, 6601566	Broad-leaved Paperbark	12	10	10:0	Yes	100

Tree Code	GPS Location (UTM coordinates GDA94, Zone 56)	Tree Species	Height (m)	DBH (cm)	Demographic Ratio (female:male)	Presence of Dependant Young (yes/no)	% Females with Dependant Young
MC7	492184, 6601569	Broad-leaved Paperbark	12	15	10:0	Yes	90
MC8	492180, 6601569	Broad-leaved Paperbark	12	20	10:3	Yes	80
MC9	492164, 6601574	Broad-leaved Paperbark	12	15	10:0	Yes	100
MC10	492183, 6601573	Broad-leaved Paperbark	12	15	10:0	Yes	100

Table 2.2 Demographic Data of GHFF at the Bellingen Island Camp

Tree Code	*GPS Location (UTM coordinates GDA94, Zone 56)*	*Tree Species*	*Height (m)*	*DBH (cm)*	*Demographic Ratio (female:male)*	*Presence of Dependant Young (yes/no)*	*% Females with Dependant Young*
BI1	490044, 6631571	Giant Stinging Tree (*Dendrocnide excelsa*)	14	30	10:5	Yes	60
BI2	490036, 6631544	Creek Sandpaper Fig (*Ficus coronata*) and stag	15/ 13	35/ 18	10:5	Yes	50
BI3	490045, 6631518	Giant Stinging Tree	15/ 18	40/ 90	10:3	Yes	60
BI4	490083, 6631510	Giant Stinging Tree	16/ 19	60/ 90	10:3	Yes	60
BI5	490104, 6631526	Giant Stinging Tree	10	90	10:1	Yes	50

2.2.3.3 Water Level at the Site

Water level at the site measured at the representative measurement location was approximately 53 cm in depth; a slight decrease in when compared to the previous monitoring event (refer to **Figure 2.1**).

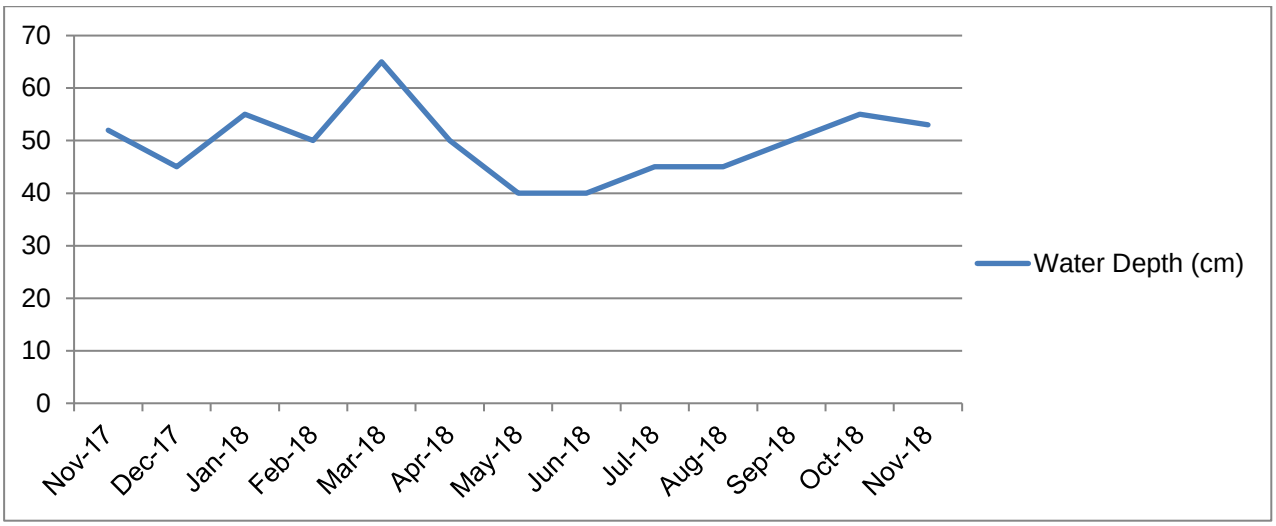


Figure 2.1 Water Level Measurements at the Site

2.3 Discussion

2.3.1 Population Estimates

The following discussion refers to the Australian Government Department of the Environment and Energy (DEE)/ CSIRO *Monitoring flying-fox Populations* (DEE 2018) categories (refer to **Section 2.2.2.2**). The trend in flying-fox numbers over the last 12-month period at the site and other monitored regional flying-fox camps are shown in **Figure 2.2**. No flying-foxes were recorded at the site again this month. Flying-foxes have not occupied the site (excluding a brief return in January 2015) since mid-April 2014.

At the Macksville Cemetery camp, since flying-foxes were absent in August 2018 numbers have increased each month. A sharp increase has been recorded in the last month from 10,900 flying-foxes (category 4) in October 2018 to 40,800 (category 5) in November 2018. The seasonal trend of summer/ autumn peaks and late autumn to spring reductions (including periodic absences) in the camp population has been consistently observed throughout the monitoring program at the Macksville Cemetery camp; though the durations and the exact timing of the peaks and reductions has varied slightly.

At the Bellingen Island camp, it was estimated that approximately 5,000 flying-foxes (category 3) were present. This represents a decrease in numbers compared to the October 2018 monitoring where approximately 20,000 flying-foxes (category 5) were recorded. The camp footprint was similar to that recorded in October 2018, however the flying-foxes were roosting more sparsely throughout the camp and higher in the vegetation canopy. Current flying-fox numbers at Bellingen Island are at their lowest since mid-September 2016 when an estimated 5,000 flying-foxes were also recorded (GeoLINK 2016a).

The number of flying-foxes at the Gordon Park camp has decreased since last month to 3,000 flying-foxes from 7,500 during October 2018 (both within DEE 2018 category 3). This observation is lower than the same time during 2016 and 2017 where 15,000 (category 4) and 7,500 (category 3) flying-foxes were recorded respectively during November. Gordon Park numbers are currently at their lowest since June 2016 monthly monitoring where an estimated 1,000 flying-foxes (category 2) were recorded (GeoLINK 2016b).

No flying-foxes were recorded at Bowraville during the current monitoring event. Flying-foxes have been absent from this site for nearly two years and were last recorded in December 2016 in low numbers.

2.3.2 Species Composition and Demographic Data

At occupied camps, GHFF dominated the species composition making up approximately 90 to 95% of all individuals. High proportions of GHFF have consistently been recorded throughout the monitoring program. Female flying-foxes dominated the demographic composition at both the Macksville Cemetery and Bellingen Island camps (90% and 76% of individuals excluding bachelor male groups respectively).

The first recording of dependant flying-foxes at the camp this 2018/19 breeding season was recorded during the October 2018 monitoring. Moderate levels of females supporting dependent young were recorded in November 2018 at both the Macksville Cemetery (74%) and Bellingen Island camps (56%).

2.3.3 Phenology of Trees in the Region

October/ November bimonthly flowering of highly productive nectar source trees in the upper North Coast region of NSW includes the following key GHFF diet species: Blackbutt (*Eucalyptus pilularis*), Grey Ironbark (*E. siderophloia*), Forest Red Gum (*E. tereticornis*) and Silky Oak (*Grevillea robusta*). Opportunistic observations when travelling between regional flying-fox camps did not record any key GHFF diet species in flower. Smooth-barked Apple (*Angophora costata*) was however in heavy flower locally.

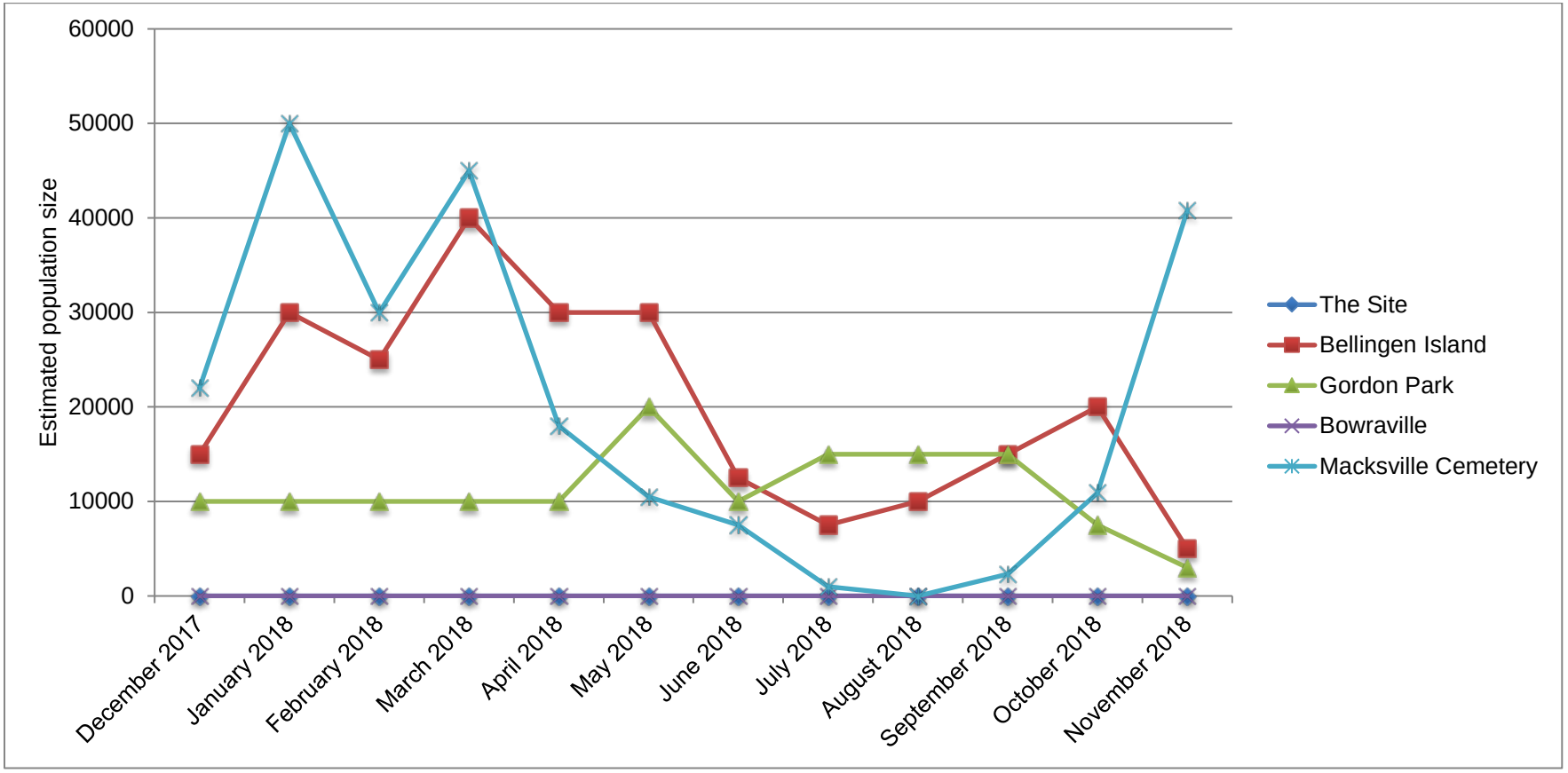


Figure 2.2 Population Trends at the Site and Regional Camps Over Past 12 Months

2.4 Summary and Conclusion

The results of the November 2018 flying-fox monitoring indicate that, excluding a brief stopover at the site observed in mid-January 2015, flying-foxes have been absent from the site since April 2014. Flying-foxes were also absent from the Bowraville and Wheatley Street camps.

Bellingen Island, Gordon Park and Macksville Cemetery camps were occupied. The number of flying-foxes at Bellingen Island and Gordon Park are at the lowest levels recorded since September and June 2016 respectively.

Flying-fox numbers at the Macksville Cemetery have increased by approximately 30,000 since the October 2018 monitoring. This increase is in line with the recorded population trends that show summer/ autumn peaks.

GHFF dominated the species composition at occupied camps at approximately 90 to 95% of all individuals present. The proportion of female GHFF remains relatively high. Dependent young GHFF were present at a moderate level within occupied camps in the current monitoring event.

Heavy flowering of Smooth-barked Apple was recorded within the region however no GHFF key diet species were observed in flower at the time of the November 2018 monitoring.

The November 2018 flying-fox monitoring event concludes the flying-fox monitoring program for the WC2NH project. A summary assessment of the broad trends recorded throughout the monitoring program will be provided in a separate report.

David Andrighetto
Senior Ecologist

References

DEE (2018). *Monitoring Flying-fox Populations*, Australian Government Department of the Environment and Energy, Canberra, viewed 11 July 2018. http://www.environment.gov.au/biodiversity/threatened/species/flying-fox-monitoring/

Eby, P. (2012). *An Assessment of the Flying-fox Camp at Macksville*. Unpublished report to NSW Roads and Maritime Services.

Eby, P. (2013). *A Field Monitoring Program Proposed for the Macksville Flying-fox Roost*. Unpublished report to Sinclair Knight Merz.

GeoLINK (2016a). *Fortnightly Flying-fox Monitoring September 2016: Warrell Creek to Nambucca Heads Pacific Highway Upgrade*. Unpublished report to NSW Roads and Maritime Services.

GeoLINK (2016b). *Flying-fox Monitoring June 2016: Warrell Creek to Nambucca Heads Pacific Highway Upgrade*. Unpublished report to NSW Roads and Maritime Services.

GeoLINK (2017). *Flying-fox Monitoring November 2017: Warrell Creek to Nambucca Heads Pacific Highway Upgrade*. Unpublished report to NSW Roads and Maritime Services.

GeoLINK. (2018). *Flying-fox Monitoring October 2018: Warrell Creek to Nambucca Heads Pacific Highway Upgrade*. Unpublished report to NSW Roads and Maritime Services.

Appendix B Grey-headed Flying-fox habitat

Warrell Creek to Nambucca Heads

Grey-headed Flying Fox – Operational Habitat Monitoring

Roads and Maritime Services | 2019

NSW GOVERNMENT

THIS PAGE LEFT INTENTIONALLY BLANK

Document control

Report name	Warrell Creek to Nambucca Heads - Grey-headed Flying Fox – Operational Habitat Monitoring	
Date	February 2019	
Document version	Revision 1	Summer 2018 Stage 2A monitoring report
	Revision 2	Autumn 2018 Stage 2A monitoring report.
	Revision 3	Winter 2018 Stage 2A and Stage 2B monitoring report
	Revision 4	Spring 2018 Stage 2A and Stage 2B monitoring report
	Revision 5	Summer 2019 Stage 2B monitoring report

Contents

1.Introduction 1

2.Purpose of this report..... 1

Appendix 1 Summer 2018 Stage 2A monitoring report.

Appendix 2 Autumn 2018 Stage 2A monitoring report.

Appendix 3 Winter 2018 Stage 2A and Stage 2B monitoring report.

Appendix 4 Spring 2018 Stage 2A and Stage 2B monitoring report.

Appendix 5 Summer 2019 Stage 2B monitoring report.

1. Introduction

Grey-headed Flying Fox habitat monitoring is a requirement of the approved Warrell Creek to Nambucca Heads Flying-fox management plan and the Ecological Monitoring Program.

The aim of the monitoring program is to;

1. monitoring of identified revegetation/rehabilitation areas to ensure the establishment /restoration of seedlings and plants. These areas could be areas cleared in grey-headed flying fox habitat for temporary ancillary facilities, access tracks, watercourse crossings etc;

2. monitoring both revegetation/rehabilitation areas and other habitat areas adjacent to the Project to manage invasion of noxious and environmental weeds;

3. monitoring water quality (contamination, isolation, etc) for notable changes due to the Project, to manage impacts on foraging and roosting habitat.

4. monitoring notable changes to groundwater and ponded surface water regimes to manage impacts on foraging and roosting habitat.

Quarterly monitoring of the quality of the habitat adjacent to the Project for up to one year after the opening of the Project to traffic unless otherwise agreed with P&I, EPA and DoEE.

2. Purpose of this report

The purpose of this report is to provide the monitoring data for aspects 1 and 2 of the monitoring program. Aspects 3 and 4 are monitored as part of the construction and operational surface and ground water monitoring program and reported separately following the collection, analysis and assessment of water quality data.

Due to the staged opening of the project the Grey-headed Flying Fox habitat monitoring will be undertaken as follows:

Season	Stage 2A (Chainage 47,700 to 61,300)	Stage 2B (Chainage 41,700 to 47,700)
Summer 2017/2018		
Autumn 2018		
Winter 2018		
Spring 2018		
Summer 2018/2019		
Autumn 2019		

At the end of each monitoring cycle an annual report will be produced for each section. i.e. Stage 2A annual report will be produced at the end of spring 2018. Stage 2B will be produced at the end of autumn 2019.

The results of monitoring are provided in the Appendices.

Appendix 1: Summer 2018 Stage 2A monitoring report

ABN 79 896 839 729
ACN 101 084 557

Return address:
PO Box 119
LENNOX HEAD
NSW 2478

LENNOX HEAD
T 02 6687 7666
F 02 6687 7782

COFFS HARBOUR
T 02 6651 7666

ARMIDALE
T 0488 677 666

LISMORE
T 02 6621 6677

www.geolink.net.au

28 March 2018
Ref No: 2692-1090

Roads and Maritime Service
24 Albert Drive
WARRELL CREEK NSW 2447

Attention: Mr Kris Hincks

Dear Kris

WC2NH GHFF Habitat Monitoring – First quarterly monitoring 2018

Introduction

This report presents the results of the first quarterly monitoring for 2018 of Grey-Headed Flying-fox (GHFF) habitat adjacent to the Warrell Creek to Nambucca Heads Highway Upgrade (WC2NH) Project. Quarterly monitoring will be undertaken between chainage 47 700 and 61 300 (Stage 2A) for up to one year after the opening of the Project to traffic.

The *Warrell Creek to Nambucca Heads Flying-fox Management P*lan (Sinclair Knight Merz, 2017) recognised that the quality of vegetation adjacent to the Project area could be detrimentally affected by invasion of noxious and environmental weeds. A main goal identified for management during operation of the Project is '*no reduction of the quality of flying-fox habitats adjacent to the Project corridor due to the operation of the Project and to minimise the impact of edge effects'* (Sinclair Knight Merz, 2017).

Methodology

The monitoring of Grey-headed Flying-fox habitat includes the following components:

1. Monitoring of identified revegetation/rehabilitation areas to ensure the establishment/restoration of seedlings and plants. These areas could be areas cleared in GHFF habitat for temporary ancillary facilities, access tracks, watercourse crossings etc.

2. Monitoring both revegetation/rehabilitation areas and other habitat areas adjacent to the Project to manage invasion of noxious and environmental weeds.

For brevity, component 1 is henceforth referred to as 'rehabilitation site monitoring', and component 2 is referred to as 'weed monitoring'.

The field survey was undertaken on 25-27 February 2018 by GeoLINK ecologists Grant McLean and Garon Staines.

Further detail on the two monitoring components is provided below.

Urban and Regional Planning | Environmental Engineering | Civil Design | Environmental Impact Assessment | Ecological Surveys and Monitoring | Landscape Architecture | Urban Design |

Rehabilitation Site Monitoring

The locations of the GHFF habitat areas requiring revegetation/rehabilitation are shown in **Table 1** below. Monitoring of these areas aimed to assess the effectiveness of rehabilitation of GHFF habitat areas cleared during the construction of the Project.

Table 1 Location of GHFF Habitat Rehabilitation Sites

Habitat type	*Location*	*Area Type*
Open Blackbutt	CH: 59450 East	15c ancillary compound
Open Blackbutt	CH: 60800 East	Old Coast Rd Temporary Deviation

The following data was recorded for each location:

- Date and time of monitoring.
- Weed abundance and composition.
- Evidence of management and control of noxious and environmental weeds.
- Evidence of any progressive revegetation/rehabilitation during the construction phase using collected topsoil and seed at specific sites and to develop different successional stages of rehabilitation.
- Evidence of native plant establishment of seedlings.
- Identification of any of the GHFF food tree plants referred to in Appendix B of the brief.

Four fixed photo points were also established at these rehabilitation sites (refer to **Table 2**).

Table 2 Locations of Fixed Photo Points for Rehabilitation Sites

Photo Point ID	*Photo Point GPS Coordinates (UTM eastings, northings; Zone 56J)*
1RS	497441, 6610257
2RS	497279, 6610248
3RS	497229, 6610231
4RS	496438, 6609098

Weed Monitoring

The Project *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) approval defined GHFF habitat as habitat consisting of:

- Swamp Mahogany/Paperbark Swamp Forest
- Flooded Gum Moist Open Forest.
- White Mahogany/Grey Gum/Ironbark Moist Open Forest
- Mixed Floodplain Forest
- Blackbutt Open Forest.

All instances of the above plant communities occurring along the outside of the Project clearing corridor were targeted in the field survey. Within 2 metres of the cleared edge of these habitat areas the following data was recorded in relation to weeds:

- Date and time of monitoring.
- Weed abundance and composition.
- Evidence of management and control of noxious and environmental weeds.

Weed abundance was measured using modified Braun-Blanquet cover classes between 1 and 5: 1(<5%), 2 (6-25%), 3 (26-50%), 4 (51-75%), and 5 (76-100%).

Weed monitoring sites were classified as per the categories in Table 3. Priority weed sites for management were identified based on species present and the percentage cover.

Table 3 Weed Monitoring Site Classification

Noxious/Environmental Weed Cover (%)	*Weed Site Classification*
0-10	NA
11-39	Low
40-69	Medium
70-100	High

Fixed photo points were also established adjacent to representative areas of GHFF habitat to monitor weeds. Locations of these fixed photo points are shown in Table 4.

Table 4 Locations of Fixed Photo Points

Photo Point ID (number + side of alignment heading north: E=east, W=west)	*Photo Point GPS Coordinates (UTM eastings, northings; Zone 56J)*	*Notes on photo direction*
1E	491906, 6598292	looking north
1W	492671, 6600507	looking north
2E	492372, 6599033	looking northeast
2W	496675, 6609675	looking north
3E	492778, 6600567	looking southwest
3W	496494, 6609010	looking south
4E	494575, 6605139	looking northeast
4W	496131, 6608279	looking north
5E	494960, 6606206	looking south
5W	495668, 6607684	looking north
6E	495433, 6607052	looking northeast
6W	494890, 6606346	looking southwest
7E	496240, 6608213	looking west
7W	494355, 6604185	looking north
8E	496724, 6609444	looking south

Results

Rehabilitation Site Monitoring

Surveys of rehabilitation sites were undertaken on 8 March by GeoLINK ecologist Jess O'Leary.

The results of the rehabilitation site monitoring are detailed in Table 5 along with photos from the four photo points that were established. Plantings at these sites are either young or have not been undertaken (in the case of the rehabilitation site at the 15c ancillary compound). Subsequent monitoring events will provide more useful data for assessing the success of these rehabilitation sites.

Table 5 Rehabilitation Site Monitoring

	Rehabilitation Site		
	Old Coast Rd Temporary Deviation		***15c ancillary compound***
	CH: 60800 West	***CH: 60800 East***	***CH: 59450 East***
Photo Point GPS Coordinates (UTM eastings, northings; Zone 56J)	Photo Point RS1: 497441, 6610257 Photo Point RS2: 497279, 6610248	Photo Point RS4: 496438, 6609098	Photo Point RS3: 497229, 6610231
Date and time	8/03/2018 – 9:00 am – 12:00 pm		
Weed Abundance and Composition	No weed infestations were observed within the newly landscaped area.	No weed infestations were observed within trimmed, topsoiled and hydroseeded batter.	Not applicable as this area is yet to be rehabilitated still part of the active construction site.
Evidence of management and control of noxious and environmental weeds	Not applicable - site recently finished and landscaped, no weeds present at the time of monitoring.	Not applicable - site recently finished and landscaped, no weeds at the time of monitoring.	As above.
Evidence of any progressive revegetation/ rehabilitation during the construction phase using collected topsoil and seed at specific sites and to develop different successional stages of rehabilitation	It appears that the site was topsoiled and landscaped at the same time. Therefore, there was no observed progressive revegetation or successional stages of rehabilitation.	It appears that the site was topsoiled and landscaped at the same time. Therefore, there was no observed progressive revegetation or successional stages of rehabilitation.	As above.
Evidence of native establishment of seedlings and plants	Semi established native plant species have been planted as part of rehabilitation landscaping. Very minimal seed germination was observed at the time of monitoring other than the hydroseeded grass cover crop.	No establishment of native species at the time of monitoring.	As above.
Identification of any of the GHFF food tree plants referred to in Appendix B of the brief	Landscape plantings have included species, as identified within Appendix B. Natural regeneration of native species is not yet developed enough to allow for accurate identification of species. Plants planted as part of landscape planting include Water Gum (*Tristaniopsis laurina*).	No landscape plantings had been undertaken at the time of monitoring. No obvious establishment of native species from the topsoil seed bank at the time of monitoring.	As above.
Photo Points	 Photo Point RS1 – view to the south	 Photo Point RS4 - view to the west (no peg installed)	 Photo Point RS3 - view to the east, no rehabilitation works started at time of monitoring.

	Rehabilitation Site		
	Old Coast Rd Temporary Deviation		15c ancillary compound
	CH: 60800 West	CH: 60800 East	CH: 59450 East
	 Photo Point RS1 – view to the north-east Photo Point RS2 – view to the south-west		 Site reference photo view to the west looking towards Photo Point #3, no rehabilitation works started at time of monitoring.

Weed Monitoring

Surveys of GHFF habitat areas were undertaken 25-27 February 2018 by GeoLINK ecologists Grant McLean and Garon Staines.

Occurrence of noxious and/or environmental weeds was recorded at 28 sites within the edge of GHFF habitat adjacent to the Project area. These weed occurrences are shown in **Appendix A** and are listed in Table 6. Photographs of GHFF habitat areas taken from fixed photo points are shown in Table 7**.**

Nineteen noxious and environmental weed species were recorded in the field surveys. Lantana (*Lantana camara*), Salvinia (*Salvinia molesta*) and Blackberry (*Rubus fruticosus*) were recorded onsite and are listed as priority weed species for the North Coast of NSW. They must not be imported into the State or sold.

Lantana, Broad-leaved Paspalum (*Paspalum mandiocanum*) and Camphor Laurel (*Cinnamomum camphora*) were recorded within GHFF habitat areas at the highest density, and were also the dominant weed species in those GHFF areas that recorded a 'Medium' weed infestation level (refer to **Table 6**).

One weed occurrence area (site 25) was considered to have a high weed management priority and nine areas were considered to have a medium weed management priority (sites 5, 16, 18, 22, 23, 24, 26, 27 and 28). These areas should be targeted during weed management works.

Table 6 Sites of Noxious and/or Environmental Weeds

Site No.	*Chainage (side of highway heading north)*	*Weeds Present (Cover Class*)*	*GHFF Habitat Type (Plant Community)*	*Weed Infestation Level^*	*Comments*	*Evidence of Management and Control*	*Weed Management Priority*
1	49790 - 50100 (west)	Setaria (*Setaria sphacelata*) (2), Annual Ragweed (*Ambrosia artemisiifolia*) (1)	Swamp Forest - Swamp Mahogany / Paperbark	Low	Majority of weed infestation concentrated on batter edge. Blue Water Lily (on swamp fringe) 40% cover in concentrated areas of open water.	None – initial monitoring event	Low
2	51010 - 51165 (west)	Salvinia (*Salvinia molesta*) (within open water area – approx. chainage 51020) (2)	Swamp Forest - Swamp Mahogany / Paperbark	Low	Very minor Flax-leaf Fleabane (*Conyza bonariensis*), Broad-leaved Paspalum (*Paspalum mandiocanum*) and Annual Ragweed on fauna fence edge Salvinia is listed as a priority weed species for the North Coast of NSW. It must not be imported into the State or sold.	None – initial monitoring event	Low (although Salvinia is a WONS this species would have minimal impact on GHFF habitat value).
3	53750 - 53840 (west)	Broad-leaved Paspalum (2), Annual Ragweed (1), White Passionflower (*Passiflora subpeltata*) (1), Paddy's Lucerne (*Sida rhombifolia*) (1), Purple-top (*Verbena bonariensis*) (1)	Moist Open Forest - White Mahogany - Grey Gum	Low		None – initial monitoring event	Low
4	54115 - 54150 (west)	Broad-leaved Paspalum (2), Lantana (*Lantana camara*) (1)	Open Forest - Blackbutt	Low	Setaria, Flax-leaf Fleabane and Purple-top present in very low abundance Lantana is listed as a priority weed species for the North Coast of NSW. It must not be imported into the State or sold.	None – initial monitoring event	Low
5	54480 - 54530, (west)	Broad-leaved Paspalum (3), Lantana (1), Wild Tobacco (*Solanum mauritianum*) (1),	Open Forest - Blackbutt	Medium		None – initial monitoring	Medium

		Flaxleaf Fleabane (1)				event	
6	55220 - 55260 (west)	Setaria (1)	Open Forest - Blackbutt	Low		None – initial monitoring event	Low
7	56160 - 56360 (west)	Broad-leaved Paspalum (2), Setaria (1), Lantana (1)	Open Forest - Blackbutt	Low	Lantana present in low abundance on fringe	None – initial monitoring event	Low
8	57370 – 57450 (west)	Lantana (2)	Open Forest - Blackbutt	Low		None – initial monitoring event	Low
9	58440 - 58550 (west)	Broad-leaved Paspalum (2), Lantana (1)	Flooded Gum Moist Open Forest	Low		None – initial monitoring event	Low
10	58850 – 58940 (west)	Lantana (1)	Open Forest - Blackbutt	Low		None – initial monitoring event	Low
11	59200 - 59250, (west)	Broad-leaved Paspalum (1)	Open Forest - Blackbutt	Low		None – initial monitoring event	Low
12	59700 - 59740 (west)	Broad-leaved Paspalum (2)	Open Forest - Blackbutt	Low		None – initial monitoring event	Low
13	59780 - 59810 (west)	Broad-leaved Paspalum (2)	Flooded Gum Moist Open Forest	Low		None – initial monitoring event	Low
14	60400 - 60540,	Broad-leaved Paspalum (2), Morning	Open Forest -	Low	Some sections without GHFF	None – initial	Low

	60640 – 60665 (west)	Glory (*Ipomoea indica*) (1), Rhodes Grass (*Chloris gayana*) (1)	Blackbutt		habitat (old hardstand area and stockpile site).	monitoring event	
15	61240 – 61260 (east)	Lantana (1)	Open Forest - Blackbutt	Low		None – initial monitoring event	Low
16	59780 - 59850 59550 - 59590 59200 - 59260 59000 - 59080 58470 – 58550 58050 - 58110 57650 - 57770 57210 - 57250 (east)	Lantana (3), Broad-leaved Paspalum (1), Blue Billy-goat Weed (*Ageratum houstonianum*) (1)	Flooded Gum Moist Open Forest	Medium	Lantana cover >25% to >50% in some gullies	None – initial monitoring event	Medium
17	56100 – 56420 (east)	Broad-leaved Paspalum (3), Lantana (2)	Open Forest - Blackbutt Flooded Gum Moist Open Forest	Low	Mostly intact native canopy but more scattered trees around big house in north. Lower weed cover in south,	None – initial monitoring event	Low
18	56420 – 56580 (east)	Broad-leaved Paspalum (4), Lantana (2)	Open Forest - Blackbutt	Medium	Very weedy understorey in north around big house. Very weedy north section.	None – initial monitoring event	Medium
19	55630 – 56080 (east)	Lantana (1), Broad-leaved Paspalum (1), Setaria (1)	Open Forest Blackbutt	Low		None – initial monitoring event	Low
20	52980 – 53040 (east)	Lantana (1), Mile a Minute (*Ipomoea cairica*) (1), Groundsel Bush (*Baccharis halimifolia*) (1), Annual Ragweed (1), Setaria (1)	Swamp Forest - Swamp Mahogany / Paperbark	Medium		None – initial monitoring event	Medium
21	49830 - 50220 (east)	Vasey Grass (*Paspalum urvillei*) (2), Setaria (1)	Swamp Forest - Swamp Mahogany / Paperbark	Low	Mel quin open forest in good condition including understorey except for some sections with blue water lily and some minor incursions of weedy grasses along fence.	None – initial monitoring event	Low

22	49560 – 49670 (east)	Broad-leaved Paspalum (4), Lantana (1)	Moist Open Forest - White Mahogany - Grey Gum	Medium		None – initial monitoring event	Medium
23	49030 - 49070 (east)	Broad-leaved Paspalum (5), Camphor Laurel (*Cinnamomum camphora*) (1)	Flooded Gum Moist Open Forest	High	Scattered native overstorey of Hard Quandong, Foambark, Broad-leaved Paperbark, with few shrubs and groundcover dominated by Broad-leaved Paspalum.	None – initial monitoring event	Medium
24	48430 - 48550 (east)	Broad-leaved Paspalum (5)	Moist Open Forest - Flooded Gum	High	Scattered overstorey of flooded gum, guioa, Mel quin, but lack of shrub layer and ground cover dominated by bl paspalum	None – initial monitoring event	Medium
25	48260 – 48380 (east)	Lantana (5), Broad-leaved Paspalum (2), Mile a Minute (1), Winter Senna (Senna septemtrionalis) (1).	Moist Open Forest - Flooded Gum	High	Mostly intact overstorey dominated by flooded gum with some river oak on edge creek. Understorey dominated by weeds mostly Lantana.	None – initial monitoring event	High
26	47800 – 47832 (east)	Lantana (2), Wild Tobacco (2), Setaria (1), White Passionflower (1)	Open Forest Blackbutt	Medium		None – initial monitoring event	Medium
27	47510 – 47530 (east)	Broad-leaved Paspalum (3), Camphor Laurel (2), Purple Top (2), Wild Tobacco (2)	Moist Open Forest – White Mahogany – Grey Gum	Medium		None – initial monitoring event	Medium
28	47450 – 47490 (east)	Camphor Laurel (2), Broad-leaved Paspalum (2), Lantana (2), Blackberry (*Rubus fruticosus*) (1), Narrow-leaved Privet (*Ligustrum sinense*) (1)	Moist Open Forest - White Mahogany - Grey Gum	Medium	Blackberry is listed as a priority weed species for the North Coast of NSW. It must not be imported into the State or sold.	None – initial monitoring event	Medium.

* Modified Braun-Blanquet cover classes of 1=<5%, 2=6-25%, 3=26-50%, 4=51-75%, and 5=76-100%; ^ Refer to **Table 3**

Table 7 Fixed Photo Points

Photo Point ID (number + side of alignment heading north: E=east, W=west)	*Photo Point GPS Coordinates (UTM eastings, northings; Zone 56J)*	*February 2018 photograph*
1E	491906, 6598292	
1W	492671, 6600507	

Photo Point ID (number + side of alignment heading north: E=east, W=west)	*Photo Point GPS Coordinates (UTM eastings, northings; Zone 56J)*	*February 2018 photograph*
2E	492372, 6599033	
2W	496675, 6609675	

Photo Point ID (number + side of alignment heading north: E=east, W=west)	*Photo Point GPS Coordinates (UTM eastings, northings; Zone 56J)*	*February 2018 photograph*
3E	492778, 6600567	
3W	496494, 6609010	

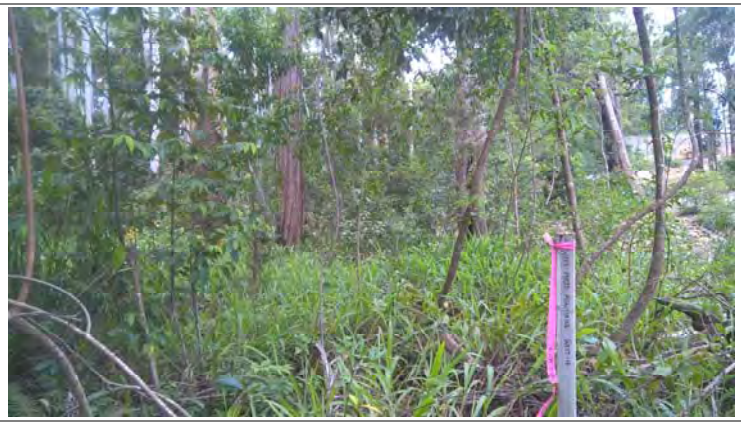
Photo Point ID (number + side of alignment heading north: E=east, W=west)	*Photo Point GPS Coordinates (UTM eastings, northings; Zone 56J)*	*February 2018 photograph*
4E	494575, 6605139	
4W	496131, 6608279	

Photo Point ID (number + side of alignment heading north: E=east, W=west)	*Photo Point GPS Coordinates (UTM eastings, northings; Zone 56J)*	*February 2018 photograph*
5E	494960, 6606206	
5W	495668, 6607684	

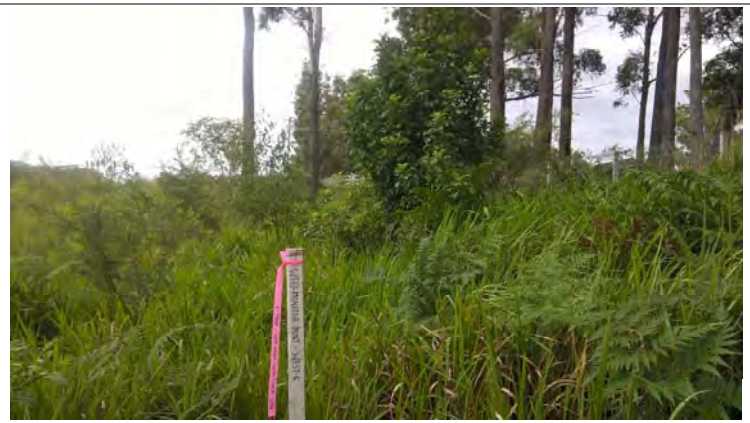
Photo Point ID (number + side of alignment heading north: E=east, W=west)	*Photo Point GPS Coordinates (UTM eastings, northings; Zone 56J)*	*February 2018 photograph*
6E	495433, 6607052	
6W	494890, 6606346	

Photo Point ID (number + side of alignment heading north: E=east, W=west)	*Photo Point GPS Coordinates (UTM eastings, northings; Zone 56J)*	*February 2018 photograph*
7E	496240, 6608213	
7W	494355, 6604185	

Photo Point ID (number + side of alignment heading north: E=east, W=west)	*Photo Point GPS Coordinates (UTM eastings, northings; Zone 56J)*	*February 2018 photograph*
8E	496724, 6609444	

Recommendations

The following recommendations are provided based on the outcomes of the GHFF habitat monitoring:

Site 25 comprises an understorey dominated by Lantana. Site 16 encompasses eight discrete small areas of Flooded Gum Moist Open Forest generally in association with small low-lying gullies. In these areas infestations of Lantana are prominent, with some gullies recording densities of >25% to >50% cover. With the potential for Lantana to alter community structure and inhibit regeneration, sites 25 and 16 are important target areas to avoid any degradation to GHFF habitat.

Sites with dense Broad-leaved Paspalum (sites 5, 17, 18, 22, 23, 24 and 27) should be considered a somewhat lower priority for management than sites 25 and 16 for the following reasons:

- There may be a lower likelihood of weed management success (it is difficult to remove this species successfully from degraded communities that have a suitable semi-shaded understorey environment); and
- Being an understorey weed species that occurs in disturbed environments and edges, Broad-leaved Paspalum has a low potential to alter either the structure or regeneration potential, and hence the quality of relatively intact GHFF habitat.

Future monitoring should aim to identify any significant increase in the density of the exotic vines Morning Glory (*Ipomoea indica*) and Mile-a-minute (*Ipomoea cairica*) both of which have the potential to inhibit native regeneration and smother the canopy of intact GHFF habitat.

Please contact the undersigned if require any further information.

Yours sincerely
GeoLINK

Jessica O'Leary
Ecologist

References

Sinclair Knight Merz (2017). *Warrell Creek to Nambucca Heads Upgrade of the Pacific Highway; Flying-fox Management Plan.* Report to Roads and Maritime Services.

Issue Log

UPR	*Description*	*Date issued*	*Issued By*
2692-1090	First issue	28/03/2018	JOL

Appendix A

GHFF Weed Survey Areas and Weed Infestation Levels (February 2018)

Information shown is for illustrative purposes only

Drawn by: GJM Checked by: DSA Reviewed by: GJM Date: 27/03/2018
Source of base data: DFS&I & AFJV

LEGEND

- Project boundary
- Clearing limit
- Fixed photo point
- GHFF weed survey area

Weed Infestation Level

- High
- Medium

Vegetation

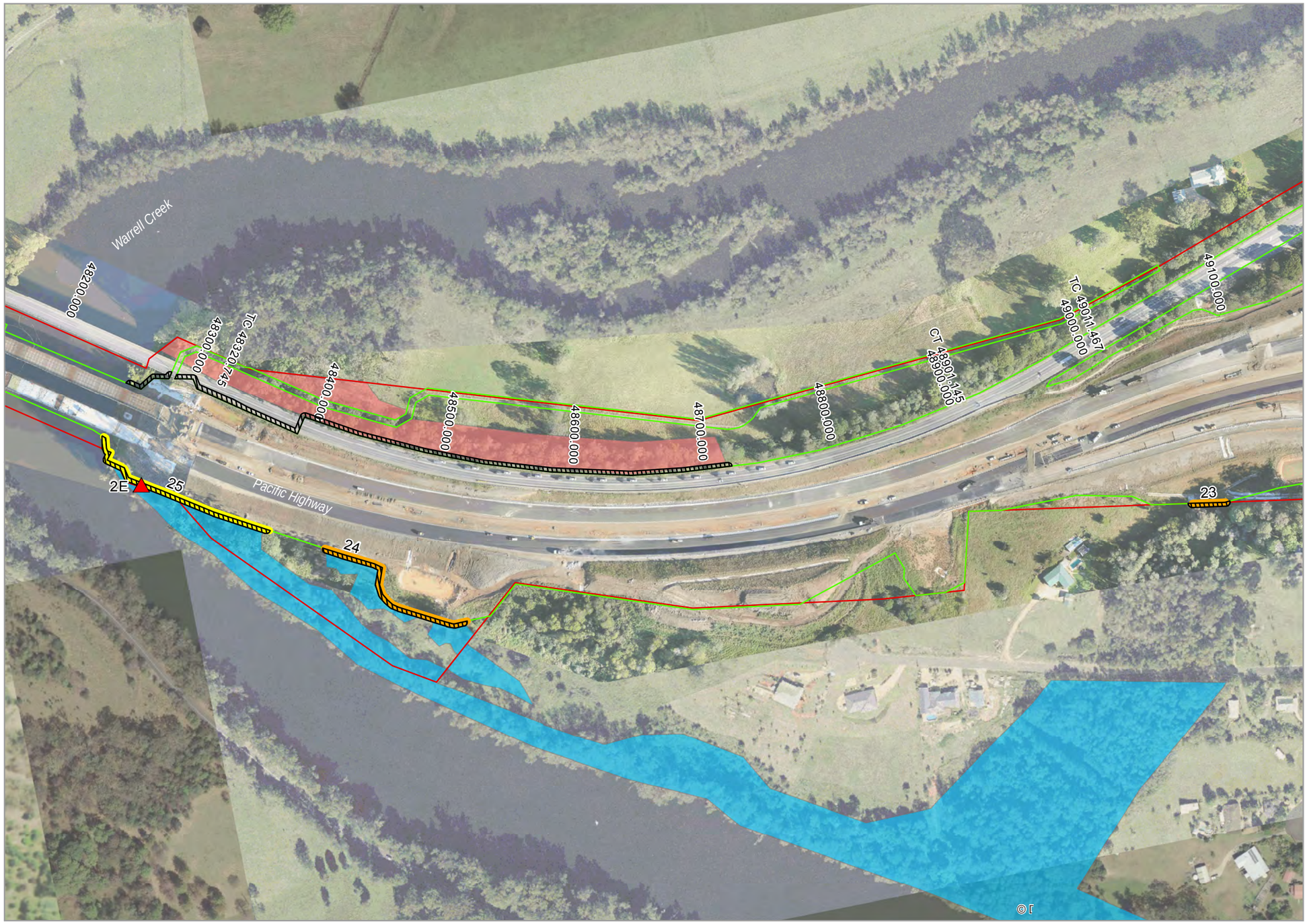
- Mixed Floodplain Forest (EEC)
- Moist Open Forest - White Mahogany - Grey Gum

0 60

GHFF Weed Survey Areas and Weed Infestation Levels

Information shown is for illustrative purposes only

Drawn by: GJM Checked by: DSA Reviewed by: GJM Date: 27/03/2018
Source of base data: DFS&I & AFJV



LEGEND

- Project boundary
- Clearing limit
- Fixed photo point
- GHFF weed survey area

Weed Infestation Level

- High
- Medium

Vegetation

- Mixed Floodplain Forest (EEC)
- Moist Open Forest - White Mahogany - Grey Gum

0 60

GHFF Weed Survey Areas and Weed Infestation Levels

Information shown is for illustrative purposes only

Drawn by: GJM Checked by: DSA Reviewed by: GJM Date: 27/03/2018
Source of base data: DFS&I & AFJV

LEGEND

- Project boundary
- Clearing limit
- Fixed photo point
- GHFF weed survey area

Weed Infestation Level

- Medium
- Low

Vegetation

- Mixed Floodplain Forest (EEC)
- Moist Open Forest - White Mahogany - Grey Gum
- Swamp Forest - Swamp Mahogany/ Paperbark EEC

0 60

GHFF Weed Survey Areas and Weed Infestation Levels

Information shown is for illustrative purposes only

Drawn by: GJM Checked by: DSA Reviewed by: GJM Date: 27/03/2018
Source of base data: DFS&I & AFJV

LEGEND

- Project boundary
- Clearing limit
- Fixed photo point
- GHFF weed survey area

Weed Infestation Level

- Low

Vegetation

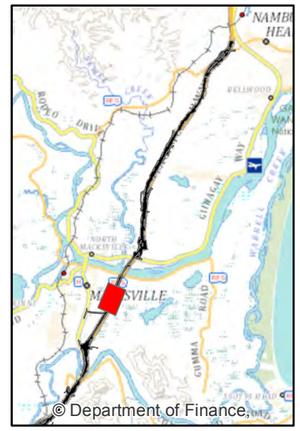
- Swamp Forest - Swamp Mahogany/ Paperbark EEC

0 60

GHFF Weed Survey Areas and Weed Infestation Levels

Information shown is for illustrative purposes only

Drawn by: GJM Checked by: DSA Reviewed by: GJM Date: 27/03/2018
Source of base data: DFS&I & AFJV



LEGEND

- Project boundary
- Clearing limit
- GHFF weed survey area

Weed Infestation Level

- Low

Vegetation

- Swamp Forest - Swamp Mahogany/ Paperbark EEC

0 60

GHFF Weed Survey Areas and Weed Infestation Levels

Information shown is for illustrative purposes only

Drawn by: GJM Checked by: DSA Reviewed by: GJM Date: 27/03/2018
Source of base data: DFS&I & AFJV

LEGEND

- Project boundary
- Clearing limit
- GHFF weed survey area

Vegetation

- Mixed Floodplain Forest (EEC)
- Swamp Forest - Swamp Mahogany/ Paperbark EEC

0 60

GHFF Weed Survey Areas and Weed Infestation Levels

Information shown is for illustrative purposes only

Drawn by: GJM Checked by: DSA Reviewed by: GJM Date: 27/03/2018
Source of base data: DFS&I & AFJV

LEGEND

- Project boundary
- Clearing limit
- GHFF weed survey area

Weed Infestation Level

- Low

Vegetation

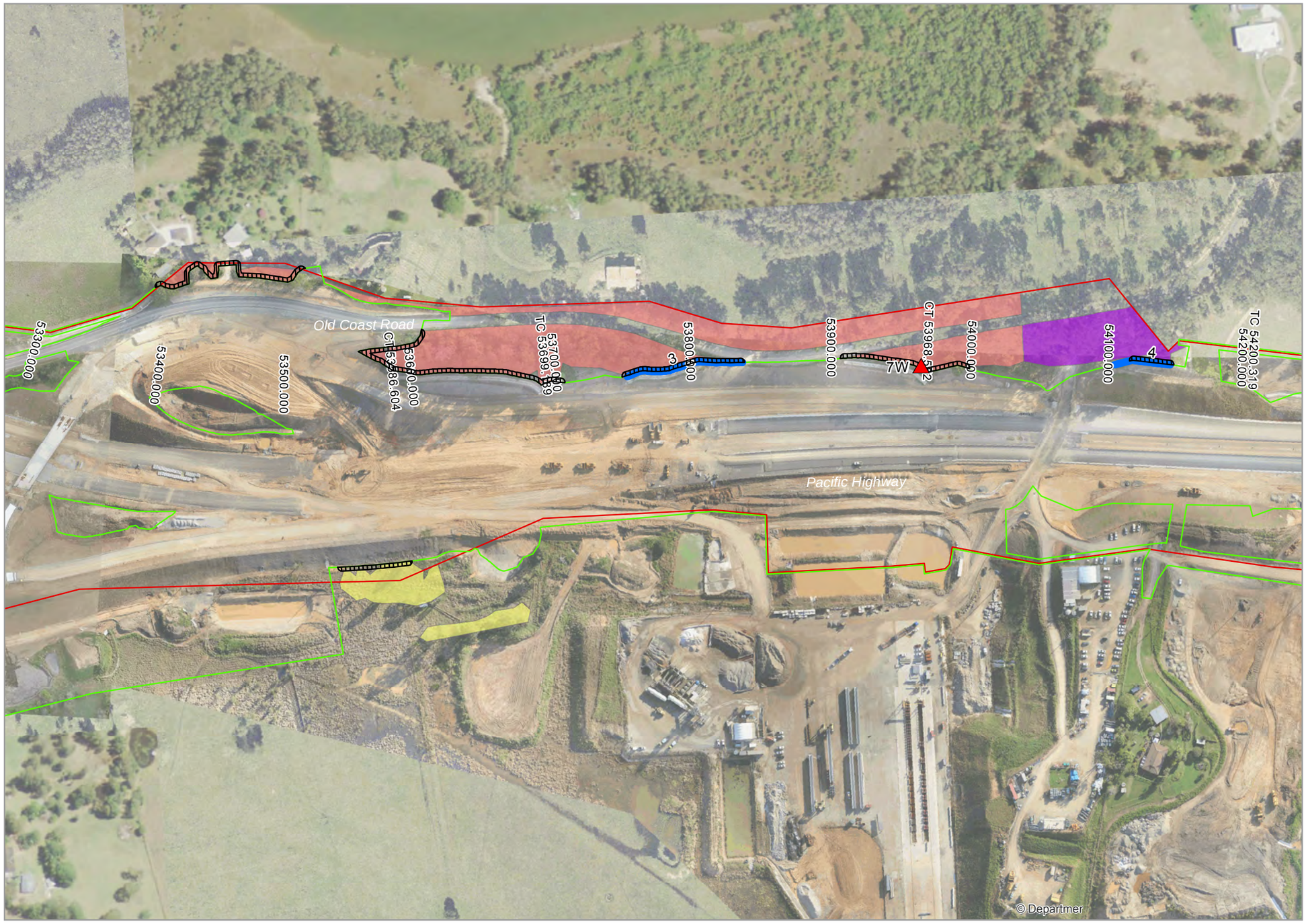
- Moist Open Forest - White Mahogany - Grey Gum
- Swamp Forest - Swamp Mahogany/ Paperbark EEC

0 60

GHFF Weed Survey Areas and Weed Infestation Levels

Information shown is for illustrative purposes only

Drawn by: GJM Checked by: DSA Reviewed by: GJM Date: 27/03/2018
Source of base data: DFS&I & AFJV



LEGEND

- Project boundary
- Clearing limit
- Fixed photo point
- GHFF weed survey area

Weed Infestation Level

- Low

Vegetation

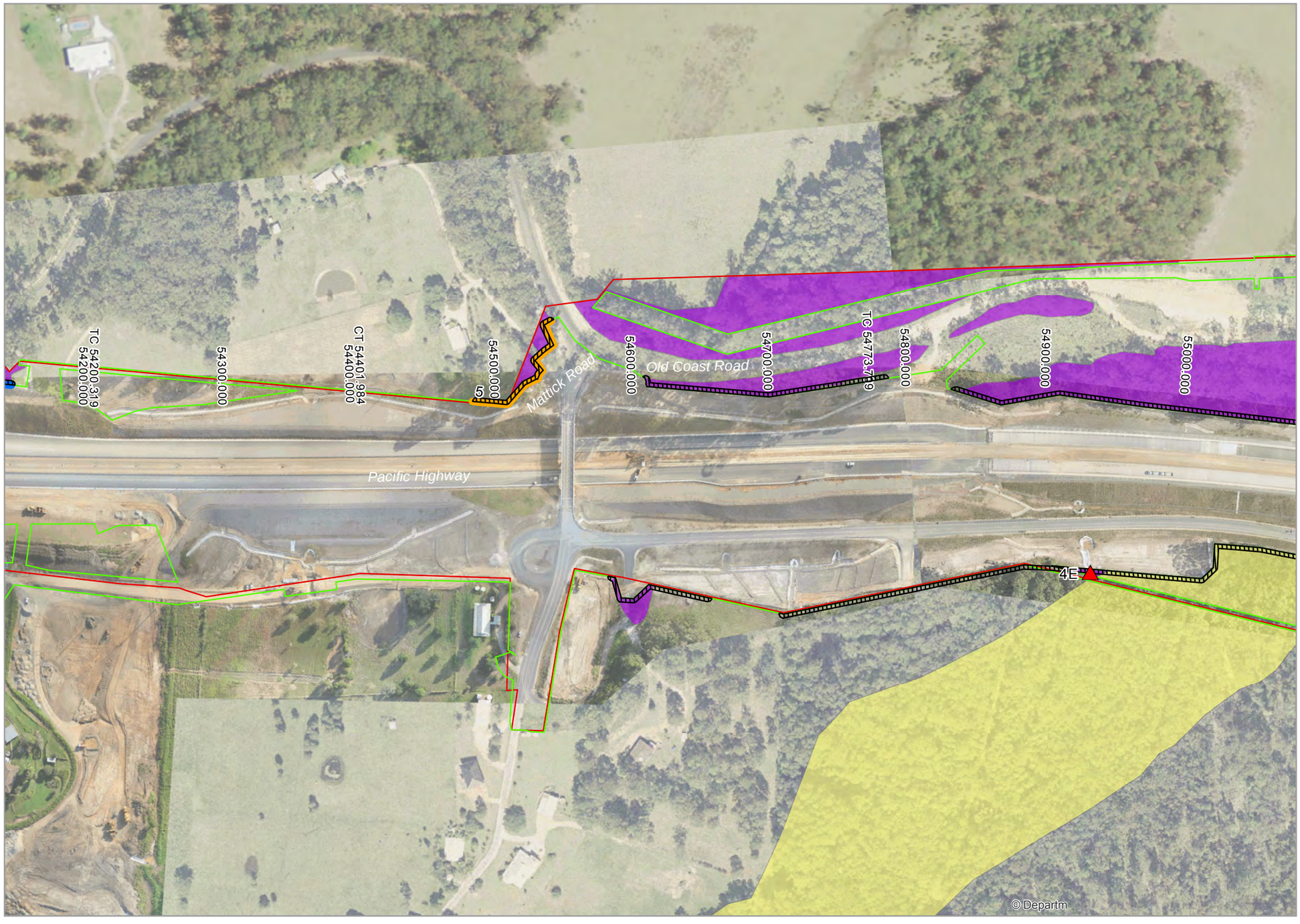
- Moist Open Forest - White Mahogany - Grey Gum
- Open Forest - Blackbutt
- Swamp Forest - Swamp Mahogany/ Paperbark EEC

0 60

GHFF Weed Survey Areas and Weed Infestation Levels

Information shown is for illustrative purposes only

Drawn by: GJM Checked by: DSA Reviewed by: GJM Date: 27/03/2018
Source of base data: DFS&I & AFJV



LEGEND

- Project boundary
- Clearing limit
- Fixed photo point
- GHFF weed survey area

Weed Infestation Level

- Medium
- Low

Vegetation

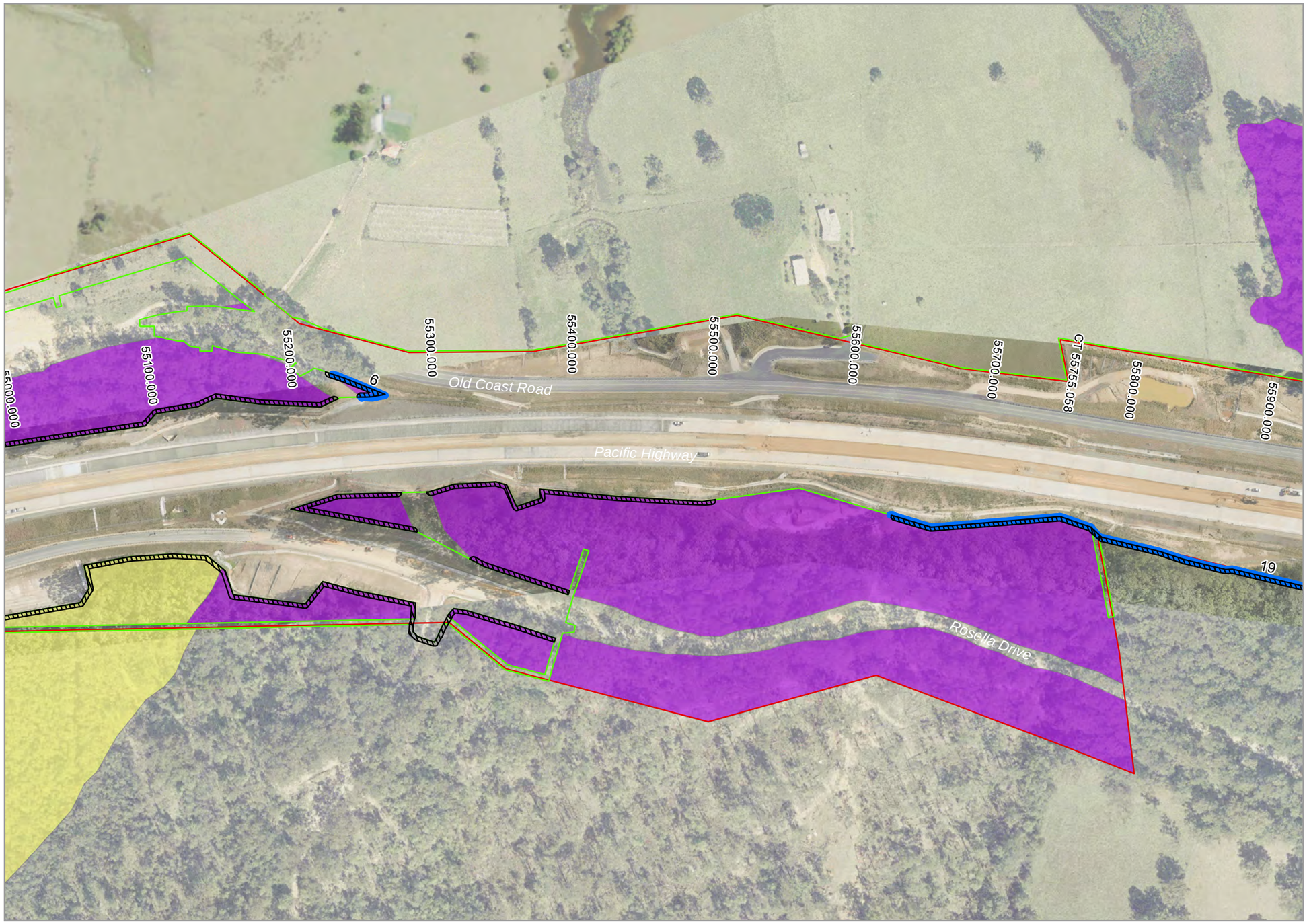
- Open Forest - Blackbutt
- Swamp Forest - Swamp Mahogany/ Paperbark EEC

0 60

GHFF Weed Survey Areas and Weed Infestation Levels

Information shown is for illustrative purposes only

Drawn by: GJM Checked by: DSA Reviewed by: GJM Date: 27/03/2018
Source of base data: DFS&I & AFJV



LEGEND

- Project boundary
- Clearing limit
- GHFF weed survey area

Weed Infestation Level

- Low

Vegetation

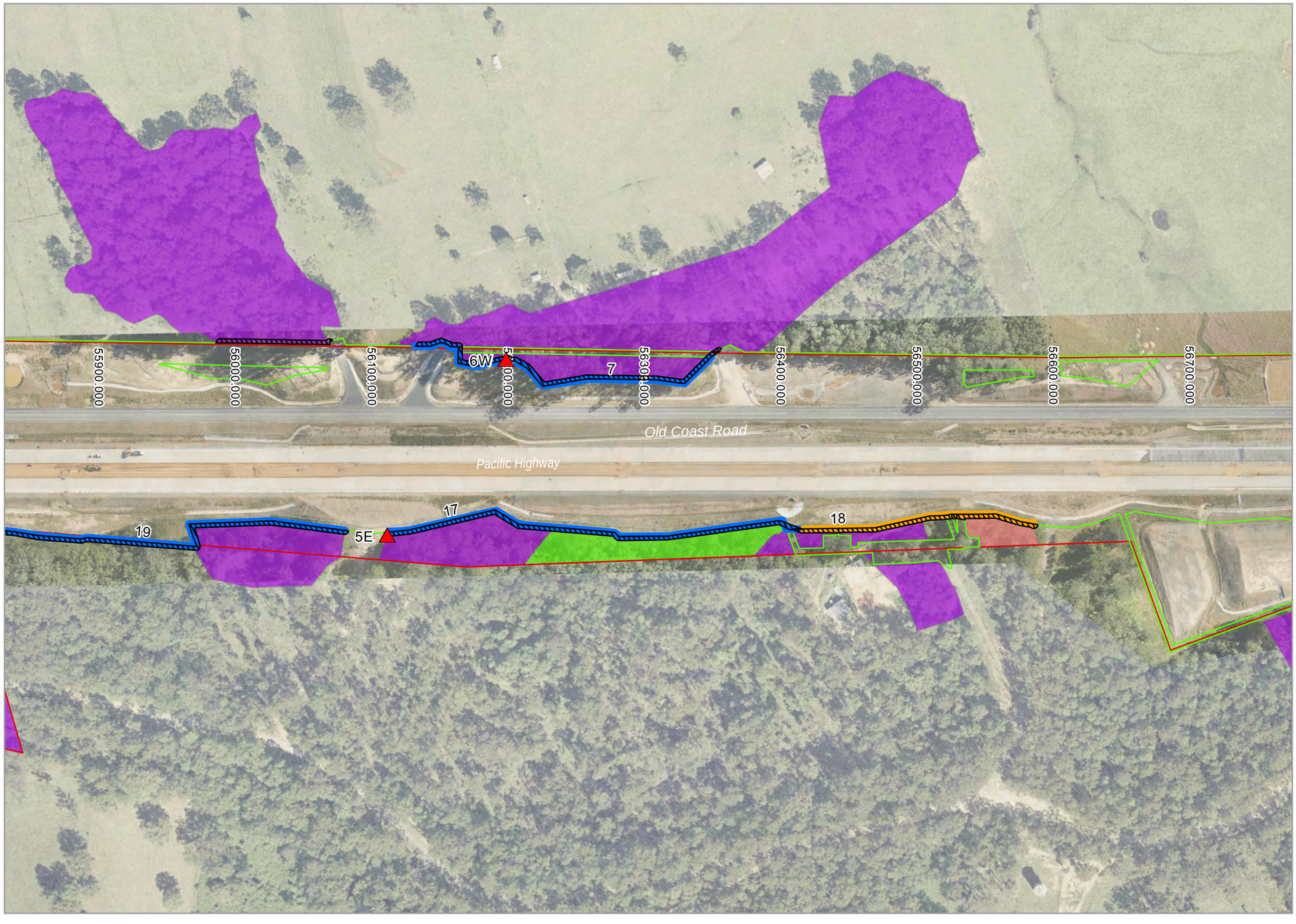
- Open Forest - Blackbutt
- Swamp Forest - Swamp Mahogany/ Paperbark EEC

0 60

GHFF Weed Survey Areas and Weed Infestation Levels

Information shown is for illustrative purposes only

Drawn by: GJM Checked by: DSA Reviewed by: GJM Date: 27/03/2018
Source of base data: DFS&I & AFJV



LEGEND

- Project boundary
- Clearing limit
- Fixed photo point
- GHFF weed survey area

Weed Infestation Level

- Medium
- Low

Vegetation

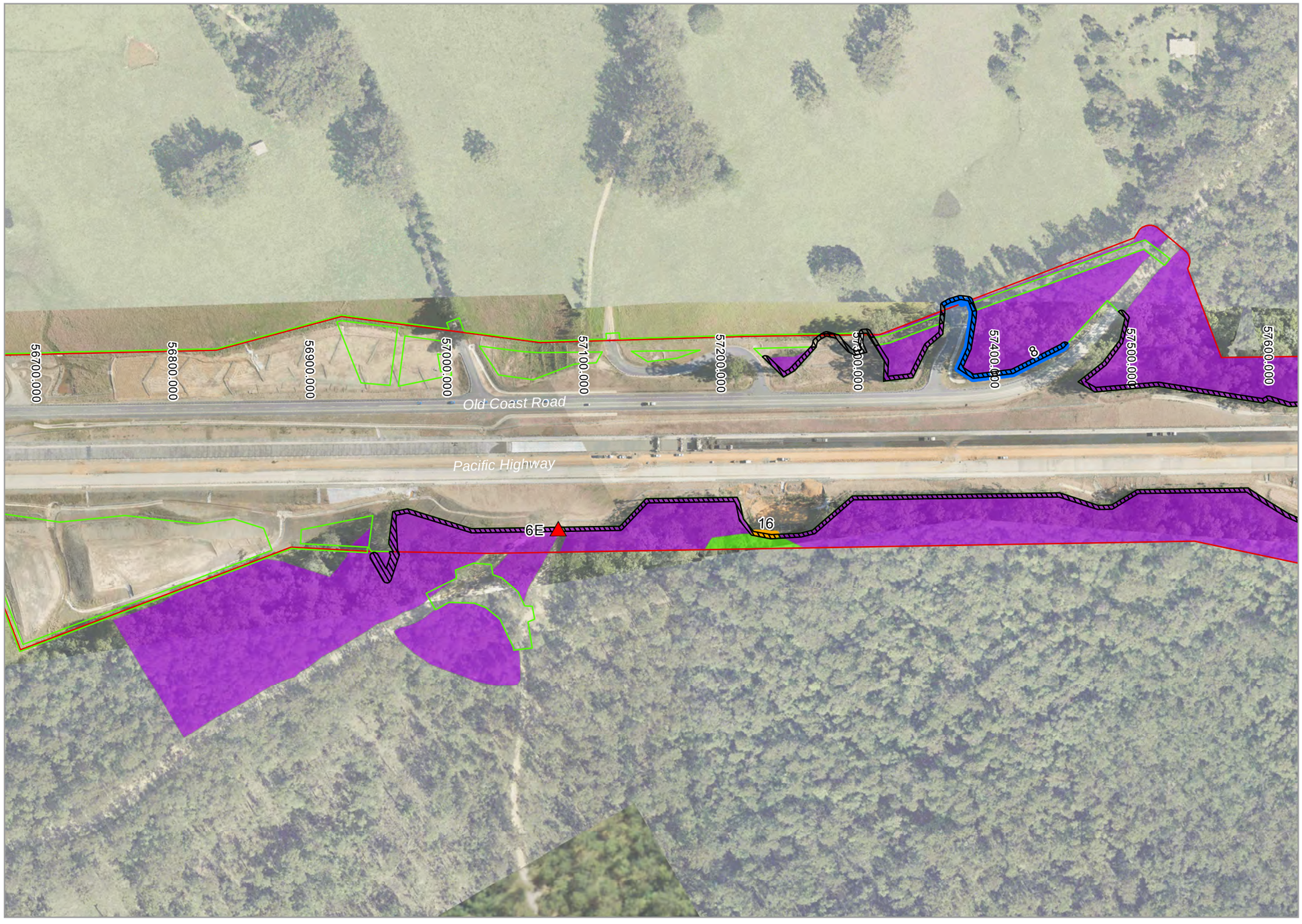
- Moist Open Forest - Flooded Gum
- Moist Open Forest - White Mahogany - Grey Gum
- Open Forest - Blackbutt

0 60

GHFF Weed Survey Areas and Weed Infestation Levels

Information shown is for illustrative purposes only

Drawn by: GJM Checked by: DSA Reviewed by: GJM Date: 27/03/2018
Source of base data: DFS&I & AFJV



LEGEND

- Project boundary
- Clearing limit
- Fixed photo point
- GHFF weed survey area

Weed Infestation Level

- Medium
- Low

Vegetation

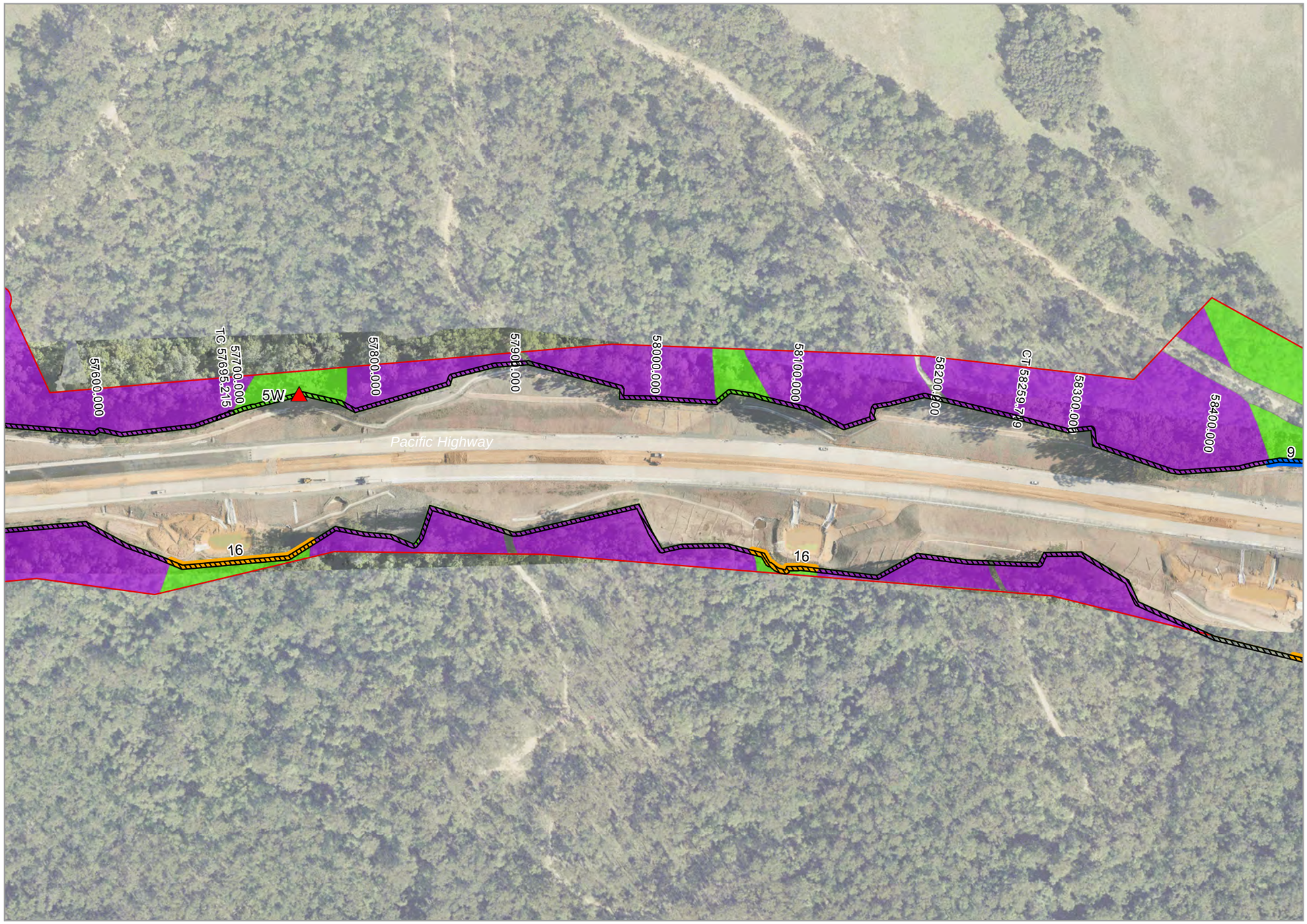
- Moist Open Forest - Flooded Gum
- Open Forest - Blackbutt

0 60

GHFF Weed Survey Areas and Weed Infestation Levels

Information shown is for illustrative purposes only

Drawn by: GJM Checked by: DSA Reviewed by: GJM Date: 27/03/2018
Source of base data: DFS&I & AFJV



LEGEND

- Project boundary
- Clearing limit
- Fixed photo point
- GHFF weed survey area

Weed Infestation Level

- Medium
- Low

Vegetation

- Moist Open Forest - Flooded Gum
- Open Forest - Blackbutt

0 60

GeoLINK environmental management and design

WC2NH GHFF Habitat Monitoring – First Quarterly 2018
2692-1091

GHFF Weed Survey Areas and Weed Infestation Levels

Information shown is for illustrative purposes only

Drawn by: GJM Checked by: DSA Reviewed by: GJM Date: 27/03/2018
Source of base data: DFS&I & AFJV

LEGEND

- Project boundary
- Clearing limit
- Fixed photo point
- GHFF weed survey area

Weed Infestation Level

- Medium
- Low

Vegetation

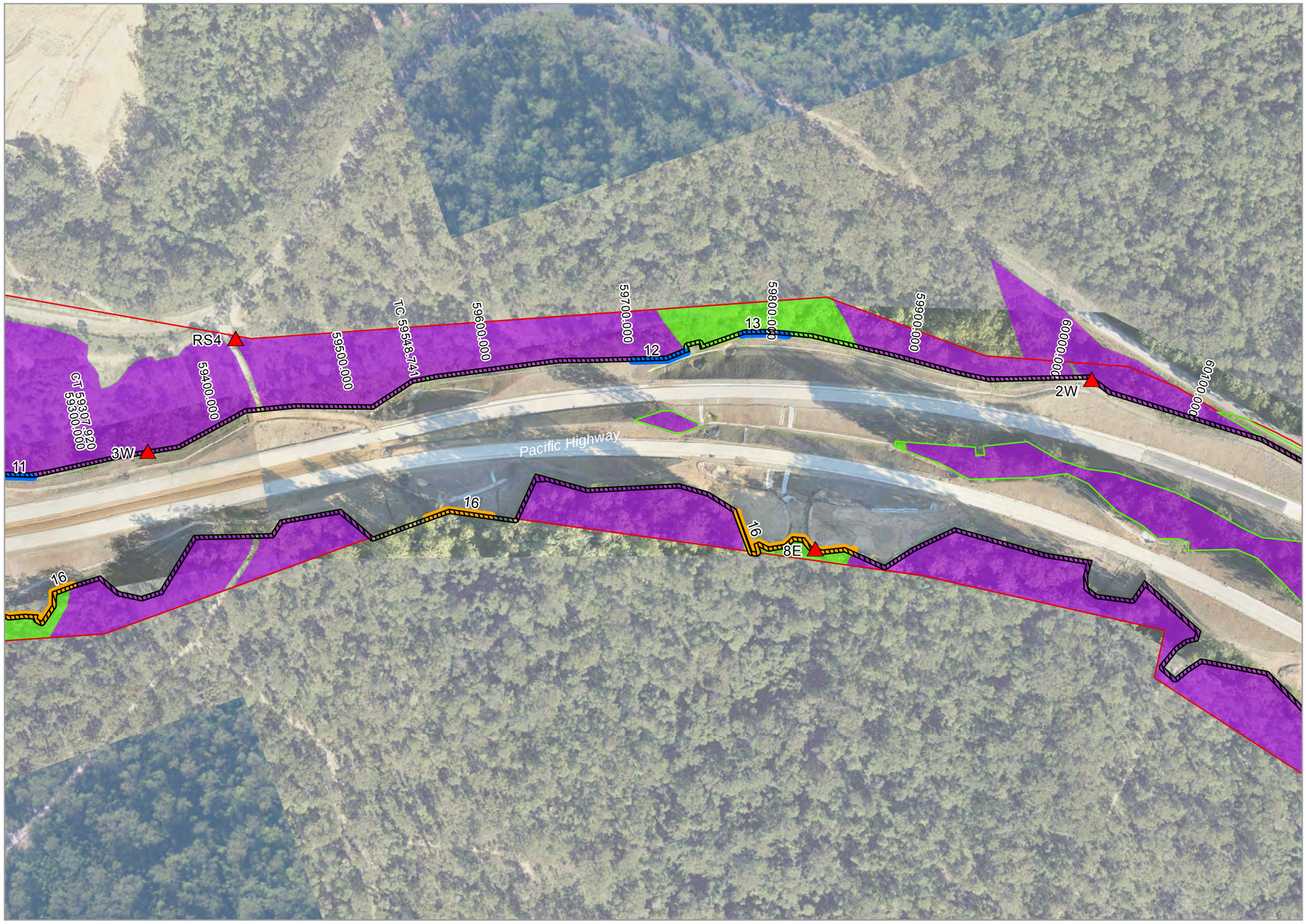
- Moist Open Forest - Flooded Gum
- Open Forest - Blackbutt

0 60

GHFF Weed Survey Areas and Weed Infestation Levels

Information shown is for illustrative purposes only

Drawn by: GJM Checked by: DSA Reviewed by: GJM Date: 27/03/2018
Source of base data: DFS&I & AFJV



LEGEND

- Project boundary
- Clearing limit
- Fixed photo point
- GHFF weed survey area

Weed Infestation Level

- Medium
- Low

Vegetation

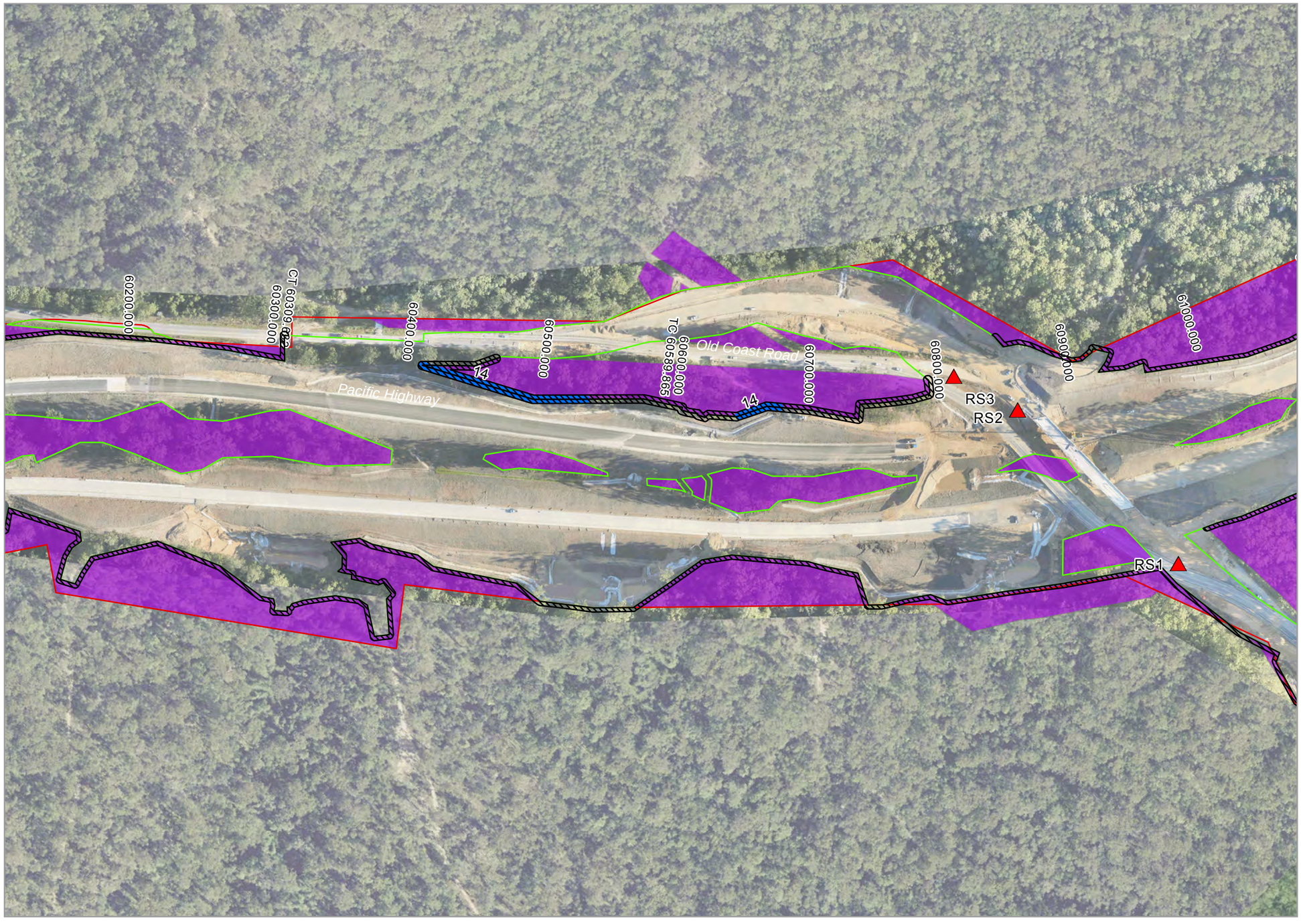
- Moist Open Forest - Flooded Gum
- Open Forest - Blackbutt

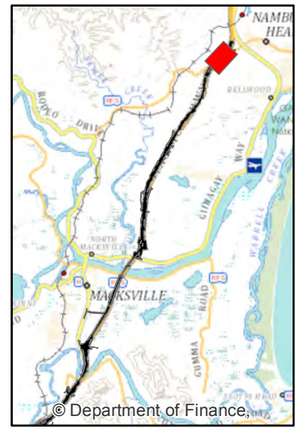
0 60

GHFF Weed Survey Areas and Weed Infestation Levels

Information shown is for illustrative purposes only

Drawn by: GJM Checked by: DSA Reviewed by: GJM Date: 27/03/2018
Source of base data: DFS&I & AFJV





LEGEND

- Project boundary
- Clearing limit
- Fixed photo point
- GHFF weed survey area

Weed Infestation Level

- Low

Vegetation

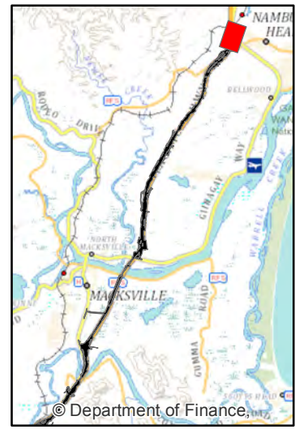
- Open Forest - Blackbutt

0 60

GHFF Weed Survey Areas and Weed Infestation Levels

Information shown is for illustrative purposes only

Drawn by: GJM Checked by: DSA Reviewed by: GJM Date: 27/03/2018
Source of base data: DFS&I & AFJV



LEGEND

- Project boundary
- Clearing limit
- GHFF weed survey area

Weed Infestation Level

- Low

Vegetation

- Open Forest - Blackbutt

0 60

GHFF Weed Survey Areas and Weed Infestation Levels

Appendix 2: Autumn 2018 Stage 2A monitoring report

GeoLINK environmental management and design

ABN 79 896 839 729
ACN 101 084 557

Return address:
PO Box 119
LENNOX HEAD
NSW 2478

LENNOX HEAD
T 02 6687 7666
F 02 6687 7782

COFFS HARBOUR
T 02 6651 7666

ARMIDALE
T 0488 677 666

LISMORE
T 02 6621 6677

www.geolink.net.au

08 June 2018
Ref No: 2692-1121

Roads and Maritime Service
124 Albert Drive
DONNELLYVILLE NSW 2447

Attention: Mr Kris Hincks

Dear Kris

WC2NH GHFF Habitat Monitoring – Autumn 2018

Introduction

This report presents the results of the second quarterly habitat monitoring event (Autumn 2018) of Grey-Headed Flying-fox (GHFF) habitat adjacent to Stage 2A section of the Warrell Creek to Nambucca Heads Highway Upgrade (WC2NH) project. Quarterly GHFF habitat monitoring is required at Stage 2A (chainage 47700 and 61300 – refer to **Appendix A**) for up to one year after the opening of this section of WC2NH to traffic.

The *Warrell Creek to Nambucca Heads Flying-fox Management P*lan (Sinclair Knight Merz, 2017) recognised that the quality of vegetation adjacent to the Project area could be detrimentally affected by invasion of noxious and environmental weeds. A main goal identified for management during operation of the Project is '*no reduction of the quality of flying-fox habitats adjacent to the Project corridor due to the operation of the Project and to minimise the impact of edge effects'* (Sinclair Knight Merz, 2017).

Methodology

The monitoring of Grey-headed Flying-fox habitat includes the following components:

1. Monitoring of identified revegetation/ rehabilitation areas to ensure the establishment/ restoration of seedlings and plants. These areas could be areas cleared in GHFF habitat for temporary ancillary facilities, access tracks, watercourse crossings, etc.

2. Monitoring both revegetation/ rehabilitation areas and other habitat areas adjacent to the Project to manage invasion of noxious and environmental weeds.

For brevity, component 1 is henceforth referred to as 'rehabilitation site monitoring', and component 2 is referred to as 'weed monitoring'.

Urban and Regional Planning | Environmental Engineering | Civil Design | Environmental Impact Assessment | Ecological Surveys and Monitoring | Landscape Architecture | Urban Design |

Field surveys were undertaken by GeoLINK ecologists Jessica O'Leary, Frank Makin and Garon Staines on:

- 22 May 2018 between 7.00 am to 4.00 pm.
- 23 May 2018 between 7.30 am to 2.30 pm.

Rehabilitation Site Monitoring

The locations of the GHFF habitat areas requiring revegetation/ rehabilitation are listed in **Table 1**. Monitoring of these areas aimed to assess the effectiveness of rehabilitation of GHFF habitat areas cleared during the construction of the Project.

Table 1 Location of GHFF Habitat Rehabilitation Sites

Habitat type	*Location*	*Site*
Open Blackbutt	CH: 59450 East	15c ancillary compound
Open Blackbutt	CH: 60800 East	Old Coast Rd Temporary Deviation

The following data was recorded for each location:

- Date and time of monitoring
- Weed abundance and composition
- Evidence of management and control of noxious and environmental weeds
- Evidence of any progressive revegetation/ rehabilitation during the construction phase using collected topsoil and seed at specific sites and to develop different successional stages of rehabilitation
- Evidence of native plant establishment of seedlings
- Identification of any of the GHFF food tree plants referred to in **Appendix B**.

Photos were also taken at the four fixed photo points associated with the rehabilitation sites (refer to **Table 2**).

Table 2 Locations of Fixed Photo Points for Rehabilitation Sites

Photo Point ID	*Photo Point GPS Coordinates**	*Corresponding Rehabilitation Site*
1RS	497441, 6610257	Old Coast Rd Temporary Deviation
2RS	497279, 6610248	Old Coast Rd Temporary Deviation
3RS	497229, 6610231	Old Coast Rd Temporary Deviation
4RS	496438, 6609098	15c ancillary compound

** UTM eastings, northings; Zone 56J*

Weed Monitoring

The Project *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) approval defined GHFF habitat as habitat consisting of:

- Swamp Mahogany/ Paperbark Swamp Forest
- Flooded Gum Moist Open Forest
- White Mahogany/ Grey Gum/ Ironbark Moist Open Forest
- Mixed Floodplain Forest
- Blackbutt Open Forest.

All instances of the above plant communities occurring along the outside of the Project clearing corridor were targeted during the field surveys. Within two metres of the cleared edge of these habitat areas the following data was recorded in relation to weeds:

- Date and time of monitoring
- Weed abundance and composition
- Evidence of management and control of noxious and environmental weeds.

Weed abundance was measured using modified Braun-Blanquet cover classes between 1 and 5: 1 (<5%), 2 (6-25%), 3 (26-50%), 4 (51-75%), and 5 (76-100%).

Weed monitoring sites were classified as per the categories in **Table 3**. Priority weed sites for management were identified based on species present and the percentage cover.

Table 3 Weed Management Priority Site Classification

Noxious/Environmental Weed Cover (%)	*Weed Management Priority Classification*
0-10	NA
11-39	Low
40-69	Medium
70-100	High

Photos were also taken at the fixed photo points established during the Summer 2018 weed monitoring. Locations of the fixed photo points are listed in **Table 4**.

Table 4 Locations of Fixed Photo Points

*Photo Point ID**	*Photo Point GPS Coordinates^*	*Notes on Photo Direction*	*Vegetation Type*	*Corresponding Weed Infestation (where relevant)*
1E	491906, 6598292	Looking north	Moist Open Forest - White Mahogany - Grey Gum	W28
1W	492671, 6600507	Looking north north-east	Swamp Forest - Swamp Mahogany / Paperbark	W1b
2E	492372, 6599033	Looking north-east	Moist Open Forest - Flooded Gum	W25
2W	496675, 6609675	Looking north-east	Open Forest - Blackbutt	-
3E	492778, 6600567	Looking south-west	Swamp Forest - Swamp Mahogany / Paperbark	W21
3W	496494, 6609010	Looking south	Open Forest - Blackbutt	-

Photo Point ID*	Photo Point GPS Coordinates^	Notes on Photo Direction	Vegetation Type	Corresponding Weed Infestation (where relevant)
4E	494575, 6605139	Looking north north-east	Swamp Forest - Swamp Mahogany / Paperbark	-
4W	496131, 6608279	Looking north-east	Moist Open Forest – Flooded Gum	W9
5E	494960, 6606206	Looking south south-west	Open Forest - Blackbutt	W17
5W	495668, 6607684	Looking north-east	Moist Open Forest – Flooded Gum	
6E	495433, 6607052	Looking north	Open Forest - Blackbutt	-
6W	494890, 6606346	Looking south south-west	Open Forest - Blackbutt	W7
7E	496240, 6608213	Looking west	Moist Open Forest – Flooded Gum	W16
7W	494355, 6604185	Looking north	Moist Open Forest - White Mahogany - Grey Gum	-
8E	496724, 6609444	Looking south south-west	Moist Open Forest – Flooded Gum	W16

** number + side of alignment heading north: E=east, W=west.*

^ UTM eastings, northings; Zone 56J.

Results and Discussion

Rehabilitation Site Monitoring

The results of the rehabilitation site monitoring are provided in **Table 5**. Photos from the four fixed photo points are shown in **Appendix C**. Plantings and/or seeding at these sites are either young or have not been undertaken (in the case of the rehabilitation site at the 15c ancillary compound).

Native seed germination is now evident at the Old Coast Rd Temporary Deviation (CH60800) with a number of native species recorded growing from the native seed mix applied on both sides of the highway alignment. Subsequent monitoring events will provide more useful data for assessing the success of these rehabilitation sites.

Table 5 Rehabilitation Site Monitoring

	Rehabilitation Site		
	Old Coast Rd Temporary Deviation		***15c ancillary compound***
	CH: 60800 West	***CH: 60800 East***	***CH: 59450 East***
Photo Point GPS Coordinates (UTM eastings, northings; Zone 56J)	Photo Point RS1: 497441, 6610257 Photo Point RS2: 497279, 6610248	Photo Point RS4: 496438, 6609098	Photo Point RS3: 497229, 6610231
Date and time	22/05/2018 – 2:30 pm – 3:30 pm		
Weed Abundance and Composition	No weed infestations were observed within the newly landscaped area.	No weed infestations were observed within trimmed, topsoiled and hydroseeded batter.	Not applicable as this area is yet to be rehabilitated.
Evidence of management and control of noxious and environmental weeds	Not applicable - site recently finished and landscaped, no weeds present at the time of monitoring.	Not applicable - site recently finished and landscaped, no weeds at the time of monitoring.	As above.
Evidence of any progressive revegetation/ rehabilitation during the construction phase using collected topsoil and seed at specific sites and to develop different successional stages of rehabilitation	It appears that the site was topsoiled and landscaped at the same time. Therefore, there was no observed progressive revegetation or successional stages of rehabilitation.	It appears that the site was topsoiled and landscaped at the same time. Therefore, there was no observed progressive revegetation or successional stages of rehabilitation.	As above.
Evidence of native establishment of seedlings and plants	Semi established native plant species have been planted as part of rehabilitation landscaping. Native seed germination is now evident with several native species growing across the rehabilitated area. These species appear to be from the Bush land Reconstruction seed mix. Native regeneration species account for <2% cover with maximum plant height to 35 cm.	Some encroachment (<1% cover) from the edge of the cleared area was recorded with Bracken Fern (*Pteridum esculentum*) and Blady Grass (*Imperata cylindrica*) beginning to recolonise the disturbed area. Very minor (<1%) native regeneration of bushland reconstruction hydroseed mix are regenerating to maximum height of 20 cm.	As above.

	Rehabilitation Site		
	Old Coast Rd Temporary Deviation		15c ancillary compound
	CH: 60800 West	CH: 60800 East	CH: 59450 East
	Identifiable species include: ■ Dusky Coral Pea (*Kennedia rubicunda*) ■ Purple Coral Pea (*Hardenbergia violacea*) ■ Pink Kunzea (*Kunzea capitata*) ■ Hickory Wattle (*Acacia falcata*) ■ Green Wattle (*Acacia irrorata*) ■ White Sally Wattle (*Acacia floribunda*) ■ Austral indigo (*Indigofera australis*) ■ Goodenia sp. likely heterophylla. The hydroseeded grass cover crop has died off.	Identifiable species include: ■ Dusky Coral Pea (*Kennedia rubicunda*) ■ Purple Coral Pea (*Hardenbergia violacea*) ■ Green Wattle (*Acacia irrorata*) ■ White Sally Wattle (*Acacia floribunda*). The hydroseeded grass cover crop has died off.	
Identification of any of the GHFF food tree species (refer to Appendix B)	Landscape plantings have included species, as identified within **Appendix B**. Natural regeneration of native species identified does not yet consist of any GHFF food tree species as referred to in **Appendix B**.	No landscape plantings had been undertaken at the time of monitoring. It appears that no landscape plantings are proposed for this area of the Old Coast Road temporary deviation rehabilitation. Natural regeneration of native species identified does not yet consist of any GHFF food tree species as referred to in **Appendix B**.	As above.

Weed Monitoring

Occurrence of noxious and/or environmental weeds was recorded at 29 sites within the edge of GHFF habitat adjacent to the Project area. These weed occurrences are shown in **Appendix A** and are listed in **Table 6**. Photographs of GHFF habitat areas taken from the fixed photo points are shown in **Appendix C.**

Only very minor changes to weed densities and composition were observed during the Autumn (May) 2018 monitoring event compared to the Summer (February) 2018 monitoring event. This was expected given the cool and dry weather conditions experienced in the weeks lead up to the Autumn survey (i.e. low growth conditions). Observed changes include

- Weed site 16 has been downgraded in some sections from medium to low infestation level and weed management priority due to a reduction in per cent of foliage cover of Lantana. Weed sites 6 and 15 have similarly been downgraded from low to NA due to a reduction in foliage cover of Lantana.
- Two weed infestations located at weed sites 16 and 19 recorded a higher ranking of weed cover. Specifically, medium cover Lantana infestations were recorded at chainage 55960 – 56080 (site 16) and chainage 60300 – 60400 (site 19).

A total of 19 noxious and environmental weed species were recorded. Lantana (*Lantana camara*), Salvinia (*Salvinia molesta*) and Blackberry (*Rubus fruticosus*) were recorded on-site and are listed as priority weed species for the North Coast of NSW under the *Biosecurity Act 2015*. The primary management duty for these is they '*must not be imported into the state or sold*'.

Lantana, Broad-leaved Paspalum (*Paspalum mandiocanum*) and Camphor Laurel (*Cinnamomum camphora*) were recorded within GHFF habitat areas at the highest density, and were also the dominant weed species in those GHFF areas that recorded a 'Medium' weed infestation level (refer to **Table 6**).

One weed site (site 25) was considered to have a high weed management priority, while 11 weed sites were considered to have a medium weed management priority (sites 5, 16 {part}, 18, 19 {part}, 20, 22, 23, 24, 26, 27 and 28). These areas should be targeted during weed management works.

No obvious changes were recorded between the Summer and Autumn fixed photo point monitoring sites (refer to **Appendix C**).

No increase in density of the exotic vines Morning Glory (*Ipomoea indica*) and Mile-a-minute (*Ipomoea cairica*) were recorded during the Autumn 2018 habitat monitoring. Both of these species have potential to inhibit native regeneration and smother the canopy of intact GHFF habitat.

Table 6 Abundance and Composition of Noxious and/or Environmental Weeds Sites

Weed Site No.	*Chainage (side of highway)*	*Autumn 2018 Weed Composition (Cover Class*)*	*GHFF Habitat Type (Plant Community)*	*Summer 2018 Weed Abundance^*	*Autumn 2018 Weed Abundance^*	*Comments*	*Evidence of Management and Control*	*Weed Management Priority*
Date and time	▪ 22 May 2018 between 7.00 am to 4.00 pm. ▪ 23 May 2018 between 7.30 am to 2.30 pm.							
1a	48400 to 48700	Lantana (2)	Moist Open Forest - White Mahogany - Grey Gum	NA	Low	Not recorded during Summer although 10-25% cover of Lantana within this area	Weed control has not yet commenced	Low
1b	49790 - 50100 (west)	Setaria (*Setaria sphacelata*) (2), Annual Ragweed (*Ambrosia artemisiifolia*) (1)	Swamp Forest - Swamp Mahogany / Paperbark	Low	Low	Majority of weed infestation concentrated on batter edge. Blue Water Lily (on swamp fringe) 40% cover in concentrated areas of open water.	Weed control has not yet commenced	Low
2	51010 - 51165 (west)	Salvinia (*Salvinia molesta*) (within open water area – approx. chainage 51020) (2)	Swamp Forest - Swamp Mahogany / Paperbark	Low	Low	Very minor Flax-leaf Fleabane (*Conyza bonariensis*), Broad-leaved Paspalum (*Paspalum mandiocanum*) and Annual Ragweed on fauna fence edge Salvinia is listed as a priority weed species for the North Coast of NSW. It must not be imported into the State or sold.	Weed control has not yet commenced	Low (this species would have minimal impact on GHFF habitat value).

Weed Site No.	Chainage (side of highway)	Autumn 2018 Weed Composition (Cover Class*)	GHFF Habitat Type (Plant Community)	Summer 2018 Weed Abundance^	Autumn 2018 Weed Abundance^	Comments	Evidence of Management and Control	Weed Management Priority
3	53750 - 53840 (west)	Broad-leaved Paspalum (2), Annual Ragweed (1), White Passionflower (*Passiflora subpeltata*) (1), Paddy's Lucerne (*Sida rhombifolia*) (1), Purple-top (*Verbena bonariensis*) (1)	Moist Open Forest - White Mahogany - Grey Gum	Low	Low		Weed control has not yet commenced	Low
4	54115 - 54150 (west)	Broad-leaved Paspalum (2), Lantana (*Lantana camara*) (1) Winter Senna (1)	Open Forest - Blackbutt	Low	Low	Setaria, Flax-leaf Fleabane and Purple-top present in very low abundance Lantana is listed as a priority weed species for the North Coast of NSW. It must not be imported into the State or sold.	Weed control has not yet commenced	Low
5	54480 - 54530, (west)	Broad-leaved Paspalum (3), Lantana (1), Wild Tobacco (*Solanum mauritianum*) (1), Flaxleaf Fleabane (1)	Open Forest - Blackbutt	Medium	Medium	-	Weed control has not yet commenced	Medium
6	55220 - 55260 (west)	Setaria (1)	Open Forest - Blackbutt	Low	NA	Weed infestation level has been downgraded due to reduction of	Weed control has not yet commenced	NA

Weed Site No.	Chainage (side of highway)	Autumn 2018 Weed Composition (Cover Class*)	GHFF Habitat Type (Plant Community)	Summer 2018 Weed Abundance^	Autumn 2018 Weed Abundance^	Comments	Evidence of Management and Control	Weed Management Priority
						foliage cover of Lantana during May monitoring period.		
7	56160 - 56360 (west)	Broad-leaved Paspalum (2), Setaria (1), Lantana (1)	Open Forest - Blackbutt	Low	Low	Lantana present in low abundance on fringe	Weed control has not yet commenced	Low
8	57370 – 57450 (west)	Lantana (1), Broad-leaved Paspalum (1)	Open Forest - Blackbutt	Low	Low	-	Weed control has not yet commenced	Low
9	58440 - 58550 (west)	Broad-leaved Paspalum (2), Lantana (1)	Flooded Gum Moist Open Forest	Low	Low	-	Weed control has not yet commenced	Low
10	58850 – 58940 (west)	Lantana (1)	Open Forest - Blackbutt	Low	Low	-	Weed control has not yet commenced	Low
11	59200 - 59250, (west)	Broad-leaved Paspalum (1)	Open Forest - Blackbutt	Low	Low	-	Weed control has not yet commenced	Low
12	59700 - 59740 (west)	Broad-leaved Paspalum (2)	Open Forest - Blackbutt	Low	Low	-	Weed control has not yet commenced	Low
13	59780 - 59810 (west)	Broad-leaved Paspalum (2)	Flooded Gum Moist Open Forest	Low	Low	-	Weed control has not yet commenced	Low
14	60400 - 60540, 60640 –	Broad-leaved Paspalum (2), Morning Glory	Open Forest - Blackbutt	Low	Low	Some sections without GHFF habitat (old hardstand area and	Weed control has not yet commenced	Low

Weed Site No.	Chainage (side of highway)	Autumn 2018 Weed Composition (Cover Class*)	GHFF Habitat Type (Plant Community)	Summer 2018 Weed Abundance^	Autumn 2018 Weed Abundance^	Comments	Evidence of Management and Control	Weed Management Priority
	60665 (west)	(*Ipomoea indica*) (1), Rhodes Grass (*Chloris gayana*) (1), Winter Senna (*Senna septemtrionalis*) (1), Blue Billygoat (1)				stockpile site).		
15	61240 – 61260 (east)	Lantana (1)	Open Forest - Blackbutt	Low	NA	Weed infestation level has been downgraded due to reduction of foliage cover of Lantana (<2%) during May monitoring period.	Weed control has not yet commenced	NA
16	60570 - 60600	Lantana (3), Broad-leaved Paspalum (1), Blue Billy-goat Weed (*Ageratum houstonianum*) (1)	Flooded Gum Moist Open Forest	Medium	Low	All chainage sections have been downgraded to low (10 – 25% cover) (in May) from medium (in February) levels of Lantana. With the exception of one newly recorded section, between 60300 and 60400, where the infestation level of Lantana is Medium.	Weed control has not yet commenced	Low
	60300 - 60400			NA	Medium Lantana			Medium
	60040 - 60060			NA	Low			Low
	59780 - 59850			Medium	Low			Low
	59550 - 59590			Medium	Low			Low
	59200 - 59260			Medium	Low			Low
	59000 - 59080			Medium	Low			Low

Weed Site No.	Chainage (side of highway)	Autumn 2018 Weed Composition (Cover Class*)	GHFF Habitat Type (Plant Community)	Summer 2018 Weed Abundance^	Autumn 2018 Weed Abundance^	Comments	Evidence of Management and Control	Weed Management Priority
	58470 – 58550			Medium	Low			Low
	58050 - 58110			Medium	Low			Low
	57650 - 57770			Medium	Low			Low
	57210 - 57250 (east)			Medium	Low			Low
17	56100 – 56420 (east)	Broad-leaved Paspalum (3), Lantana (2)	Open Forest - Blackbutt Flooded Gum Moist Open Forest	Low	Low	Mostly intact native canopy but more scattered trees around big house in north. Lower weed cover in south.	Weed control has not yet commenced	Low
18	56420 – 56580 (east)	Broad-leaved Paspalum (4), Lantana (2)	Open Forest - Blackbutt	Medium	Medium	Very weedy understorey in north around big house. Very weedy north section.	Weed control has not yet commenced	Medium
19	55960 - 56080	Lantana (2), Broad-leaved Paspalum (2), Setaria (1)	Open Forest Blackbutt	Low	Medium	The northernmost 100 m of this survey area has been upgraded to a medium infestation level of Lantana and Broad-leaved Paspalum	Weed control has not yet commenced	Medium
	55630 – 56080 (east)			Low	low			Low
20	52980 – 53040 (east)	Lantana (1), Mile a Minute (*Ipomoea cairica*) (1), Groundsel Bush (*Baccharis*	Swamp Forest - Swamp Mahogany / Paperbark	Medium	Medium	-	Weed control has not yet commenced	Medium

Weed Site No.	Chainage (side of highway)	Autumn 2018 Weed Composition (Cover Class*)	GHFF Habitat Type (Plant Community)	Summer 2018 Weed Abundance^	Autumn 2018 Weed Abundance^	Comments	Evidence of Management and Control	Weed Management Priority
		halimifolia) (1), Annual Ragweed (1), Setaria (1)						
21	49830 - 50220 (east)	Vasey Grass (*Paspalum urvillei*) (2), Setaria (1)	Swamp Forest - Swamp Mahogany / Paperbark	Low	Low	Broad-leaved Paperbark open forest in good condition including understorey except for some sections with Blue Water Lily and some minor incursions of weedy grasses along fence.	Weed control has not yet commenced	Low
22	49560 – 49670 (east)	Broad-leaved Paspalum (4), Lantana (1)	Moist Open Forest - White Mahogany - Grey Gum	Medium	Medium	-	Weed control has not yet commenced	Medium
23	49030 - 49070 (east)	Broad-leaved Paspalum (5), Camphor Laurel (*Cinnamomum camphora*) (1)	Flooded Gum Moist Open Forest	High	High	Scattered native overstorey of Hard Quandong, Foambark, Broad-leaved Paperbark, with few shrubs and groundcover dominated by Broad-leaved Paspalum.	Weed control has not yet commenced	Medium
24	48430 - 48550 (east)	Broad-leaved Paspalum (5)	Moist Open Forest - Flooded Gum	High	High	Scattered overstorey of Flooded Gum, Guioa, Broad-leaved Paperbark, but lack of shrub layer and ground cover dominated by Broad-	Weed control has not yet commenced	Medium

Weed Site No.	Chainage (side of highway)	Autumn 2018 Weed Composition (Cover Class*)	GHFF Habitat Type (Plant Community)	Summer 2018 Weed Abundance^	Autumn 2018 Weed Abundance^	Comments	Evidence of Management and Control	Weed Management Priority
						leaved Paspalum		
25	48260 – 48380 (east)	Lantana (5), Broad-leaved Paspalum (2), Mile a Minute (1), Winter Senna (*Senna septemtrionalis*) (1).	Moist Open Forest - Flooded Gum	High	High	Mostly intact overstorey dominated by Flooded Gum with some River Oak on edge creek. Understorey dominated by weeds mostly Lantana.	Weed control has not yet commenced	High
26	47800 – 47832 (east)	Lantana (2), Wild Tobacco (2), Setaria (1), White Passionflower (1)	Open Forest Blackbutt	Medium	Medium	-	Weed control has not yet commenced	Medium
27	47510 – 47530 (east)	Broad-leaved Paspalum (3), Camphor Laurel (2), Purple Top (2), Wild Tobacco (2)	Moist Open Forest – White Mahogany – Grey Gum	Medium	Medium	-	Weed control has not yet commenced	Medium
28	47450 – 47490 (east)	Camphor Laurel (2), Broad-leaved Paspalum (2), Lantana (2), Blackberry (*Rubus fruticosus*) (1), Narrow-leaved Privet (*Ligustrum sinense*) (1)	Moist Open Forest - White Mahogany - Grey Gum	Medium	Medium	Blackberry is listed as a priority weed species for the North Coast of NSW. It must not be imported into the State or sold.	Weed control has not yet commenced	Medium

** Modified Braun-Blanquet cover classes of 1=<5%, 2=6-25%, 3=26-50%, 4=51-75%, and 5=76-100%; ^ Refer to **Table 3***

Recommendations and Conclusions

Weed sites 25, 16, 19, 20, 26 and 28 are important target weed management areas to reduce degradation to GHFF habitat. At these sites, there is the potential for Lantana to alter community structure and inhibit regeneration.

Weed sites with dense Broad-leaved Paspalum (sites 5, 18, 22, 23, 24 and 27) should be considered a somewhat lower priority for management than sites comprising medium infestations of Lantana for the following reasons:

- There may be a lower likelihood of weed management success (it is difficult to remove this species successfully from degraded communities that have a suitable semi-shaded understorey environment); and
- Being an understorey weed species that occurs in disturbed environments and edges, Broad-leaved Paspalum has a low potential to alter either the structure or regeneration potential, and hence the quality of relatively intact GHFF habitat.

Future monitoring should continue to identify any significant increase in the density of the exotic vines (including Morning Glory and Mile-a-minute) which have the potential to inhibit native regeneration and smother the canopy of intact GHFF habitat.

Please contact the undersigned if require any further information.

Yours sincerely
GeoLINK

Jessica O'Leary
Ecologist

References

Sinclair Knight Merz (2017). *Warrell Creek to Nambucca Heads Upgrade of the Pacific Highway; Flying-fox Management Plan.* Report to Roads and Maritime Services.

Issue Log

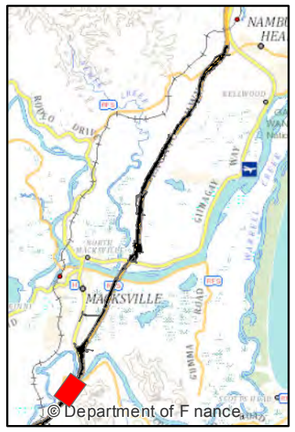
UPR	*Description*	*Date issued*	*Issued By*
2692-1114	First issue (draft)	28/05/2018	David Andrighetto
2692-1116	Second issue (final)	30/05/2018	David Andrighetto
2692-1121	Third issue (amended final)	08/06/2018	David Andrighetto

Appendix A

GHFF Weed Survey Areas and Weed Infestation Levels (Autumn 2018)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: JOL Reviewed by: DSA Date: 24/05/2018
Source of base data: DFS&I & AFJV



LEGEND

- Project boundary
- Clearing limit
- Fixed photo point
- GHFF weed survey area

Weed Management Priority

- High
- Medium

Vegetation

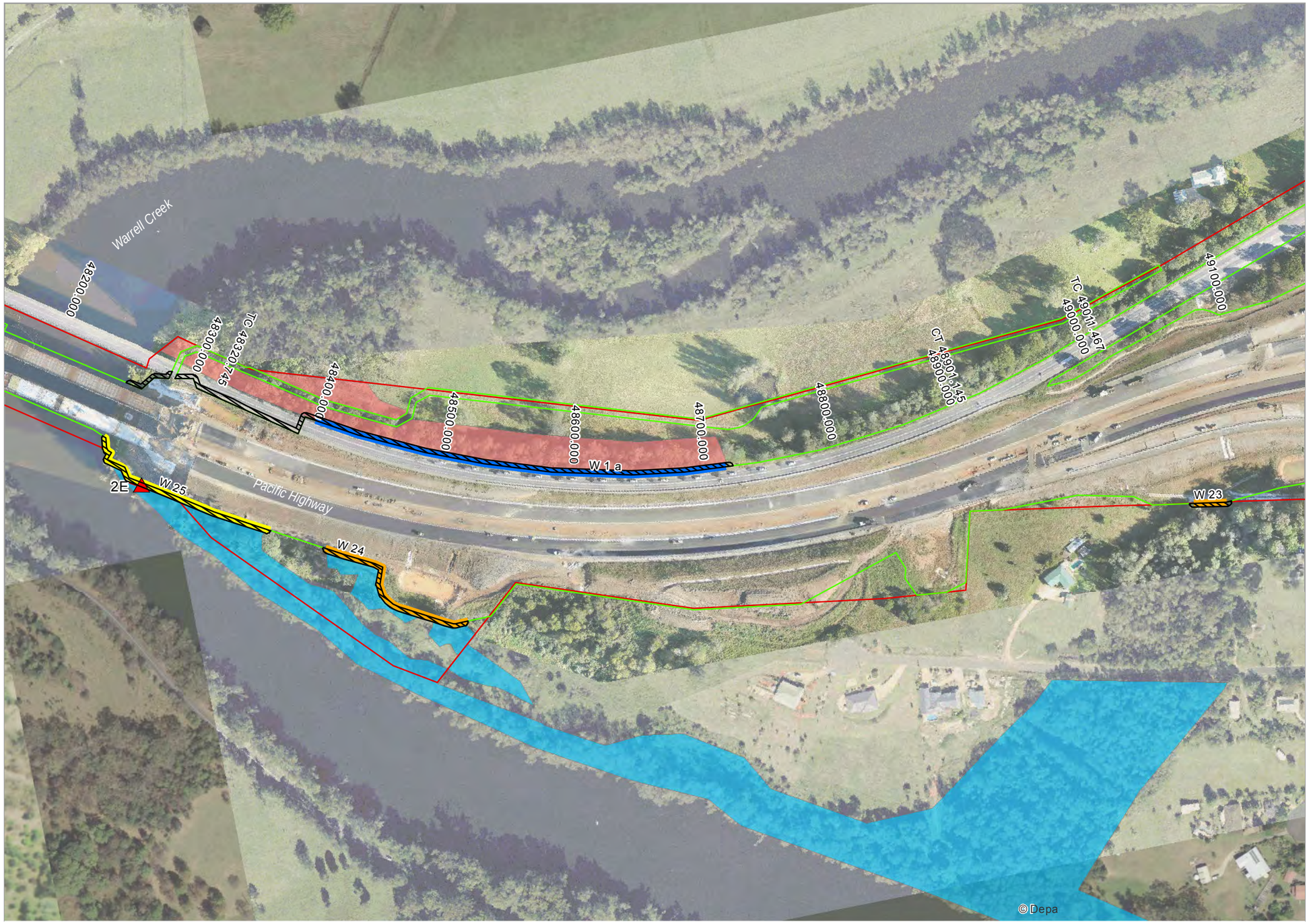
- Mixed Floodplain Forest (EEC)
- Moist Open Forest - White Mahogany - Grey Gum

0 60

GHFF Weed Survey Areas and Weed Infestation Levels

Information shown is for illustrative purposes only

Drawn by: AB Checked by: JOL Reviewed by: DSA Date: 24/05/2018
Source of base data: DFS&I & AFJV



LEGEND

- Project boundary
- Clearing limit
- Fixed photo point
- GHFF weed survey area

Weed Management Priority

- High
- Medium
- Low

Vegetation

- Mixed Floodplain Forest (EEC)
- Moist Open Forest - White Mahogany - Grey Gum

0 60

GeoLINK environmental management and design

WC2NH GHFF Habitat Monitoring – Autumn 2018
2692-1121

GHFF Weed Survey Areas and Weed Infestation Levels

Information shown is for illustrative purposes only

Drawn by: AB Checked by: JOL Reviewed by: DSA Date: 24/05/2018
Source of base data: DFS&I & AFJV

LEGEND

- Project boundary
- Clearing limit
- Fixed photo point
- GHFF weed survey area

Weed Management Priority

- Medium
- Low

Vegetation

- Mixed Floodplain Forest (EEC)
- Moist Open Forest - White Mahogany - Grey Gum
- Swamp Forest - Swamp Mahogany/ Paperbark EEC

0 60

GeoLINK environmental management and design

WC2NH GHFF Habitat Monitoring – Autumn 2018
2692-1121

GHFF Weed Survey Areas and Weed Infestation Levels

SHEET 3 OF 17

Information shown is for illustrative purposes only

Drawn by: AB Checked by: JOL Reviewed by: DSA Date: 24/05/2018
Source of base data: DFS&I & AFJV

LEGEND

- Project boundary
- Clearing limit
- Fixed photo point
- GHFF weed survey area

Weed Management Priority

- Low

Vegetation

- Swamp Forest - Swamp Mahogany/ Paperbark EEC

0 60

GHFF Weed Survey Areas and Weed Infestation Levels

Information shown is for illustrative purposes only

Drawn by: AB Checked by: JOL Reviewed by: DSA Date: 24/05/2018
Source of base data: DFS&I & AFJV

LEGEND

- Project boundary
- Clearing limit
- GHFF weed survey area

Weed Management Priority

- Low

Vegetation

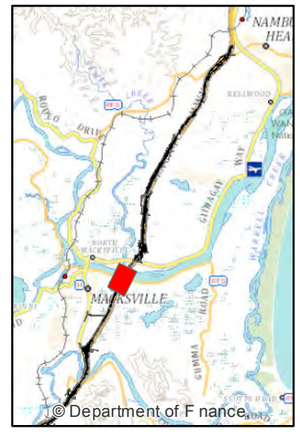
- Swamp Forest - Swamp Mahogany/ Paperbark EEC

0 60

GHFF Weed Survey Areas and Weed Infestation Levels

Information shown is for illustrative purposes only

Drawn by: AB Checked by: JOL Reviewed by: DSA Date: 24/05/2018
Source of base data: DFS&I & AFJV



LEGEND

- Project boundary
- Clearing limit
- GHFF weed survey area

Vegetation

- Mixed Floodplain Forest (EEC)
- Swamp Forest - Swamp Mahogany/ Paperbark EEC

0 60

GeoLINK environmental management and design

WC2NH GHFF Habitat Monitoring – Autumn 2018
2692-1121

GHFF Weed Survey Areas and Weed Infestation Levels

SHEET 6 OF 17

Information shown is for illustrative purposes only

Drawn by: AB Checked by: JOL Reviewed by: DSA Date: 24/05/2018
Source of base data: DFS&I & AFJV

LEGEND

- Project boundary
- Clearing limit
- GHFF weed survey area

Weed Management Priority

- Medium

Vegetation

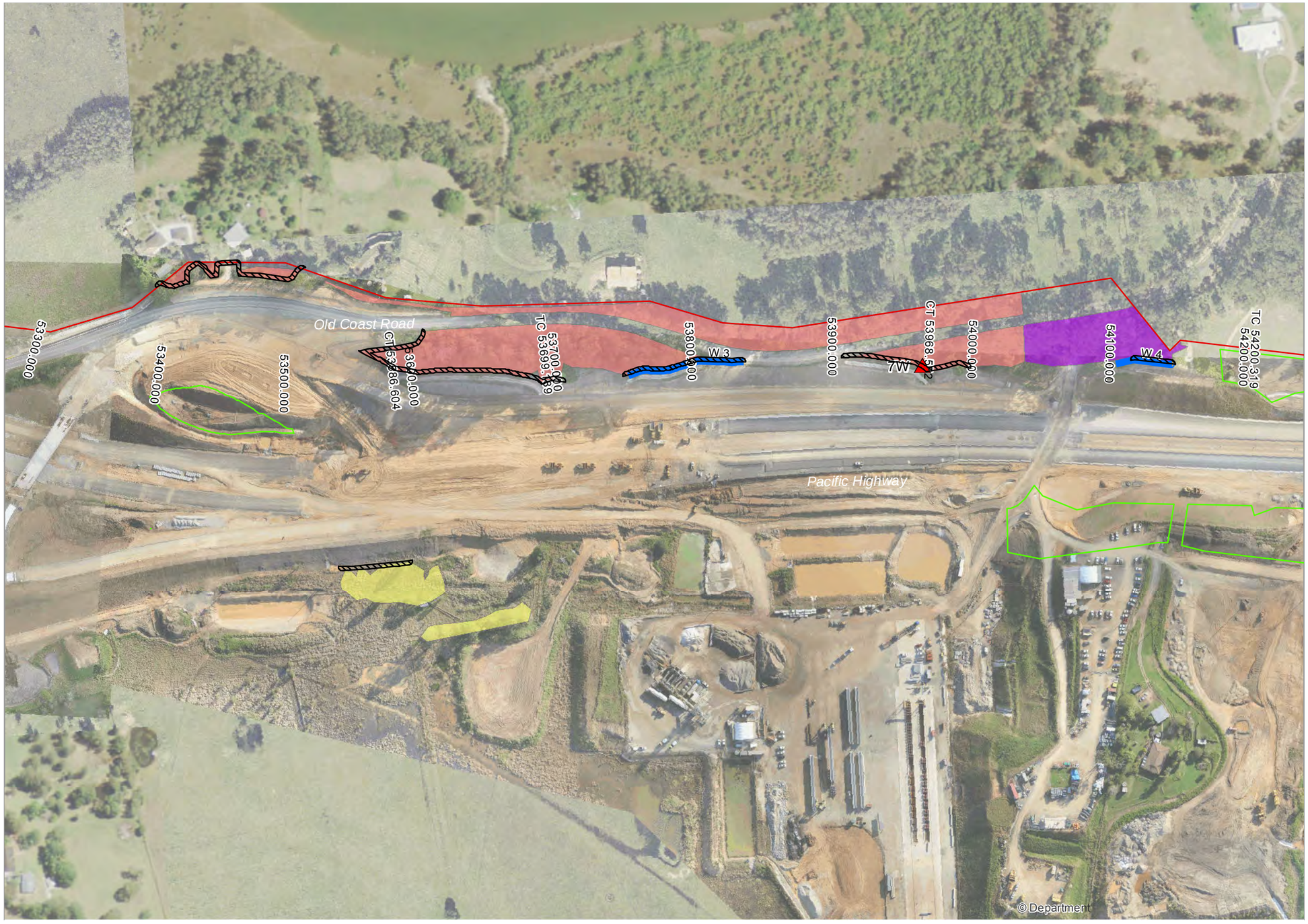
- Moist Open Forest - White Mahogany - Grey Gum
- Swamp Forest - Swamp Mahogany/ Paperbark EEC

0 60

GHFF Weed Survey Areas and Weed Infestation Levels

Information shown is for illustrative purposes only

Drawn by: AB Checked by: JOL Reviewed by: DSA Date: 24/05/2018
Source of base data: DFS&I & AFJV



LEGEND

- Project boundary
- Clearing limit
- Fixed photo point
- GHFF weed survey area

Weed Management Priority

- Low

Vegetation

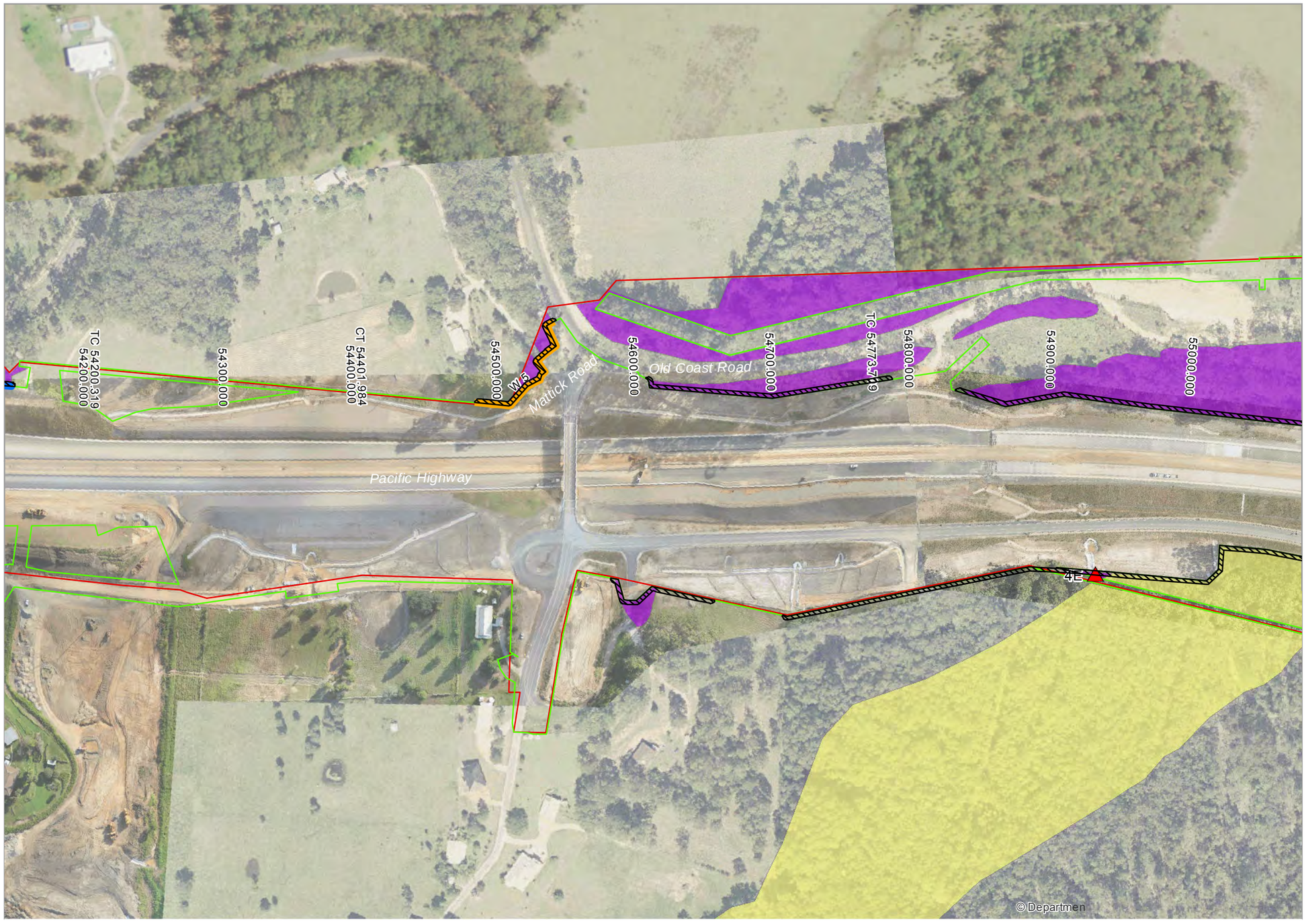
- Moist Open Forest - White Mahogany - Grey Gum
- Open Forest - Blackbutt
- Swamp Forest - Swamp Mahogany/ Paperbark EEC

0 60

GHFF Weed Survey Areas and Weed Infestation Levels

Information shown is for illustrative purposes only

Drawn by: AB Checked by: JOL Reviewed by: DSA Date: 24/05/2018
Source of base data: DFS&I & AFJV



LEGEND

- Project boundary
- Clearing limit
- Fixed photo point
- GHFF weed survey area

Weed Management Priority

- Medium
- Low

Vegetation

- Open Forest - Blackbutt
- Swamp Forest - Swamp Mahogany/ Paperbark EEC

0 60

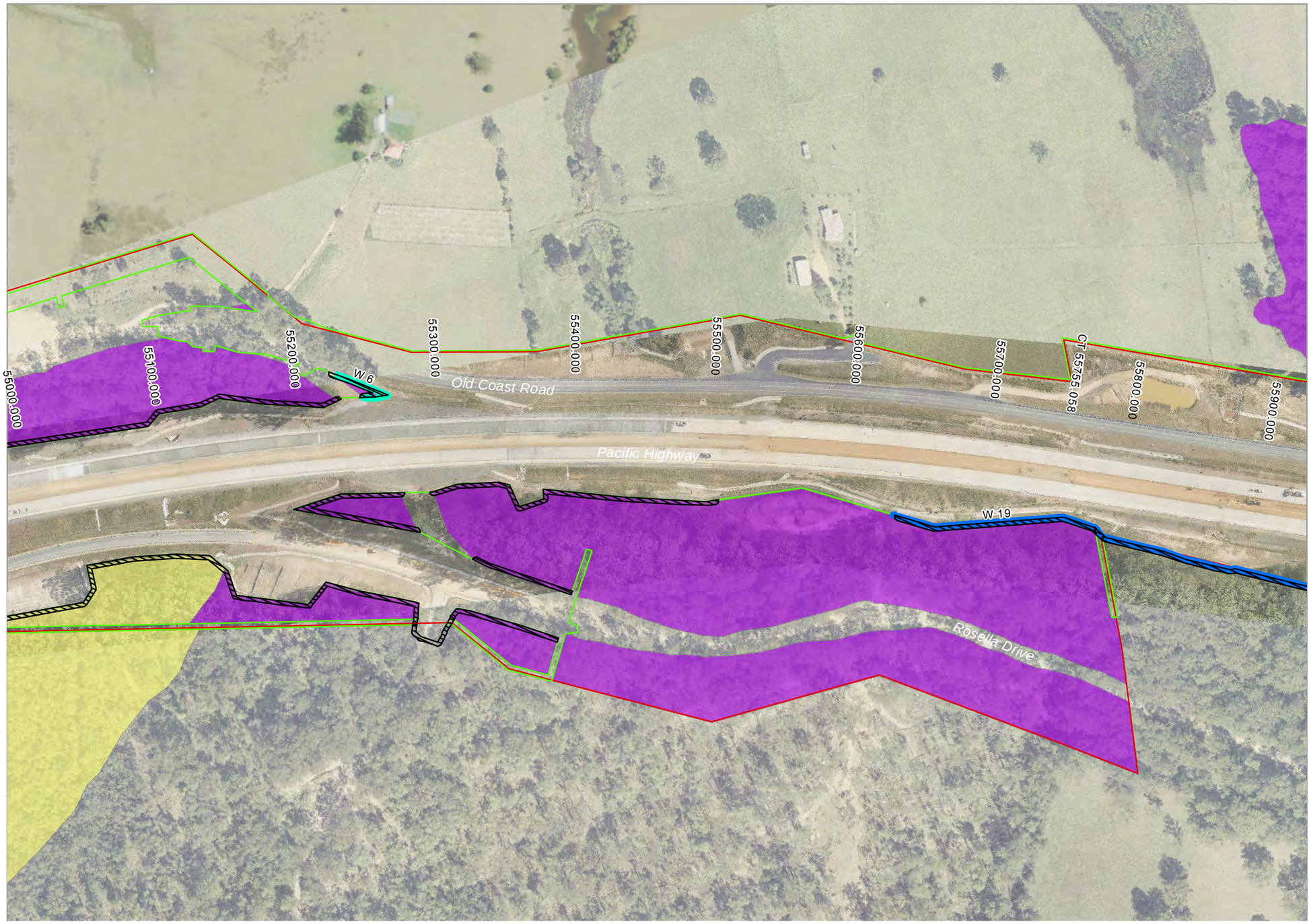
GeoLINK environmental management and design

WC2NH GHFF Habitat Monitoring – Autumn 2018
2692-1121

GHFF Weed Survey Areas and Weed Infestation Levels

Information shown is for illustrative purposes only

Drawn by: AB Checked by: JOL Reviewed by: DSA Date: 24/05/2018
Source of base data: DFS&I & AFJV



LEGEND

- Project boundary
- Clearing limit
- GHFF weed survey area

Weed Management Priority

- Low
- N/A

Vegetation

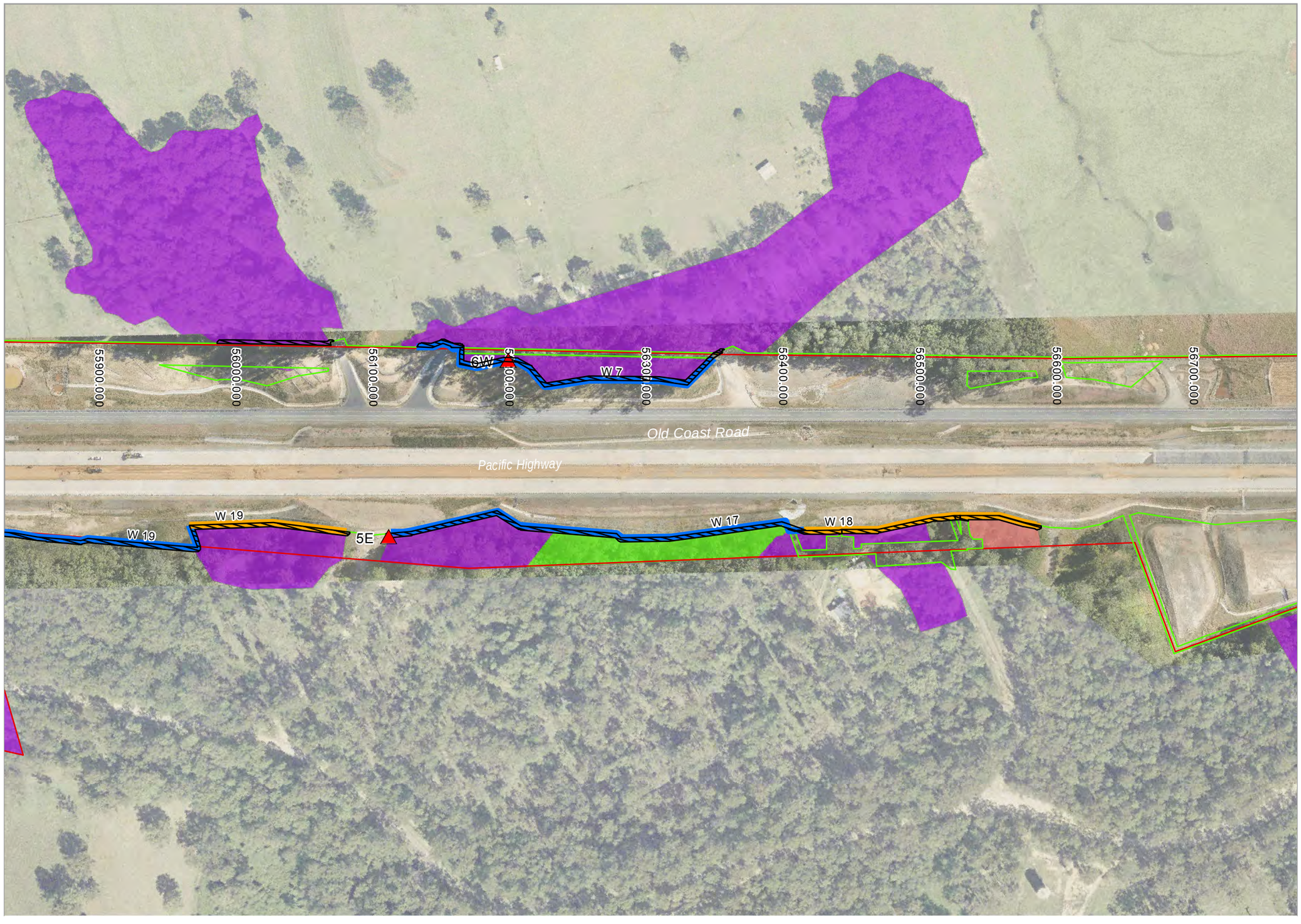
- Open Forest - Blackbutt
- Swamp Forest - Swamp Mahogany/ Paperbark EEC

0 60

GHFF Weed Survey Areas and Weed Infestation Levels

Information shown is for illustrative purposes only

Drawn by: AB Checked by: JOL Reviewed by: DSA Date: 24/05/2018
Source of base data: DFS&I & AFJV



LEGEND

- Project boundary
- Clearing limit
- Fixed photo point
- GHFF weed survey area

Weed Management Priority

- Medium
- Low

Vegetation

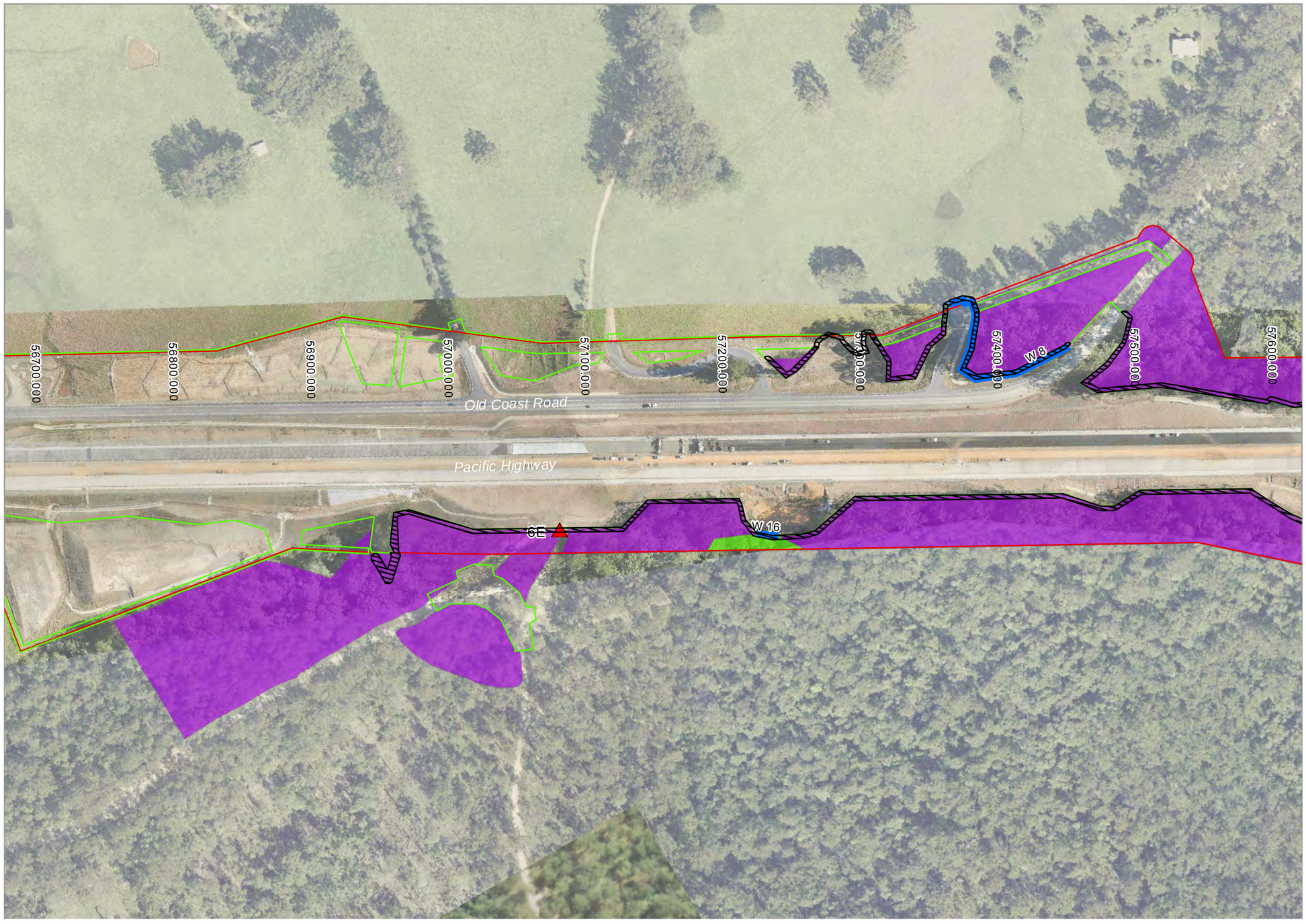
- Moist Open Forest - Flooded Gum
- Moist Open Forest - White Mahogany - Grey Gum
- Open Forest - Blackbutt

0 60

GHFF Weed Survey Areas and Weed Infestation Levels

Information shown is for illustrative purposes only

Drawn by: AB Checked by: JOL Reviewed by: DSA Date: 24/05/2018
Source of base data: DFS&I & AFJV



LEGEND

- Project boundary
- Clearing limit
- Fixed photo point
- GHFF weed survey area

Weed Management Priority

- Low

Vegetation

- Moist Open Forest - Flooded Gum
- Open Forest - Blackbutt

0 60

GeoLINK environmental management and design

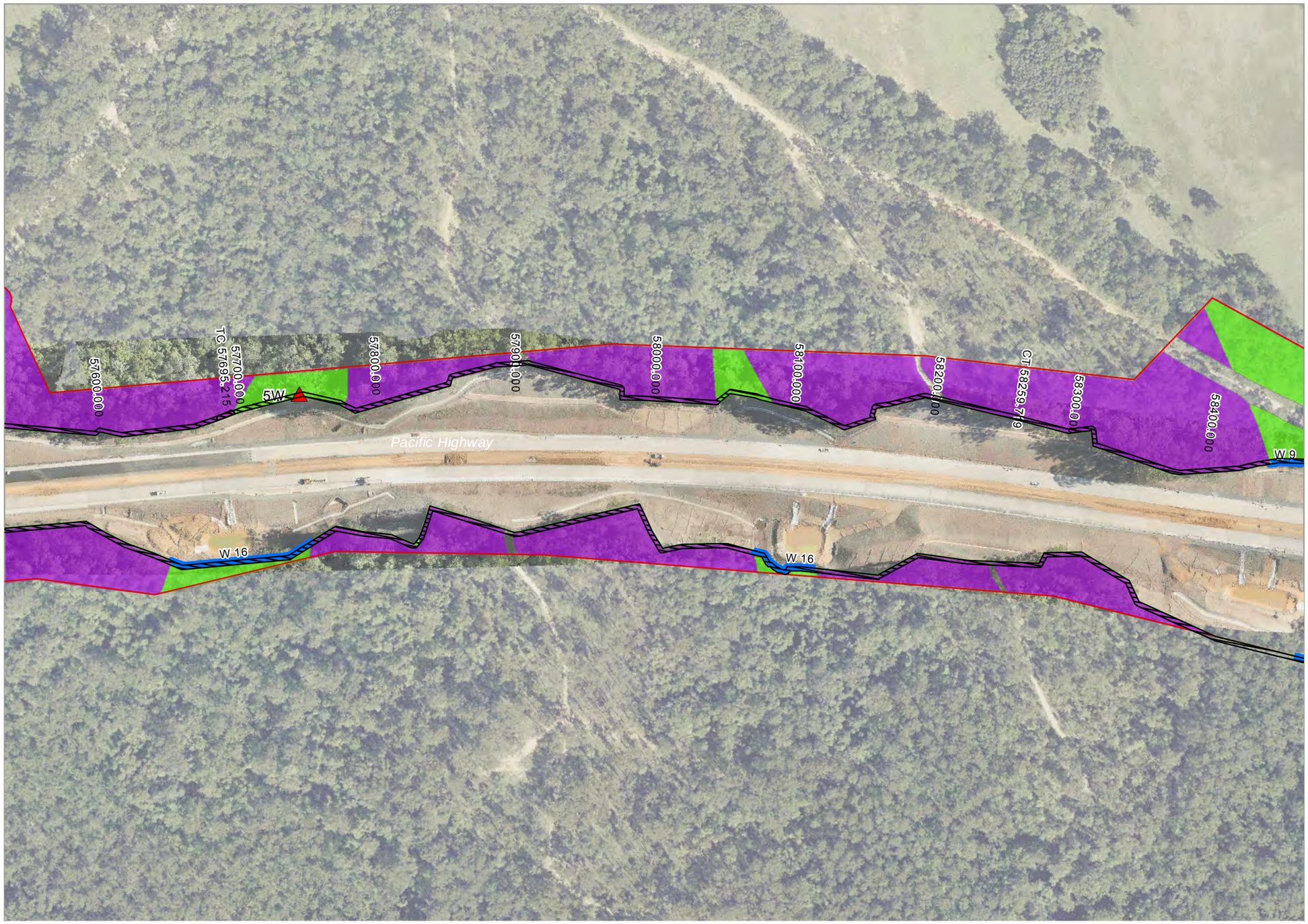
WC2NH GHFF Habitat Monitoring – Autumn 2018
2692-1121

GHFF Weed Survey Areas and Weed Infestation Levels

SHEET 12 OF 17

Information shown is for illustrative purposes only

Drawn by: AB Checked by: JOL Reviewed by: DSA Date: 24/05/2018
Source of base data: DFS&I & AFJV



LEGEND

- Project boundary
- Clearing limit
- Fixed photo point
- GHFF weed survey area

Weed Management Priority

- Low

Vegetation

- Moist Open Forest - Flooded Gum
- Open Forest - Blackbutt

0 60

GHFF Weed Survey Areas and Weed Infestation Levels

Information shown is for illustrative purposes only

Drawn by: AB Checked by: JOL Reviewed by: DSA Date: 24/05/2018
Source of base data: DFS&I & AFJV

LEGEND

- Project boundary
- Clearing limit
- Fixed photo point
- GHFF weed survey area

Weed Management Priority

- Low

Vegetation

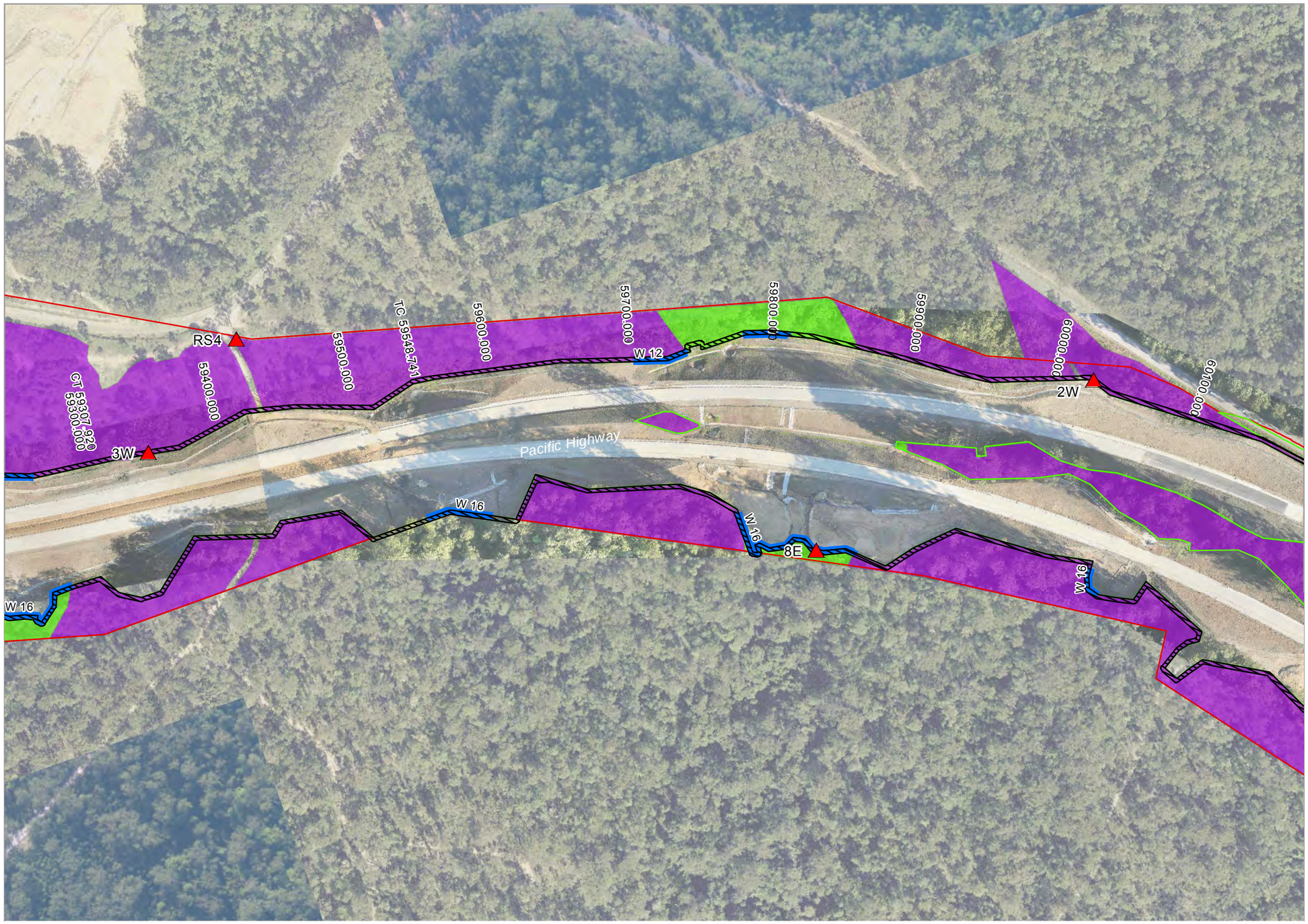
- Moist Open Forest - Flooded Gum
- Open Forest - Blackbutt

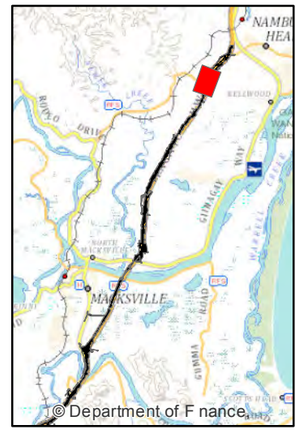
0 60

GHFF Weed Survey Areas and Weed Infestation Levels

Information shown is for illustrative purposes only

Drawn by: AB Checked by: JOL Reviewed by: DSA Date: 24/05/2018
Source of base data: DFS&I & AFJV





LEGEND

- Project boundary
- Clearing limit
- Fixed photo point
- GHFF weed survey area

Weed Management Priority

- Low

Vegetation

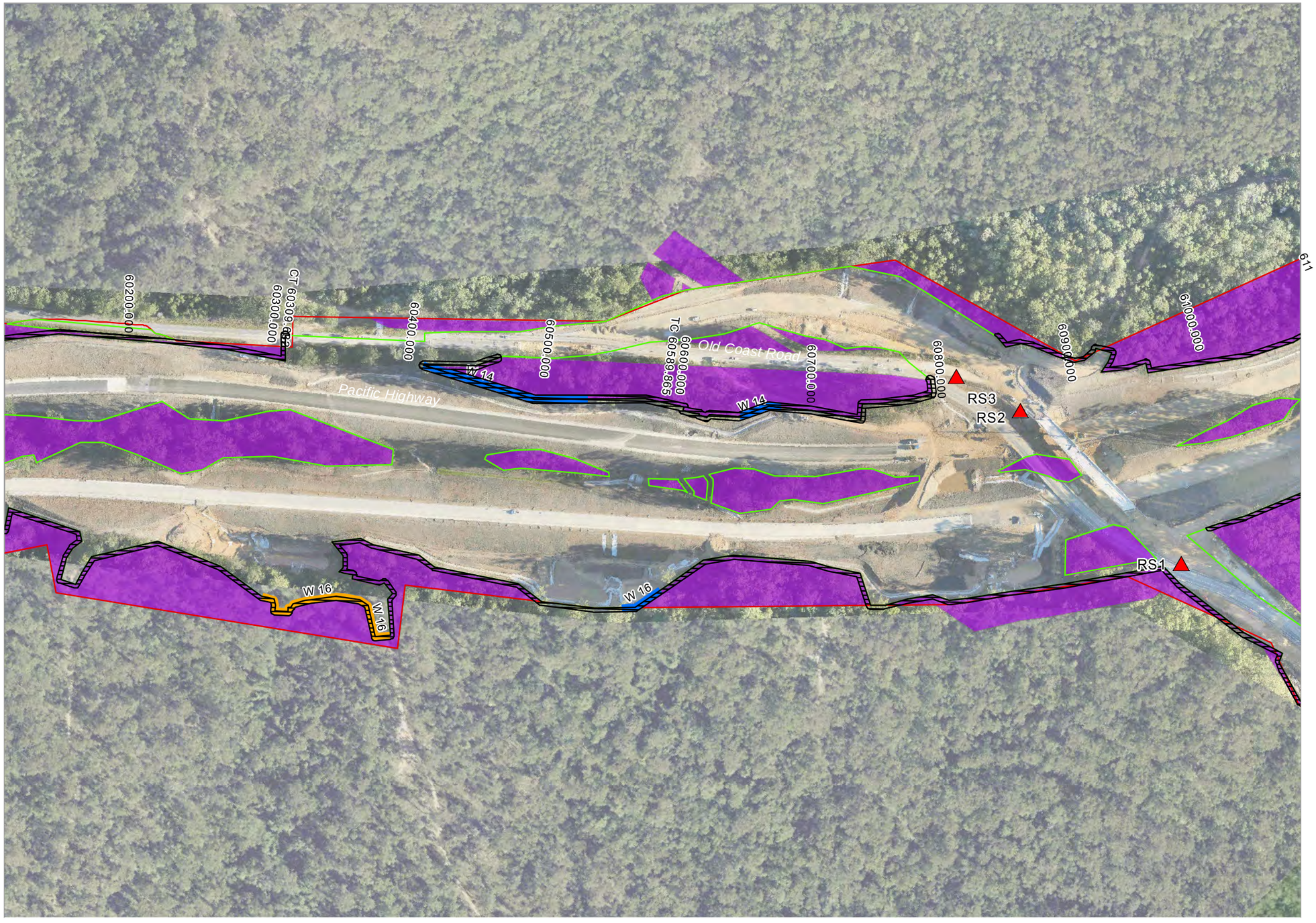
- Moist Open Forest - Flooded Gum
- Open Forest - Blackbutt

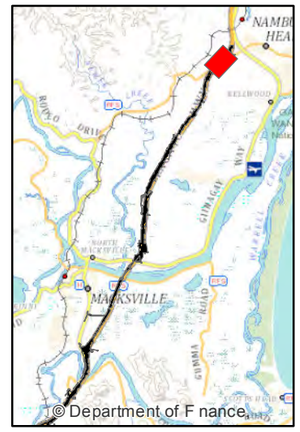
0 60

GHFF Weed Survey Areas and Weed Infestation Levels

Information shown is for illustrative purposes only

Drawn by: AB Checked by: JOL Reviewed by: DSA Date: 24/05/2018
Source of base data: DFS&I & AFJV





LEGEND

- Project boundary
- Clearing limit
- Fixed photo point
- GHFF weed survey area

Weed Management Priority

- Medium
- Low

Vegetation

- Open Forest - Blackbutt

0 60

GHFF Weed Survey Areas and Weed Infestation Levels

Information shown is for illustrative purposes only

Drawn by: AB Checked by: JOL Reviewed by: DSA Date: 24/05/2018
Source of base data: DFS&I & AFJV

LEGEND

- Project boundary
- Clearing limit
- GHFF weed survey area

Weed Management Priority

- N/A

Vegetation

- Open Forest - Blackbutt

0 60

GHFF Weed Survey Areas and Weed Infestation Levels

Appendix B

GHFF Food Trees Species List

GHFF primary food tree species (blossom diet)			
Banksia integrifolia	Coastal Banksia	*Eucalyptus robusta*	Swamp Mahogany
Corymbia gummifera	Red Bloodwood	*Eucalyptus saligna*	Sydney Blue Gum
Corymbia intermedia	Pink Bloodwood	*Eucalyptus siderophloia*	Northern Grey Ironbark
Corymbia maculata	Spotted Gum	*Eucalyptus tereticornis*	Forest Red Gum
Corymbia variegata	Spotted Gum	*Grevillea robusta*	Silky Oak
Castanospermum australe	Black Bean	*Melaleuca quinquenervia*	Broad-leaved Paperbark
Eucalyptus pilularis	Blackbutt	*Syncarpia glomulifera*	Turpentine
GHFF secondary food tree species (blossom diet)			
Angophora costata	Smooth-barked Apple	*Eucalyptus grandis*	Flooded Gum
Angophora floribunda	Rough-barked Apple	*Eucalyptus propinqua*	Grey Gum
Eucalyptus acmenoides	White Mahogany	*Eucalyptus resinifera*	Red Mahogany
GHFF food tree species (fruit diet)			
Acmena smithii	Lilly Pilly	*Hedycarya angustifolia*	Native Mulberry
Alphitonia excelsa	Red Ash	*Livistona australis*	Cabbage Palm
Archontophoenix cunninghamiana	Bangalow Palm	*Maclura cochinchinensis*	Cockspur Thorn
Avicennia marina	Grey Mangrove	*Melia azedarach*	White Cedar
Cissus hypogaluca	Five-leaf Water Vine	*Melodinus australis*	Southern Melodinus
Dendrocnide excelsa	Giant Stinging Tree	*Morinda jasminoides*	Morinda
Dendrocnide photinophylla	Shining-lved Stinging Tree	*Pennantia cunninghamii*	Brown Beech
Diospyros pentamera	Myrtle Ebony	*Pittosporum undulatum*	Sweet Pittosporum
Diploglottis australis	Native Tamarind	*Planchonella australis*	Black Apple
Eucalyptus reticulatus	Blueberry Ash	*Podocarpus elatus*	Plum Pine
Ehretia acuminata	Koda	*Polyosma cunninghamii*	Featherwood
Elaeocarpus obovatus	Hard Quandong	*Rauwenhoffia leichardtii*	Zig Zag Vine
Ficus coronata	Creek Sandpaper Fig	*Rhodamnia argentea*	Malletwood
Ficus fraseri	Sandpaper Fig	*Syzygium australe*	Brush Cherry
Ficus macrophylla	Moreton Bay Fig	*Syzygium corynanthum*	Sour Cherry
Ficus obliqua	Small-leaved Fig	*Syzygium crebrinerve*	Purple Cherry
Ficus rubiginosa	Rusty Fig	*Syzygium luehmanii*	Riberry
Ficus superba	Deciduous Fig	*Syzygium. oleosum*	Blue Lilly Pilly
Ficus watkinsiana	Strangler Fig	*Schizomeria ovata*	Crabapple

Appendix C

Fixed Photo Point Results

Table C1 Rehabilitation Site Photo Points

Photo Monitoring Point Location	*Site Rehabilitation Summer Monitoring Event – February 2018*	*Site Rehabilitation Autumn Monitoring Event – May 2018*
CH: 60800 West - Photo Point RS1 – view to the south		

Photo Monitoring Point Location	*Site Rehabilitation Summer Monitoring Event – February 2018*	*Site Rehabilitation Autumn Monitoring Event – May 2018*
CH: 60800 West - Photo Point RS1 – view to the north-east		

Photo Monitoring Point Location	*Site Rehabilitation Summer Monitoring Event – February 2018*	*Site Rehabilitation Autumn Monitoring Event – May 2018*
CH: 60800 West - Photo Point RS2 – view to the south-west		

Photo Monitoring Point Location	*Site Rehabilitation Summer Monitoring Event – February 2018*	*Site Rehabilitation Autumn Monitoring Event – May 2018*
CH: 59450 East - Photo Point RS3 - view to the east, no rehabilitation works started at time of monitoring.		

Photo Monitoring Point Location	*Site Rehabilitation Summer Monitoring Event – February 2018*	*Site Rehabilitation Autumn Monitoring Event – May 2018*
CH: 59450 East - Site reference photo view to the west looking towards Photo Point #3, no rehabilitation works started at time of monitoring.		

Photo Monitoring Point Location	*Site Rehabilitation Summer Monitoring Event – February 2018*	*Site Rehabilitation Autumn Monitoring Event – May 2018*
CH: 60800 East - Photo Point RS4 - view to the west (no peg installed)		

Table C2 Weed Monitoring Fixed Photo Points

*Photo Point ID **	*Photo Point GPS Coordinates^*	*February 2018 photograph*	*May 2018 photograph*
1E	491906, 6598292		
1W	492671, 6600507		

Photo Point ID *	Photo Point GPS Coordinates^	February 2018 photograph	May 2018 photograph
2E	492372, 6599033		
2W	496675, 6609675		

*Photo Point ID **	*Photo Point GPS Coordinates^*	*February 2018 photograph*	*May 2018 photograph*
3E	492778, 6600567		
3W	496494, 6609010		

Photo Point ID *	Photo Point GPS	February 2018 photograph	May 2018 photograph
4E	494575, 6605139		
4W	496131, 6608279		

Photo Point ID *	Photo Point GPS Coordinates^	February 2018 photograph	May 2018 photograph
5E	494960, 6606206		
5W	495668, 6607684		

Photo Point ID *	Photo Point GPS Coordinates^	February 2018 photograph	May 2018 photograph
6E	495433, 6607052		
6W	494890, 6606346		

Photo Point ID *	Photo Point GPS Coordinates^	February 2018 photograph	May 2018 photograph
7E	496240, 6608213		
7W	494355, 6604185		

*Photo Point ID **	*Photo Point GPS Coordinates^*	*February 2018 photograph*	*May 2018 photograph*
8E	496724, 6609444		

* number + side of alignment heading north: E=east, W=west.

^ UTM eastings, northings; Zone 56J.

Appendix 3: Winter 2018 Stage 2A and Stage 2B monitoring report.

ABN 79 896 839 729
ACN 101 084 557

Return address:
PO Box 119
LENNOX HEAD
NSW 2478

LENNOX HEAD
T 02 6687 7666
F 02 6687 7782

COFFS HARBOUR
T 02 6651 7666

ARMIDALE
T 0488 677 666

LISMORE
T 02 6621 6677

www.geolink.net.au

3 August 2018
Ref No: 2692-1131

Roads and Maritime Service
124 Albert Drive
DONNELLYVILLE NSW 2447

Attention: Mr Kris Hincks

Dear Kris

WC2NH Stage 2A and 2B GHFF Habitat Monitoring – Winter 2018 (Issue 1)

Introduction

This report presents the habitat monitoring results of Grey-Headed Flying-fox (GHFF) habitat adjacent to the Warrell Creek to Nambucca Heads Highway Upgrade (WC2NH) project for:

- Stage 2A: the third quarterly monitoring event (Winter 2018) within Stage 2A; and
- Stage 2B: the first quarterly monitoring event (Winter 2018) within Stage 2B.

Quarterly GHFF habitat monitoring is required for Stage 2A (chainage 47700 to 61300) and Stage 2B (chainage 41700 to 47700) (refer to **Appendix A**) for up to one year after the opening of these sections of WC2NH to traffic. Quarterly GHFF habitat monitoring is undertaken in accordance with the *Warrell Creek to Urunga Pacific Highway Upgrade Ecological Monitoring Program – Stage 2: Warrell Creek to Nambucca Heads* (Benchmark Environmental Management, 2014).

The *Warrell Creek to Nambucca Heads Flying-fox Management Plan* (Sinclair Knight Merz, 2017) recognised that the quality of vegetation adjacent to the Project area could be detrimentally affected by invasion of noxious and environmental weeds. A main goal identified for management during operation of the Project is '*no reduction of the quality of flying-fox habitats adjacent to the Project corridor due to the operation of the Project and to minimise the impact of edge effects'* (Sinclair Knight Merz, 2017).

Methodology

The monitoring of Grey-headed Flying-fox habitat includes the following components:

1. Monitoring of identified revegetation/ rehabilitation areas to ensure the establishment/ restoration of seedlings and plants.
2. Monitoring both revegetation/ rehabilitation areas and other habitat areas adjacent to the Project to manage invasion of noxious and environmental weeds.

nd Regional Planning | Environmental Engineering | Civil Design | Environmental Impact Assessment | Ecological Surveys and Monitoring | Landscape Architecture | Urban Design |

For brevity, component 1 is henceforth referred to as 'rehabilitation site monitoring', and component 2 is referred to as 'weed monitoring'.

Field surveys were undertaken by GeoLINK ecologists Grant McLean and Frank Makin on:

- 16 May 2018 between 7.30 am to 5.00 pm; and
- 17 May 2018 between 7.30 am to 3.30 pm.

Rehabilitation Site Monitoring

The locations of the GHFF habitat areas requiring revegetation/ rehabilitation are listed in **Table 1** and correspond with Stage 2A of the Project. Monitoring of these areas aims to assess the effectiveness of rehabilitation of GHFF habitat areas cleared during the construction of the Project.

Table 1 Location of GHFF Habitat Rehabilitation Sites

Habitat type	*Location*	*Site*
Open Forest - Blackbutt	CH: 59450 East	15c ancillary compound
Open Forest - Blackbutt	CH: 60800 East	Old Coast Rd Temporary Deviation

The following data was recorded for each location:

- Date and time of monitoring
- Weed abundance and composition
- Evidence of management and control of noxious and environmental weeds
- Evidence of any progressive revegetation/ rehabilitation during the construction phase using collected topsoil and seed at specific sites and to develop different successional stages of rehabilitation
- Evidence of native plant establishment of seedlings
- Identification of any of the GHFF food tree plants referred to in **Appendix B**.

Photos were also taken at the four fixed photo points associated with the rehabilitation sites (refer to **Table 2**).

Table 2 Locations of Fixed Photo Points for Rehabilitation Sites

Photo Point ID	*Photo Point GPS Coordinates**	*Corresponding Rehabilitation Site*
RS1	497272, 6610243	Old Coast Road temporary deviation (west)
RS2	497260, 6610256	Old Coast Road temporary deviation (west)
RS3	496443, 6609093	15c ancillary compound
RS4	497440, 6610248	Old Coast Road temporary deviation (east)

** UTM eastings, northings; Zone 56J*

Weed Monitoring

The Project *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) approval defined GHFF habitat as habitat consisting of:

- Swamp Forest - Swamp Mahogany/ Paperbark
- Moist Open Forest - Flooded Gum
- Moist Open Forest - White Mahogany/ Grey Gum/ Ironbark
- Mixed Floodplain Forest
- Open Forest - Blackbutt.

All instances of the above plant communities occurring along the outside of the Project clearing corridor were targeted during the field surveys. Within two metres of the cleared edge of these habitat areas the following data was recorded in relation to weeds:

- Date and time of monitoring
- Weed abundance and composition
- Evidence of management and control of noxious and environmental weeds.

Weed abundance for individual species was measured using modified Braun-Blanquet cover classes between 1 and 5: 1 (<5%), 2 (6-25%), 3 (26-50%), 4 (51-75%), and 5 (76-100%). Abundance scores for identified weed sites were classified based on the categories in **Table 3**. Priority weed sites for management were identified based on species present and the percentage cover, prioritising *Biosecurity Act 2015* listed species and weeds with potential to degrade flying-fox foraging habitat values.

Table 3 Weed Abundance Classification for Weed Sites

Noxious/Environmental Weed Cover (%)	*Weed Abundance Classification*
0-10	NA
11-39	Low
40-69	Medium
70-100	High

Fixed photo points were established adjacent to representative areas of GHFF habitat to monitor weeds for Stage 2B. Photos were also taken at the fixed photo points established during the Summer 2018 weed monitoring for Stage 2A. Locations of the fixed photo points are listed in **Table 4**.

Table 4 Locations of Fixed Photo Points

Stage	*Photo Point ID**	*Photo Point GPS Coordinates^*	*Notes on Photo Direction*	*Vegetation Type*	*Corresponding Weed Infestation*
2A	1E	491906, 6598292	Looking north	Moist Open Forest - White Mahogany/ Grey Gum/ Ironbark	W28
2A	1W	492671, 6600507	Looking north north-east	Swamp Forest - Swamp Mahogany/ Paperbark	W1b
2A	2E	492372, 6599033	Looking north-east	Moist Open Forest - Flooded Gum	W25

Stage	Photo Point ID*	Photo Point GPS Coordinates^	Notes on Photo Direction	Vegetation Type	Corresponding Weed Infestation
2A	2W	496675, 6609675	Looking north-east	Open Forest - Blackbutt	Not applicable
2A	3E	492778, 6600567	Looking south-west	Swamp Forest - Swamp Mahogany/ Paperbark	W21
2A	3W	496494, 6609010	Looking south	Open Forest - Blackbutt	Not applicable
2A	4E	494575, 6605139	Looking north north-east	Swamp Forest - Swamp Mahogany/ Paperbark	Not applicable
2A	4W	496131, 6608279	Looking north-east	Moist Open Forest – Flooded Gum	W9
2A	5E	494960, 6606206	Looking south south-west	Open Forest - Blackbutt	W17
2A	5W	495668, 6607684	Looking north-east	Moist Open Forest – Flooded Gum	Not applicable
2A	6E	495433, 6607052	Looking north	Open Forest - Blackbutt	Not applicable
2A	6W	494890, 6606346	Looking south south-west	Open Forest - Blackbutt	W7
2A	7E	496240, 6608213	Looking west	Moist Open Forest – Flooded Gum	W16
2A	7W	494355, 6604185	Looking north	Moist Open Forest - White Mahogany/ Grey Gum/ Ironbark	Not applicable
2A	8E	496724, 6609444	Looking south south-west	Moist Open Forest – Flooded Gum	W16
2B	1BE	489545, 6594390	Looking north	Moist Open Forest - Flooded Gum	W37
2B	1BW	490778, 6596540	Looking south	Moist Open Forest - Flooded Gum	W31
2B	2BE	488766, 6593840	Looking south-west	Mixed Floodplain Forest	Not applicable
2B	2BW	489407, 6594440	Looking north-east	Mixed Floodplain Forest	W36
2B	3BE	490153, 6595330	Looking south	Moist Open Forest - Flooded Gum	Not applicable
2B	3BW	489268, 6594420	Looking south	Mixed Floodplain Forest	W39

** number plus side of alignment heading north: E=east, W=west.*

^ UTM eastings, northings; Zone 56J.

Results and Discussion

Rehabilitation Site Monitoring

The results of the rehabilitation site monitoring are provided in **Table 5**. Photos from the four fixed photo points are shown in **Appendix C**. Plantings and/or seeding at these sites are either young or have not been undertaken (in the case of the rehabilitation site at the 15c ancillary compound).

Native seed germination is now evident at the Old Coast Road Temporary Deviation (CH60800) with a number of native species recorded growing from the native seed mix applied on both sides of the highway alignment. Subsequent monitoring events will provide more useful data for assessing the success of these rehabilitation sites.

Table 5 Rehabilitation Site Monitoring

Rehabilitation Site	***Old Coast Rd Temporary Deviation (CH: 60800 West)***	***Old Coast Rd Temporary Deviation (CH: 60800 East)***	***15c Ancillary Compound (CH: 59450 East)***
Photo Point GPS Coordinates (UTM eastings, northings; Zone 56J)	Photo Point RS1: 497272, 6610243 Photo Point RS2: 497260, 6610256	Photo Point RS4: 497440, 6610248	Photo Point RS3: 496443, 6609093
Date and time of survey	Winter: 17/07/2018 – 8:00 am – 9:00 am	Winter: 17/07/2018 – 8:00 am – 9:00 am	Winter: 17/07/2018 – 8:00 am – 9:00 am
Weed Abundance and Composition	No weed infestations were observed within the newly landscaped area. No change from Autumn 2018 survey.	No weed infestations were observed within trimmed, topsoiled and hydroseeded batter. No change from Autumn 2018 survey	The northern boundary of this area has <5% intrusion of Whiskey Grass (*Andropogon virginicus*), Broadleaf Paspalum (*Paspalum mandiocanum*), Lantana* (*Lantana camara*), Fireweed (*Senecio madagascariensis*), Cobblers Pegs (*Bidens pilosa*) and Blue Billygoat Weed (*Ageratum houstonianum*).
Evidence of management and control of noxious and environmental weeds	No weeds present. No change from Autumn 2018 survey.	No weeds present. No change from Autumn 2018 survey.	Not applicable as this area is yet to be rehabilitated. No change from Autumn 2018 survey.
Evidence of any progressive revegetation/ rehabilitation during the construction phase using collected topsoil and seed at specific sites and to develop different successional stages of rehabilitation	No observed progressive revegetation or successional stages of rehabilitation. No weeds present. No change from Autumn 2018 survey.	No observed progressive revegetation or successional stages of rehabilitation. No weeds present. No change from Autumn 2018 survey.	Not applicable as this area is yet to be rehabilitated.

Rehabilitation Site	Old Coast Rd Temporary Deviation (CH: 60800 West)	Old Coast Rd Temporary Deviation (CH: 60800 East)	15c Ancillary Compound (CH: 59450 East)
Evidence of native establishment of seedlings and plants	Semi established native plant species that have been planted as part of rehabilitation include Water Gum (*Tristaniopsis laurina*) to ~ 1 m height and Tea Tree (*Leptospermum brachyandrum*) to ~ 2 m height. Native regeneration species account for <2% cover with maximum plant height to 35 cm (no change from Autumn 2018 survey). Identifiable species include: ■ Dusky Coral Pea (*Kennedia rubicunda*) ■ Purple Coral Pea (*Hardenbergia violacea*) ■ Pink Kunzea (*Kunzea capitata*) ■ Hickory Wattle (*Acacia falcata*) ■ Green Wattle (*Acacia irrorata*) ■ White Sally Wattle (*Acacia floribunda*) ■ Austral indigo (*Indigofera australis*) ■ *Goodenia sp.* (likely *G. heterophylla*). The hydroseeded grass cover crop has remained died off.	No change from Autumn 2018 survey. Some encroachment (<1% cover) from the edge of the cleared area was recorded with Bracken Fern (*Pteridum esculentum*) and Blady Grass (*Imperata cylindrica*) beginning to recolonise the disturbed area. Very minor (<1%) native regeneration of bushland regeneration hydroseed mix are regenerating to maximum height of 20 cm. Identifiable species include: ■ Dusky Coral Pea ■ Purple Coral Pea ■ Green Wattle. ■ White Sally Wattle. The hydroseeded grass cover crop has remained died off.	Minor natural regrowth <5% was observed of Blackbutt (*Eucalyptus pilularis*), Sally Wattle (*Acacia melanoxylon*), Blady Grass, Water Vine (*Cissus hypoglauca*) and Bracken Fern.
Identification of any of the GHFF food tree species (refer to Appendix B)	No change from Autumn 2018 survey. Applied landscape seed mixes have included species identified within **Appendix B** (Alex Dwyer {Pacifico Environmental Manager} email 8/03/2018). No regeneration of GHFF food tree species has been detected to date.	No change from Autumn 2018 survey. No landscape plantings had been undertaken at the time of monitoring. It appears that no landscape plantings are proposed for this area of the Old Coast Road temporary deviation rehabilitation. Applied landscape seed mixes have included species identified within **Appendix B** (Alex Dwyer {Pacifico Environmental Manager} email 8/03/2018). No regeneration of GHFF food tree species has been detected to date.	Not applicable as this area is yet to be rehabilitated.

* Denotes *Biosecurity Act 2015* listed priority weed species.

Weed Monitoring

Stage 2A

Occurrence of noxious and/or environmental weeds was recorded at 30 sites within the edge of GHFF habitat adjacent to the Project area. These weed occurrences are shown in **Appendix A** and listed in **Table 6**. Photographs of GHFF habitat areas taken from the fixed photo points are shown in **Appendix C**.

Only very minor changes to weed densities and composition were observed during the subject Winter 2018 monitoring event compared to the previous monitoring event (Autumn 2018). Cool and dry weather conditions were experienced in the month leading up to the survey with the last moderate rainfall event (23 mm) occurring on 3 July 2018 (BOM, 2018). Observed changes include:

- One additional weed site (W16a) was observed during the Winter 2018 survey and comprises a low weed management priority area.
- Additional weed species were recorded at seven sites: W1a, W1b, W3, W20, W21, W22 and W23.
- Weed abundance at site W16 has reduced in several sections due to a reduction in per cent of foliage cover of Lantana.
- An increase in the weed cover of individual species was recorded at site W20. Lantana and Mile-a-minute weed cover class has increased from 1 in Autumn 2018 to 2 in Winter 2018.
- An increase in weed infestation extent was observed at site W4, extending by approximately 50 m to south.
- Evidence of weed management was observed on properties adjacent to site W7.
- Weed dieback from weed management was observed at sites W27 and W28. Current overall weed abundance remained at medium level.

A total of 19 noxious and environmental weed species were recorded. Lantana, Salvinia (*Salvinia molesta*), Fireweed and Blackberry (*Rubus fruticosus*) were recorded on site and are listed as priority weed species for the North Coast of NSW under the *Biosecurity Act 2015*. The primary management duty for these is they '*must not be imported into the state or sold*'.

Lantana, Broadleaf Paspalum and Camphor Laurel (*Cinnamomum camphora*) were recorded within GHFF habitat areas at the highest density, and were also the dominant weed species in those GHFF areas that recorded a 'Medium' weed abundance level (refer to **Table 6**).

One weed site (site W25) was considered to have a high weed management priority, while eight weed sites were considered to have a medium weed management priority (sites W18, W19 {part}, W20, W22, W23, W24, W26 and W27). These areas should be targeted during weed management works.

No obvious changes were recorded between the Autumn 2018 and Winter 2018 fixed photo point monitoring sites (refer to **Appendix C**).

An increase in density of the exotic vine Mile-a-minute (*Ipomoea cairica*) was recorded at site W20 during the Winter 2018 habitat monitoring. No increase in the density of Morning Glory (*Ipomoea indica*) was recorded during the Autumn 2018 habitat monitoring. Both of these species have potential to inhibit native regeneration and smother the canopy of intact GHFF habitat.

Table 6 Abundance and Composition of Noxious and/or Environmental Weeds Sites for Stage 2A

Weed Site Ref.	*Chainage (side of highway)*	*Winter 2018 Weed Composition (Cover Class^)*	*GHFF Habitat Type (Plant Community)*	*Summer 2018 Weed Abundance^^*	*Autumn 2018 Weed Abundance^^*	*Winter 2018 Weed Abundance^^*	*Comments*	*Evidence of Management and Control*	*Weed Management Priority*
Date and time: ■ 16 July 2018 between 7.30 am to 5.00 pm. ■ 17 July 2018 between 7.30 am to 3.30 pm.									
W1a	48400 to 48700 (west)	Lantana* (2), Camphor Laurel (1), Broadleaf Paspalum (1), **Blackberry* (1)**	Moist Open Forest - White Mahogany/ Grey Gum/ Ironbark	NA	Low	Low	**Additional weeds recorded: Blackberry*.**	No evidence of weed control	Low
W1b	49790 - 50100 (west)	Setaria (*Setaria sphacelata*) (2), Annual Ragweed (*Ambrosia artemisiifolia*) (1), **Broadleaf Paspalum (2), Fireweed* (1), Blue Billygoat Weed (1) Balloon Cotton Bush (*Gomphocarpus physocarpus*) (1)**	Swamp Forest - Swamp Mahogany/ Paperbark	Low	Low	Low	Majority of weed infestation concentrated on batter edge. Blue Water Lily (on swamp fringe) 40% cover in concentrated areas of open water. **Additional weeds recorded: Fireweed*, Broadleaf Paspalum, Blue Billygoat Weed and Balloon Cotton Bush.**	No evidence of weed control	Low

Weed Site Ref.	Chainage (side of highway)	Winter 2018 Weed Composition (Cover Class^)	GHFF Habitat Type (Plant Community)	Summer 2018 Weed Abundance^^	Autumn 2018 Weed Abundance^^	Winter 2018 Weed Abundance^^	Comments	Evidence of Management and Control	Weed Management Priority
W2	51010 - 51165 (west)	Salvinia* (within open water area – approx. chainage 51020) (2)	Swamp Forest - Swamp Mahogany/ Paperbark	Low	Low	Low	Very minor Flax-leaf Fleabane (*Conyza bonariensis*), Broadleaf Paspalum and Annual Ragweed on fauna fence edge.	No evidence of weed control	Low (this species would have minimal impact on GHFF habitat value).
W3	53750 - 53840 (west)	Broadleaf Paspalum (2), Annual Ragweed (1), White Passionflower (*Passiflora subpeltata*) (1), Paddy's Lucerne (*Sida rhombifolia*) (1), Purple-top (*Verbena bonariensis*) (1), **Fireweed* (1), Wild Tobacco Bush (*Solanum mauritianum*) (1).**	Moist Open Forest - White Mahogany/ Grey Gum/ Ironbark	Low	Low	Low	**Additional weeds recorded: Wild Tobacco Bush and Fireweed*.**	No evidence of weed control	Low
W4	54070 - 54150 (west)	Broadleaf Paspalum (2), Lantana* (1) Winter Senna (*Senna septemtrionalis*) (1), Blue Billygoat Weed (1)	Open Forest - Blackbutt	Low	Low	Low	Setaria, Flax-leaf Fleabane and Purple-top present in very low abundance **Area of weed infestation**	No evidence of weed control	Low

Weed Site Ref.	Chainage (side of highway)	Winter 2018 Weed Composition (Cover Class^)	GHFF Habitat Type (Plant Community)	Summer 2018 Weed Abundance^^	Autumn 2018 Weed Abundance^^	Winter 2018 Weed Abundance^^	Comments	Evidence of Management and Control	Weed Management Priority
							extended by approximately 50 m to the south.		
W5	54480 - 54530, (west)	Broadleaf Paspalum (3), Lantana* (1), Wild Tobacco Bush (1), Flaxleaf Fleabane (*Conyza bonariensis*) (1)	Open Forest - Blackbutt	Medium	Medium	Medium	-	No evidence of weed control	**Low**
W6	55220 - 55260 (west)	Setaria (1)	Open Forest - Blackbutt	Low	NA	NA	-	Weed control has not yet commenced	NA
W7	56160 - 56360 (west)	Broadleaf Paspalum (2), Setaria (1), Lantana* (1)	Open Forest - Blackbutt	Low	Low	Low	Lantana* present in low abundance on fringe	Weed control has not yet commenced **Evidence of weed management on adjacent property.**	Low
W8	57370 – 57450 (west)	Lantana* (1), Broadleaf Paspalum (1)	Open Forest - Blackbutt	Low	Low	Low	-	No evidence of weed control	Low
W9	58440 - 58550 (west)	Broadleaf Paspalum (2), Lantana* (1)	Moist Open Forest - Flooded Gum	Low	Low	Low	-	No evidence of weed control	Low
W10	58850 – 58940 (west)	Lantana* (1)	Open Forest - Blackbutt	Low	Low	Low	-	No evidence of weed control	Low

Weed Site Ref.	Chainage (side of highway)	Winter 2018 Weed Composition (Cover Class^)	GHFF Habitat Type (Plant Community)	Summer 2018 Weed Abundance^^	Autumn 2018 Weed Abundance^^	Winter 2018 Weed Abundance^^	Comments	Evidence of Management and Control	Weed Management Priority
W11	59200 - 59250, (west)	Broadleaf Paspalum (1)	Open Forest - Blackbutt	Low	Low	Low	-	No evidence of weed control	Low
W12	59700 - 59740 (west)	Broadleaf Paspalum (2)	Open Forest - Blackbutt	Low	Low	Low	-	No evidence of weed control	Low
W13	59780 - 59810 (west)	Broadleaf Paspalum (2)	Flooded Gum Moist Open Forest	Low	Low	Low	-	Weed control has not yet commenced	Low
W14	60400 - 60540, 60640 – 60665 (west)	Broadleaf Paspalum (2), Morning Glory (1), Rhodes Grass (*Chloris gayana*) (1), Winter Senna (1), Blue Billygoat (1)	Open Forest - Blackbutt	Low	Low	Low	Some sections without GHFF habitat (old hardstand area and stockpile site).	No evidence of weed control	Low
W15	61240 – 61260 (east)	Lantana* (1)	Open Forest - Blackbutt	Low	NA	NA	-	No evidence of weed control	NA
W16	60570 - 60600	Lantana* (2), Broadleaf Paspalum (1)	Flooded Gum Moist Open Forest	Medium	Low	Low	**Weed cover has reduced in several chainage sections due to a reduction in per cent of foliage cover of Lantana*.**	No evidence of weed control	Low
	60300 - 60400	Lantana* (1)		NA	Medium	Low			**Low**
	60040 - 60060	Lantana* (1)		NA	Low	Low			Low
	59780 - 59850	Lantana* (1)		Medium	Low	NA			**NA**
	59550 - 59610	Lantana* (1)		Medium	Low	NA			**NA**

Weed Site Ref.	Chainage (side of highway)	Winter 2018 Weed Composition (Cover Class^)	GHFF Habitat Type (Plant Community)	Summer 2018 Weed Abundance^^	Autumn 2018 Weed Abundance^^	Winter 2018 Weed Abundance^^	Comments	Evidence of Management and Control	Weed Management Priority
	59200 - 59260	Lantana* (1)		Medium	Low	Low			Low
	59000 - 59080	Broadleaf Paspalum (1)		Medium	Low	NA			**NA**
	58470 – 58550	Lantana* (1), Whiskey Grass (1)		Medium	Low	NA			**NA**
	58050 - 58110	Lantana* (1)		Medium	Low	NA			**NA**
	57650 - 57770	None		Medium	Low	NA			**NA**
	57210 - 57250 (east)	Lantana* (1)		Medium	Low	Low			Low
W16a	**56950**	**Lantana* (2), Broadleaf Paspalum (2)**	**Open Forest - Blackbutt**	**Not recorded**	**Not recorded**	**Low**	**New weed site.**	**No evidence of weed control**	**Low**
W17	56100 – 56420 (east)	Broadleaf Paspalum (3), Lantana* (2)	Open Forest - Blackbutt Flooded Gum Moist Open Forest	Low	Low	Low	Mostly intact native canopy but more scattered trees around big house in north. Lower weed cover in south.	No evidence of weed control	Low
W18	56420 – 56580 (east)	Broadleaf Paspalum (4), Lantana* (2)	Open Forest - Blackbutt	Medium	Medium	Medium	Very weedy understorey in north around big house. Very weedy north section.	No evidence of weed control	Medium

Weed Site Ref.	Chainage (side of highway)	Winter 2018 Weed Composition (Cover Class^)	GHFF Habitat Type (Plant Community)	Summer 2018 Weed Abundance^^	Autumn 2018 Weed Abundance^^	Winter 2018 Weed Abundance^^	Comments	Evidence of Management and Control	Weed Management Priority
W19	55960 - 56080	Lantana* (2), Broadleaf Paspalum (2), Setaria (1)	Open Forest - Blackbutt	Low	Medium	Medium	-	No evidence of weed control	Medium
	55630 – 56080 (east)			Low	Low	Low			Low
W20	52980 – 53040 (east)	Lantana* (**2**), Mile a Minute (**2**), Annual Ragweed (1), Setaria (1), **Rhodes Grass (1), Blue Billygoat Weed (1), Winter Senna (1)**	Swamp Forest - Swamp Mahogany/ Paperbark	Medium	Medium	Medium	**Lantana* and Mile-a-minute cover has increased from cover class 1 in Autumn to 2 in Winter 2018. Overall weed abundance has remained medium. Additional weeds recorded: Rhodes Grass, Blue Billygoat Weed and Winter Senna.**	No evidence of weed control	Medium
W21	49830 - 50220 (east)	Setaria (2), **Salvinia* (within open water area along swamp edge – approx. chainage 49830 - 49920) (2), Fireweed* on batter edge (1)**	Swamp Forest - Swamp Mahogany/ Paperbark	Low	Low	Low	Forest is overall in good condition including the understorey except for some sections with Blue Water Lily **and Salvinia*. There are also**	No evidence of weed control	Low (these weeds would have minimal impact on GHFF habitat value).

Weed Site Ref.	Chainage (side of highway)	Winter 2018 Weed Composition (Cover Class^)	GHFF Habitat Type (Plant Community)	Summer 2018 Weed Abundance^^	Autumn 2018 Weed Abundance^^	Winter 2018 Weed Abundance^^	Comments	Evidence of Management and Control	Weed Management Priority
							some minor incursions of exotic grasses and herbs along fence. **Additional weeds recorded: Salvinia* and Fireweed*.**		
W22	49560 – 49670 (east)	Broadleaf Paspalum (4), Lantana* (1), **Balloon Cotton Bush (1)**	Moist Open Forest - White Mahogany/ Grey Gum/ Ironbark	Medium	Medium	Medium	**Additional weeds: Balloon Cotton Bush**	No evidence of weed control	Medium
W23	49030 - 49070 (east)	Broadleaf Paspalum (5), Camphor Laurel (1) **Balloon Cotton Bush (1).**	Flooded Gum Moist Open Forest	High	High	High	Scattered native overstorey of Hard Quandong (*Elaeocarpus obovatus*), Foam Bark Tree (*Jagera pseudorhus*), Broad-leaved Paperbark (*Melaleuca quinquenervia*), with few shrubs and groundcover dominated by Broadleaf Paspalum.	No evidence of weed control	Medium

Weed Site Ref.	Chainage (side of highway)	Winter 2018 Weed Composition (Cover Class^)	GHFF Habitat Type (Plant Community)	Summer 2018 Weed Abundance^^	Autumn 2018 Weed Abundance^^	Winter 2018 Weed Abundance^^	Comments	Evidence of Management and Control	Weed Management Priority
							Additional weeds: Balloon Cotton Bush		
W24	48430 - 48550 (east)	Broadleaf Paspalum (5)	Moist Open Forest - Flooded Gum	High	High	High	Scattered overstorey of Flooded Gum (*Eucalyptus grandis*), Guioa (*Guioa semiglauca*), Broad-leaved Paperbark (*Melaleuca quinquenervia*), but lack of shrub layer and ground cover dominated by Broadleaf Paspalum.	No evidence of weed control	Medium
W25	48260 – 48380 (east)	Lantana* (5), Broadleaf Paspalum (2), Mile a Minute (1), Winter Senna (1).	Moist Open Forest - Flooded Gum	High	High	High	Mostly intact overstorey dominated by Flooded Gum with some River Oak (*Casuarina cunninghamiana*) on edge creek. Understorey dominated by weeds mostly Lantana*.	No evidence of weed control	High

Weed Site Ref.	Chainage (side of highway)	Winter 2018 Weed Composition (Cover Class^)	GHFF Habitat Type (Plant Community)	Summer 2018 Weed Abundance^^	Autumn 2018 Weed Abundance^^	Winter 2018 Weed Abundance^^	Comments	Evidence of Management and Control	Weed Management Priority
W26	47800 – 47832 (east)	Lantana* (2), Wild Tobacco Bush (2), Setaria (1), White Passionflower (1)	Open Forest - Blackbutt	Medium	Medium	Medium	-	No evidence of weed control	Medium
W27	47510 – 47530 (east)	Broadleaf Paspalum (3), Camphor Laurel (2), Purple Top (2), Wild Tobacco Bush (2)	Moist Open Forest – White Mahogany – Grey Gum	Medium	Medium	Medium	-	**Weed dieback evident – evidence of weed control**	**Low**
W28	47450 – 47490 (east)	Camphor Laurel (2), Broadleaf Paspalum (2), Lantana* (2), Blackberry* (1), Narrow-leaved Privet (*Ligustrum sinense*) (1)	Moist Open Forest - White Mahogany/ Grey Gum/ Ironbark	Medium	Medium	Medium	**-**	**Weed dieback evident – evidence of weed control**	Medium

^ *Modified Braun-Blanquet cover classes of 1=<5%, 2=6-25%, 3=26-50%, 4=51-75%, and 5=76-100%*

^^ Refer to Table 3.

* Denotes *Biosecurity Act 2015* listed priority weed species. Lantana, Fireweed, Blackberry and Salvinia are listed as Weeds of National Significance and as priority weed species for the North Coast of NSW. They must not be imported into the State or sold.

Stage 2B

Occurrence of noxious and/or environmental weeds was recorded at 16 sites within the edge of GHFF habitat adjacent to the Project area. These weed occurrences are shown in **Appendix A** and listed in **Table 7**. Photographs of GHFF habitat areas taken from the fixed photo points are shown in **Appendix C.**

A total of 12 noxious and environmental weed species were recorded. Fireweed and Lantana were recorded on-site and are listed as priority weed species for the North Coast of NSW under the *Biosecurity Act 2015*. The primary management duty for these is they '*must not be imported into the state or sold*'.

Broadleaf Paspalum, Setaria, and Large-leaved Privet (*Ligustrum lucidum*) were recorded within GHFF habitat areas at the highest density, and were also the dominant weed species in those GHFF areas that recorded a 'Medium' weed abundance level (refer to **Table 7**).

Two weed sites (sites 2BW8 and 2BW16) were considered to have a medium weed management priority. These areas should be targeted during weed management works.

No exotic vines with the potential to inhibit native regeneration and smother the canopy of intact GHFF habitat were observed.

Table 7 Abundance and Composition of Noxious and/or Environmental Weeds Sites for Stage 2B

Weed Site No.	*Chainage (side of highway)*	*Winter 2018 Weed Composition (Cover Class^)*	*GHFF Habitat Type (Plant Community)*	*Winter 2018 Weed Abundance^^*	*Comments*	*Evidence of Management and Control*	*Weed Management Priority*
2BW1	46180 – 46190 (east)	Broadleaf Paspalum (5), Camphor Laurel (1), Lantana* (1)	Open Forest - Blackbutt	High	-	No evidence of weed control	Medium
2BW2	45440 – 45450 (east)	Broadleaf Paspalum (2), Camphor Laurel (1), Setaria (1)	Moist Open Forest - Flooded Gum	Low	Small creek and riparian zone within survey area.	Evidence of weed control on adjoining property.	Low
2BW3	45170 – 45280 (west)	Broadleaf Paspalum (3), Camphor Laurel (2), Setaria (1)	Moist Open Forest - Flooded Gum	Medium	-	No evidence of weed control	Low
2BW4	44100 – 44200 (east)	Broadleaf Paspalum (3), Fireweed* (1), Setaria (1)	Open Forest - Blackbutt	Medium	-	No evidence of weed control	Low
2BW5	43960 – 44030 (east)	Broadleaf Paspalum (3), Balloon Cotton Bush (1), Crofton Weed (*Ageratina adenophora*) (1), Fireweed* (1)	Moist Open Forest - Flooded Gum	Medium	-	No evidence of weed control	Low
2BW6	43050 – 43090 (east)	Lantana* (2), Broadleaf Paspalum (1)	Moist Open Forest - Flooded Gum	Low	-	No evidence of weed control	Low
2BW7	42980 – 42990 (west)	Lantana* (2), Large-leaved Privet (1), Broadleaf Paspalum (1)	Mixed Floodplain Forest	Low	-	No evidence of weed control	Low
2BW8	42650 – 42880 (west)	Lantana* (3), Large-leaved Privet (3), Camphor Laurel (1), Winter Senna (1), Wild Tobacco Bush (1), Broadleaf Paspalum (1), Setaria (1).	Mixed Floodplain Forest	Medium	-	No evidence of weed control	Medium

Weed Site No.	Chainage (side of highway)	Winter 2018 Weed Composition (Cover Class^)	GHFF Habitat Type (Plant Community)	Winter 2018 Weed Abundance^^	Comments	Evidence of Management and Control	Weed Management Priority
2BW9	42770 – 42800 (east)	Broadleaf Paspalum (2), Lantana* (1)	Moist Open Forest - Flooded Gum	Low	-	No evidence of weed control	Low
2BW10	42620-42630 (east)	Setaria (4), Cobblers Pegs (1), Wild Tobacco Bush (1)	Mixed Floodplain Forest	Medium	-	Evidence of weed control.	Low
2BW11	42500 – 42600 (west)	Broadleaf Paspalum (3), Lantana* (1)	Mixed Floodplain Forest	Medium	-	No evidence of weed control	Low
2BW12	42600 – 42610 (west)	Lantana* (3), Broadleaf Paspalum (2), Wild Tobacco Bush (1), Setaria (1)	Mixed Floodplain Forest	Low	-	No evidence of weed control	Low
2BW13	42500 – 42510 (west)	Large-leaved Privet (2), Lantana* (2), Narrow-leaved Privet (1)	Mixed Floodplain Forest	Low	-	No evidence of weed control	Low
2BW14	42570 – 42600 (east)	Large-leaved Privet (2)	Mixed Floodplain Forest	Low	-	No evidence of weed control	Low
2BW15	42530 – 42600 (east)	Lantana* (2), Large-leaved Privet (2), Narrow-leaved Privet (2), Broadleaf Paspalum (1)	Mixed Floodplain Forest	Low	-	No evidence of weed control	Low
2BW16	42090 – 42220, 42290, 42390	Broadleaf Paspalum (4), Setaria (2), Lantana* (1), Camphor Laurel (1), Fireweed* (1), Wild Tobacco Bush (1).	Mixed Floodplain Forest	High	-	No evidence of weed control	Medium

^ *Modified Braun-Blanquet cover classes of 1=<5%, 2=6-25%, 3=26-50%, 4=51-75%, and 5=76-100%.*

^^ Refer to Table 3.

* Denotes *Biosecurity Act 2015* listed priority weed species. Lantana and Fireweed are listed as Weeds of National Significance and as priority weed species for the North Coast of NSW. They must not be imported into the State or sold.

Recommendations and Conclusions

Rehabilitation Site Monitoring

Limited regeneration has established to date at the Old Coast Road Temporary Deviation and rehabilitation has not been undertaken to date at the 15c Ancillary Compound. It is recommended that rehabilitation works are undertaken at the 15c Ancillary Compound if construction works at this site are confirmed to be completed. Should upcoming monitoring continue to see limited results from the rehabilitation efforts at Old Coast Rd Temporary Deviation, the rehabilitation efforts are recommended to be reviewed to ensure regeneration is achieved in line with the project landscape plans.

Weed Monitoring

Weed sites W25, W19, W20, W26, 2BW8 and 2BW16 are important target weed management areas to reduce degradation to GHFF habitat. At these sites, there is the potential for Lantana to alter community structure and inhibit regeneration. Large-leaved Privet at site W36 also has the potential to alter vegetation and suppress native regrowth. Management of the weeds at these sites would be consistent with the key objectives of the WC2NH *Weed and Pathogen Management Plan* (GeoLINK 2015) which is to '*ensure the Project avoids, suppresses and controls the spread of all weeds, plant pathogens and invasive species to ensure that impacts to the environment are minimised.*'

Weed sites primarily with dense Broadleaf Paspalum (sites W5, W18, W22, W23, W24 and W27) should be considered somewhat lower priorities for management than sites comprising medium infestations of Lantana and/or Large-leaved Privet for the following reasons:

- There may be a lower likelihood of weed management success (it is difficult to remove this species successfully from degraded communities that have a suitable semi-shaded understorey environment); and
- Being an understorey weed species that occurs in disturbed environments and edges, Broadleaf Paspalum has a low potential to alter either the structure or regeneration potential, and hence the quality of relatively intact GHFF habitat.

Future monitoring should continue to identify any significant increase in the density of the exotic vines (including Morning Glory and Mile-a-minute) which have the potential to inhibit native regeneration and smother the canopy of intact GHFF habitat.

Please contact the undersigned if require any further information.

Yours sincerely
GeoLINK

Grant McLean
Ecologist

References

Benchmark Environmental Management (2014). *Warrell Creek to Urunga Pacific Highway Upgrade Ecological Monitoring Program. Stage 2: Warrell Creek to Nambucca Heads*. Report to Roads and Maritime Services.

Bureau of Meteorology (2018). Daily rainfall. [ONLINE] Available at: http://www.bom.gov.au/jsp/ncc/cdio/wData/wdata?p_nccObsCode=136&p_display_type=dailyDataFile&p_stn_num=059150&p_startYear= . [Accessed 24 July 2018].

GeoLINK (2015). *Weed and Pathogen Management Plan: Warrell Creek to Nambucca Heads Upgrade of the Pacific Highway.* Unpublished report to Acciona and Ferrovial Joint Venture/ Roads and Maritime Services. GeoLINK Consulting, Coffs Harbour.

Sinclair Knight Merz (2017). *Warrell Creek to Nambucca Heads Upgrade of the Pacific Highway; Flying-fox Management Plan.* Report to Roads and Maritime Services.

Issue Log

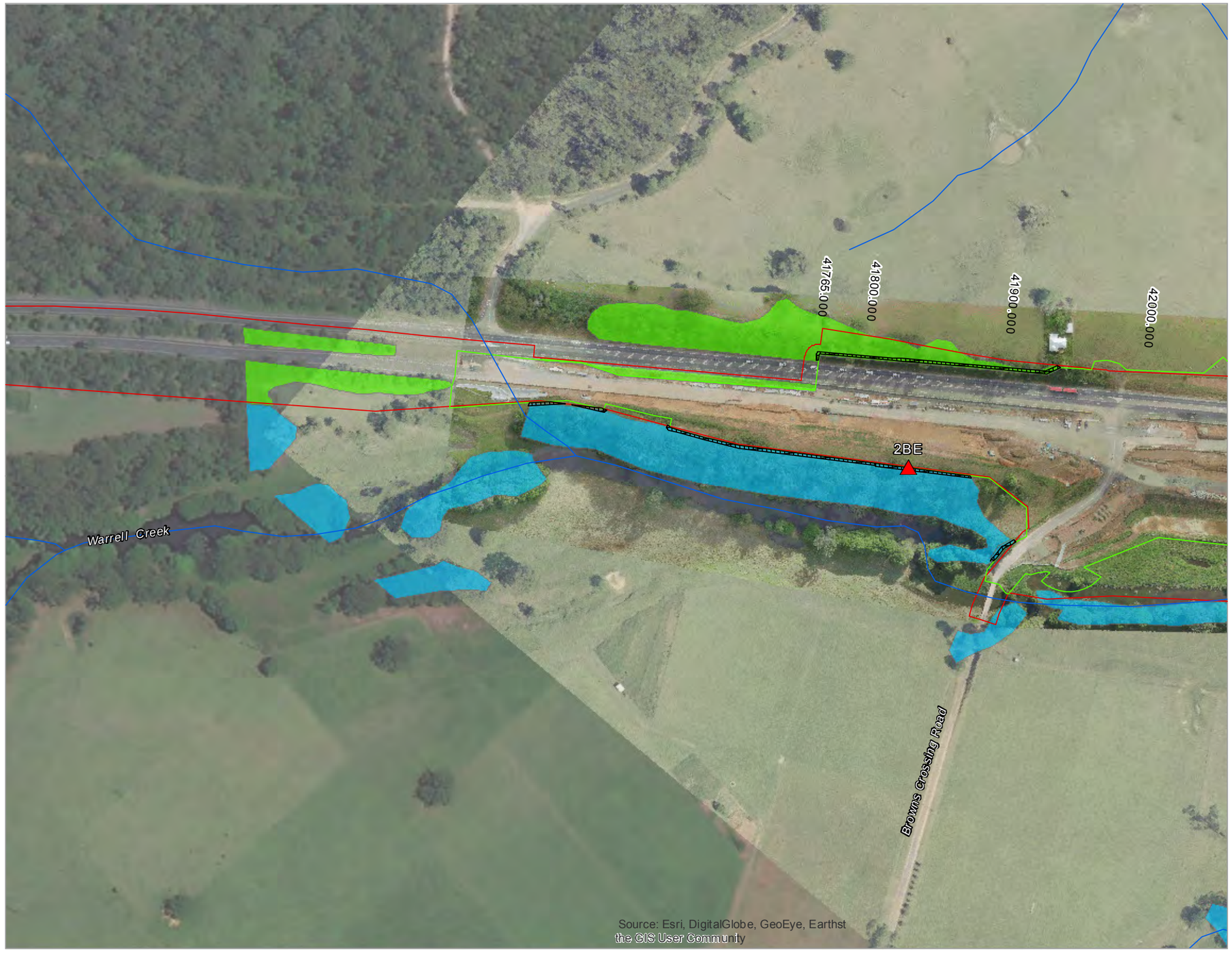
UPR	*Description*	*Date issued*	*Issued By*
2692-1128	First issue (draft)	31/07/2018	David Andrighetto
2692-1131	Second issue	03/08/2018	David Andrighetto

Appendix A

GHFF Weed Survey Areas and Weed Infestation Levels (Winter 2018)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 31/07/2018
Source of base data: ESRI and AFJV



LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2B GHFF weed survey area
- Fixed photo point

Vegetation

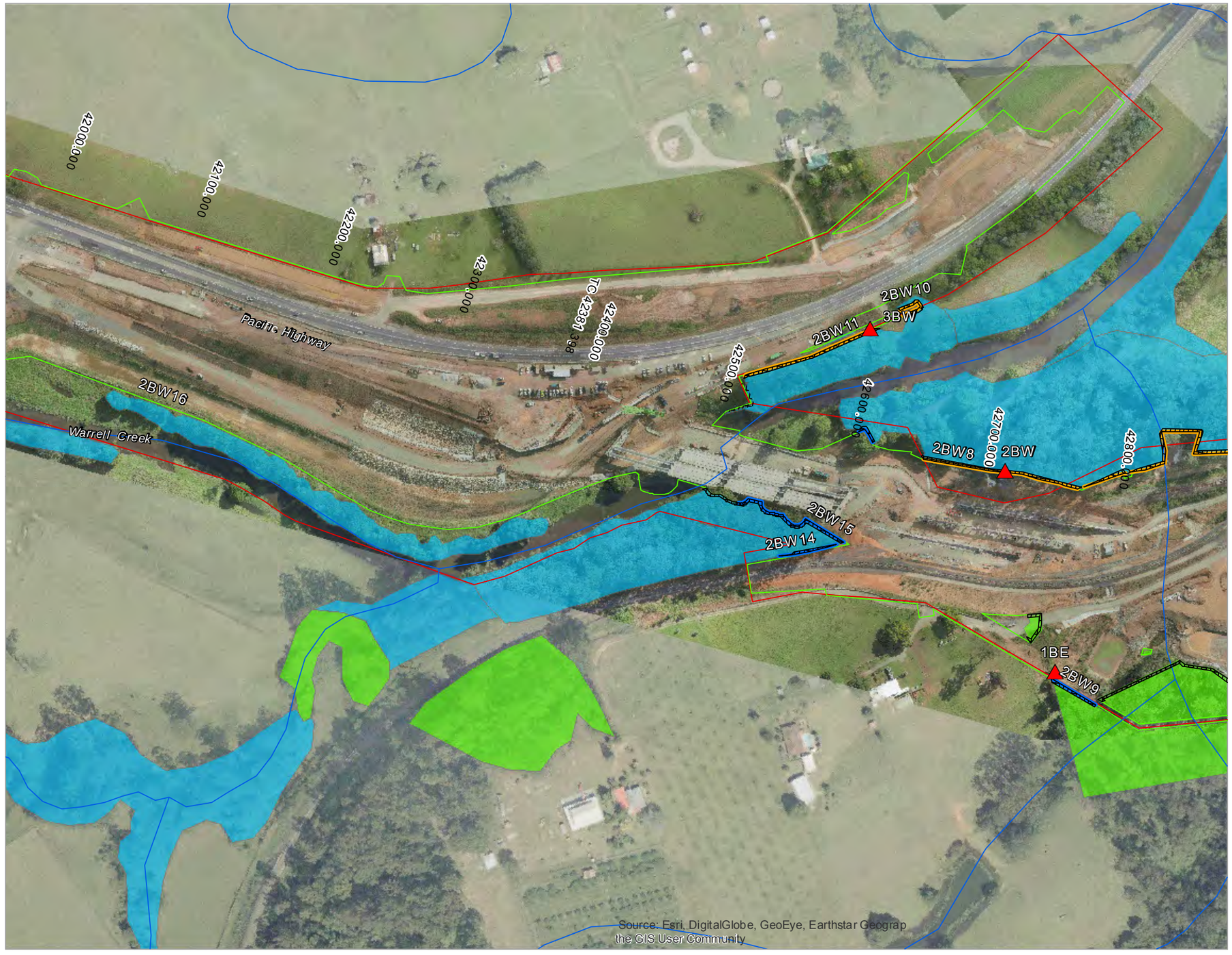
- Mixed Floodplain Forest (EEC)
- Moist Open Forest - Flooded Gum

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 31/07/2018
Source of base data: ESRI and AFJV



LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2B GHFF weed survey area
- Fixed photo point

Weed Site (Abundance)

- High
- Medium
- Low

Vegetation

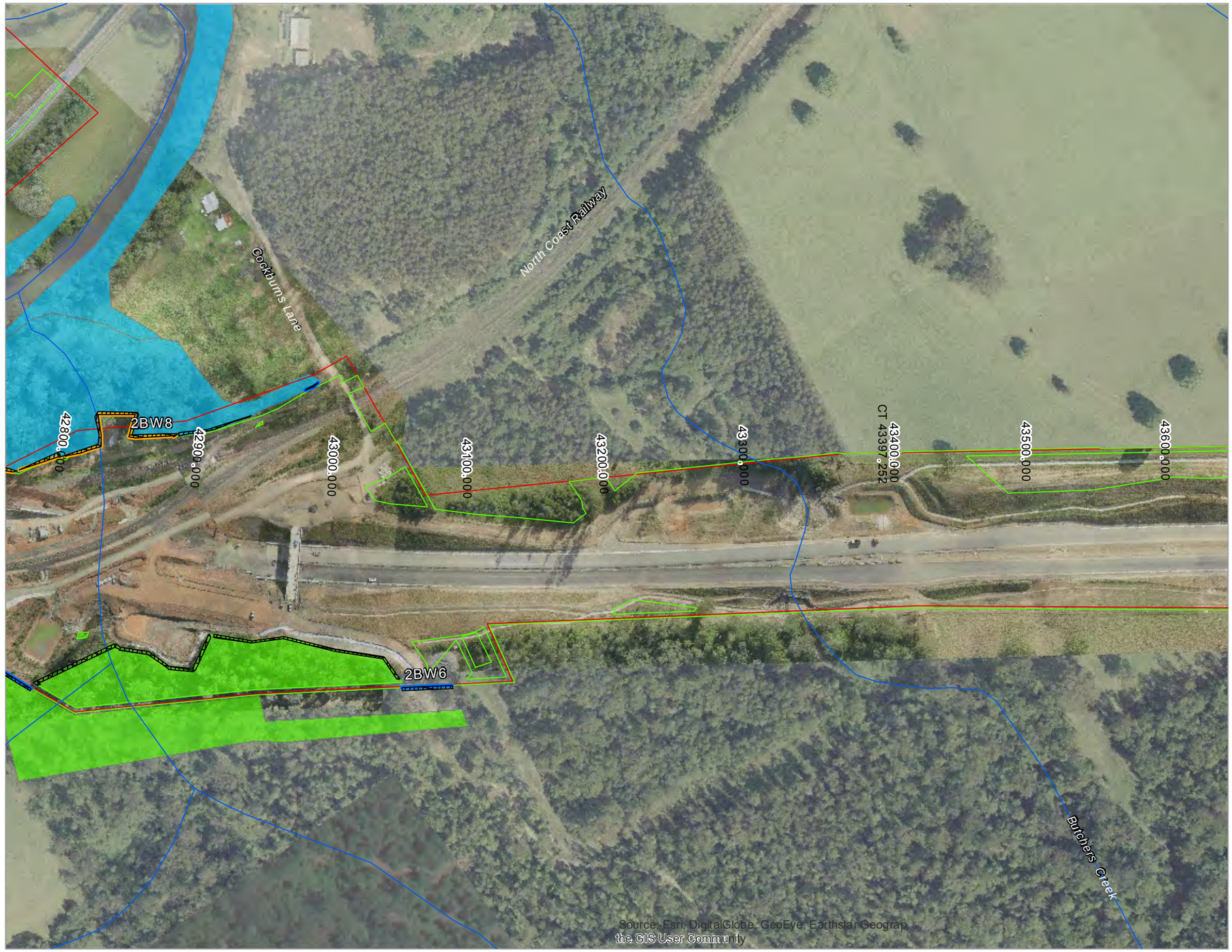
- Mixed Floodplain Forest (EEC)
- Moist Open Forest - Flooded Gum

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 31/07/2018
Source of base data: ESRI and AFJV



LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2B GHFF weed survey area

Weed Site (Abundance)

- Medium
- Low

Vegetation

- Mixed Floodplain Forest (EEC)
- Moist Open Forest - Flooded Gum

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 31/07/2018
Source of base data: ESRI and AFJV

LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2B GHFF weed survey area
- Fixed photo point

Weed Site (Abundance)

- Medium

Vegetation

- Blackbutt Open Forest
- Moist Open Forest - Flooded Gum

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 31/07/2018
Source of base data: ESRI and AFJV

LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2B GHFF weed survey area

Weed Site (Abundance)

- Medium

Vegetation

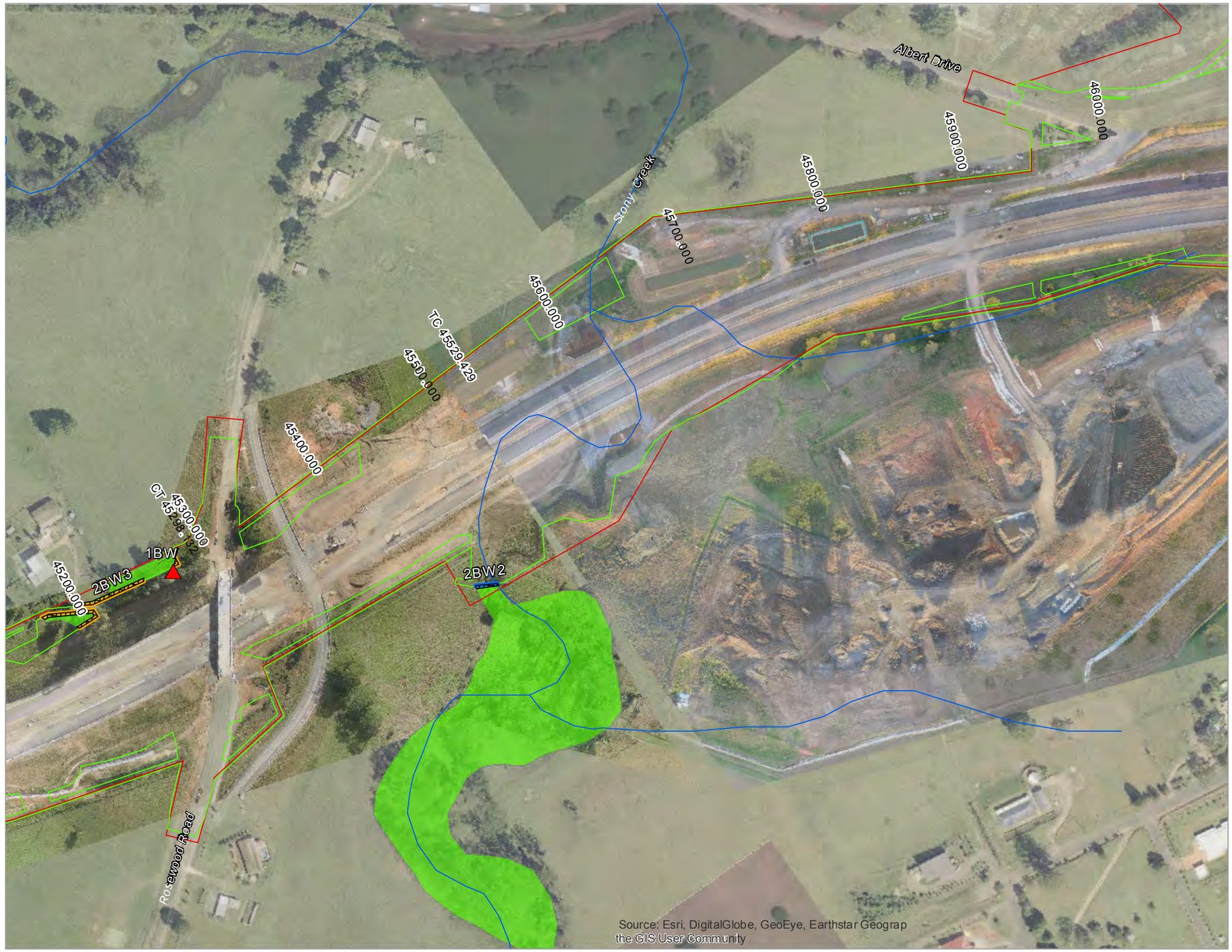
- Blackbutt Open Forest
- Moist Open Forest - Flooded Gum

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 31/07/2018
Source of base data: ESRI and AFJV



LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2B GHFF weed survey area
- Fixed photo point

Weed Site (Abundance)

- Medium
- Low

Vegetation

- Moist Open Forest - Flooded Gum

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 31/07/2018
Source of base data: ESRI and AFJV

LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2B GHFF weed survey area

Weed Site (Abundance)

- High

Vegetation

- Blackbutt Open Forest

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 31/07/2018
Source of base data: ESRI and AFJV

LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2A GBFF weed survey area
- Fixed photo point

Weed Site (Abundance)

- Medium

Vegetation

- Moist Open Forest - White Mahogany / Grey Gum / Ironbark

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 31/07/2018
Source of base data: ESRI and AFJV

LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2A GBFF weed survey area
- Fixed photo point

Weed Site (Abundance)

- Medium

Vegetation

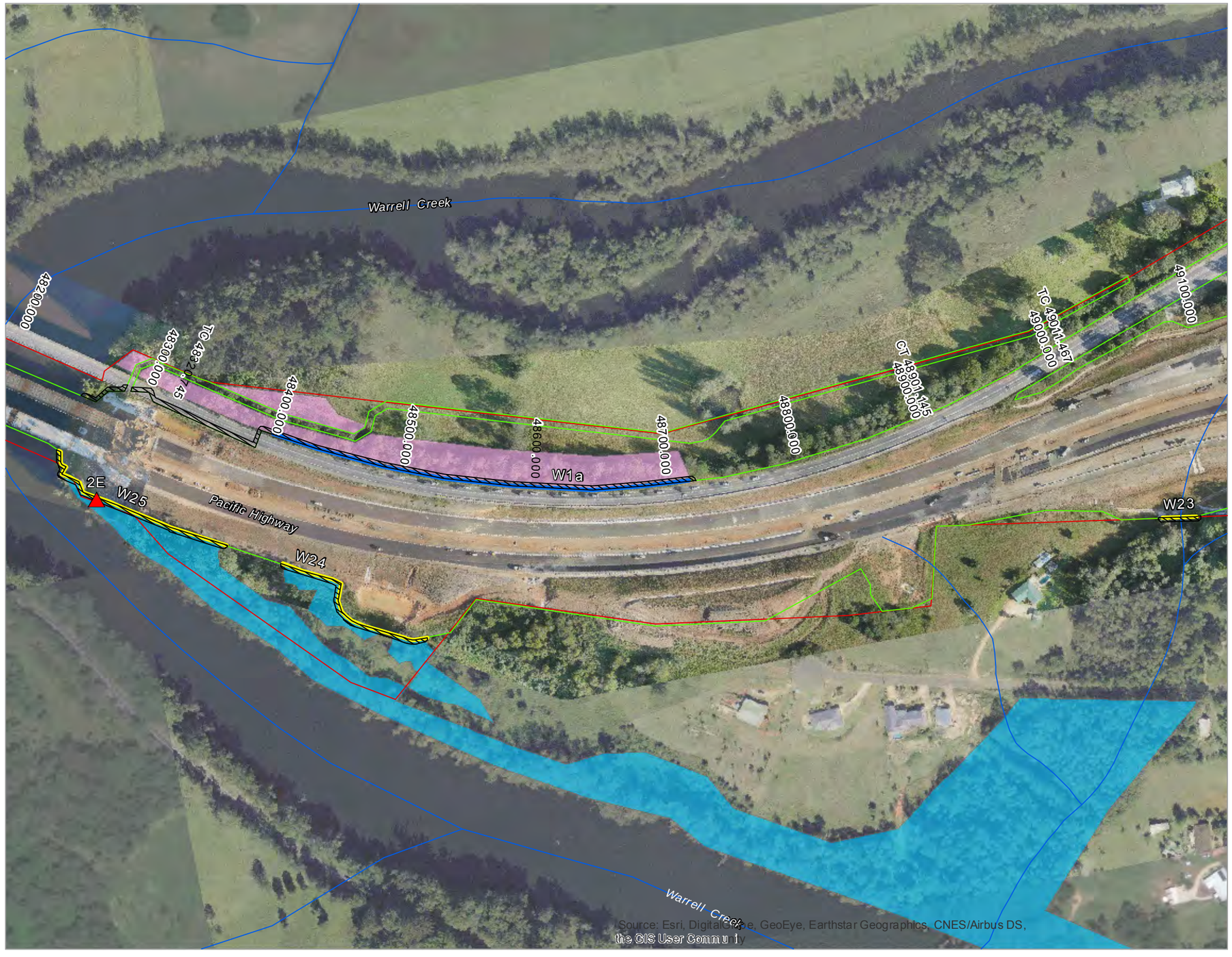
- Moist Open Forest - White Mahogany / Grey Gum / Ironbark

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 31/07/2018
Source of base data: ESRI and AFJV



LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2A GBFF weed survey area
- Fixed photo point

Weed Site (Abundance)

- High
- Low

Vegetation

- Mixed Floodplain Forest (EEC)
- Moist Open Forest - White Mahogany / Grey Gum / Ironbark

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 31/07/2018
Source of base data: ESRI and AFJV

LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2A GBFF weed survey area
- Fixed photo point

Weed Site (Abundance)

- High
- Medium
- Low

Vegetation

- Mixed Floodplain Forest (EEC)
- Moist Open Forest - White Mahogany / Grey Gum / Ironbark
- Swamp Forest - Swamp Mahogany/ Paperbark (EEC)

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 31/07/2018
Source of base data: ESRI and AFJV

LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2A GBFF weed survey area

Weed Site (Abundance)

- Low

Vegetation

- Swamp Forest - Swamp Mahogany/ Paperbark (EEC)

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 31/07/2018
Source of base data: ESRI and AFJV

LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2A GBFF weed survey area

Weed Site (Abundance)

- Low

Vegetation

- Swamp Forest - Swamp Mahogany/ Paperbark (EEC)

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 31/07/2018
Source of base data: ESRI and AFJV

LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2A GBFF weed survey area

Vegetation

- Mixed Floodplain Forest (EEC)

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 31/07/2018
Source of base data: ESRI and AFJV

LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2A GBFF weed survey area

Weed Site (Abundance)

- Medium

Vegetation

- Moist Open Forest - White Mahogany / Grey Gum / Ironbark
- Swamp Forest - Swamp Mahogany/ Paperbark (EEC)

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 31/07/2018
Source of base data: ESRI and AFJV

LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2A GBFF weed survey area
- Fixed photo point

Weed Site (Abundance)

- Low

Vegetation

- Blackbutt Open Forest
- Moist Open Forest - White Mahogany / Grey Gum / Ironbark
- Swamp Forest - Swamp Mahogany/ Paperbark (EEC)

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 31/07/2018
Source of base data: ESRI and AFJV

LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2A GBFF weed survey area
- Fixed photo point

Weed Site (Abundance)

- Medium

Vegetation

- Blackbutt Open Forest
- Swamp Forest - Swamp Mahogany/ Paperbark (EEC)

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 31/07/2018
Source of base data: ESRI and AFJV

LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2A GBFF weed survey area

Weed Site (Abundance)

- Low
- N/A

Vegetation

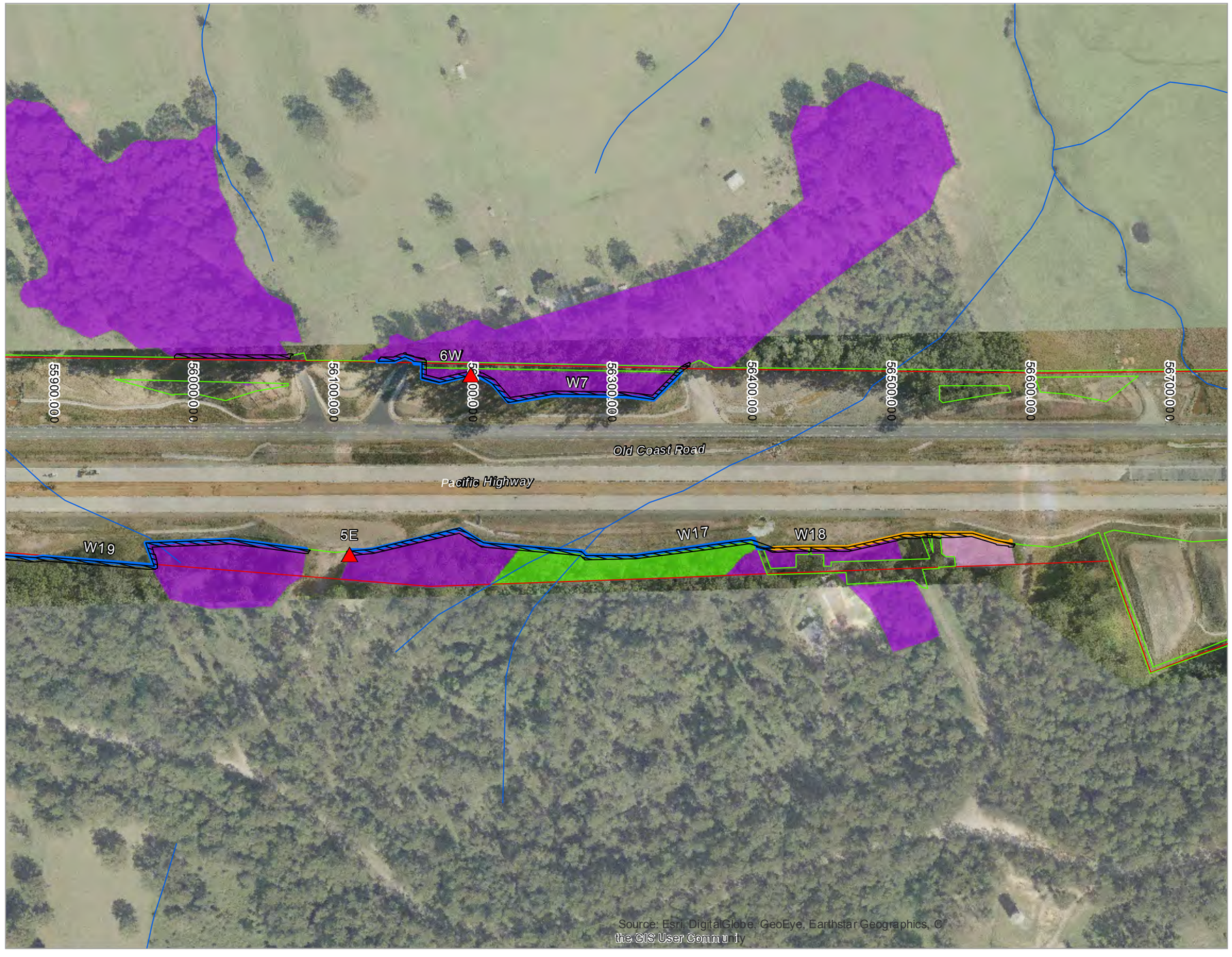
- Blackbutt Open Forest
- Swamp Forest - Swamp Mahogany/ Paperbark (EEC)

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 31/07/2018
Source of base data: ESRI and AFJV



LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2A GBFF weed survey area
- Fixed photo point

Weed Site (Abundance)

- Medium
- Low

Vegetation

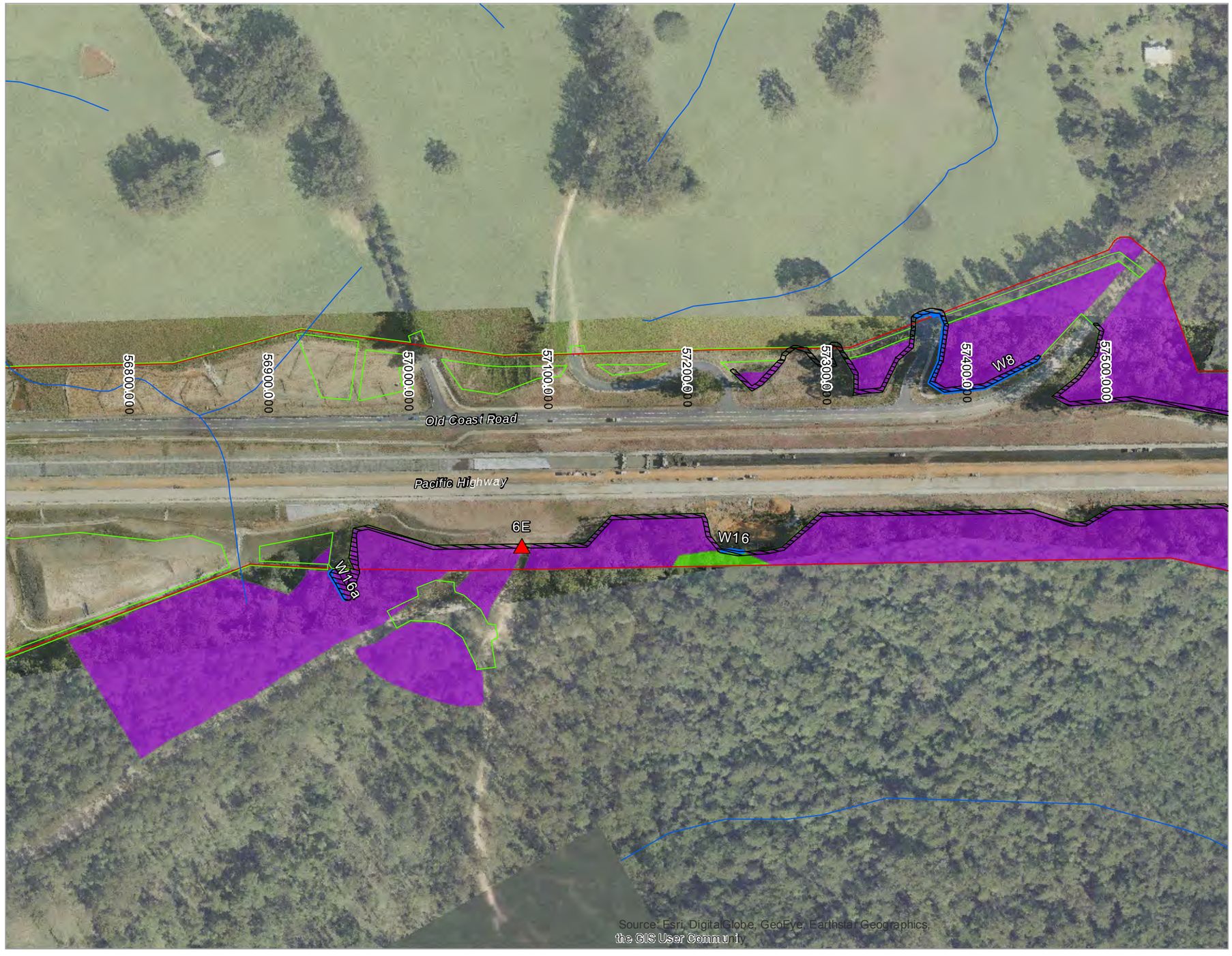
- Blackbutt Open Forest
- Moist Open Forest - Flooded Gum
- Moist Open Forest - White Mahogany / Grey Gum / Ironbark

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 31/07/2018
Source of base data: ESRI and AFJV



LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2A GBFF weed survey area
- Fixed photo point

Weed Site (Abundance)

- Low

Vegetation

- Blackbutt Open Forest
- Moist Open Forest - Flooded Gum

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 31/07/2018
Source of base data: ESRI and AFJV

LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2A GBFF weed survey area
- Fixed photo point

Weed Site (Abundance)

- N/A

Vegetation

- Blackbutt Open Forest
- Moist Open Forest - Flooded Gum

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 31/07/2018
Source of base data: ESRI and AFJV

LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2A GBFF weed survey area
- Fixed photo point

Weed Site (Abundance)

- Low
- N/A

Vegetation

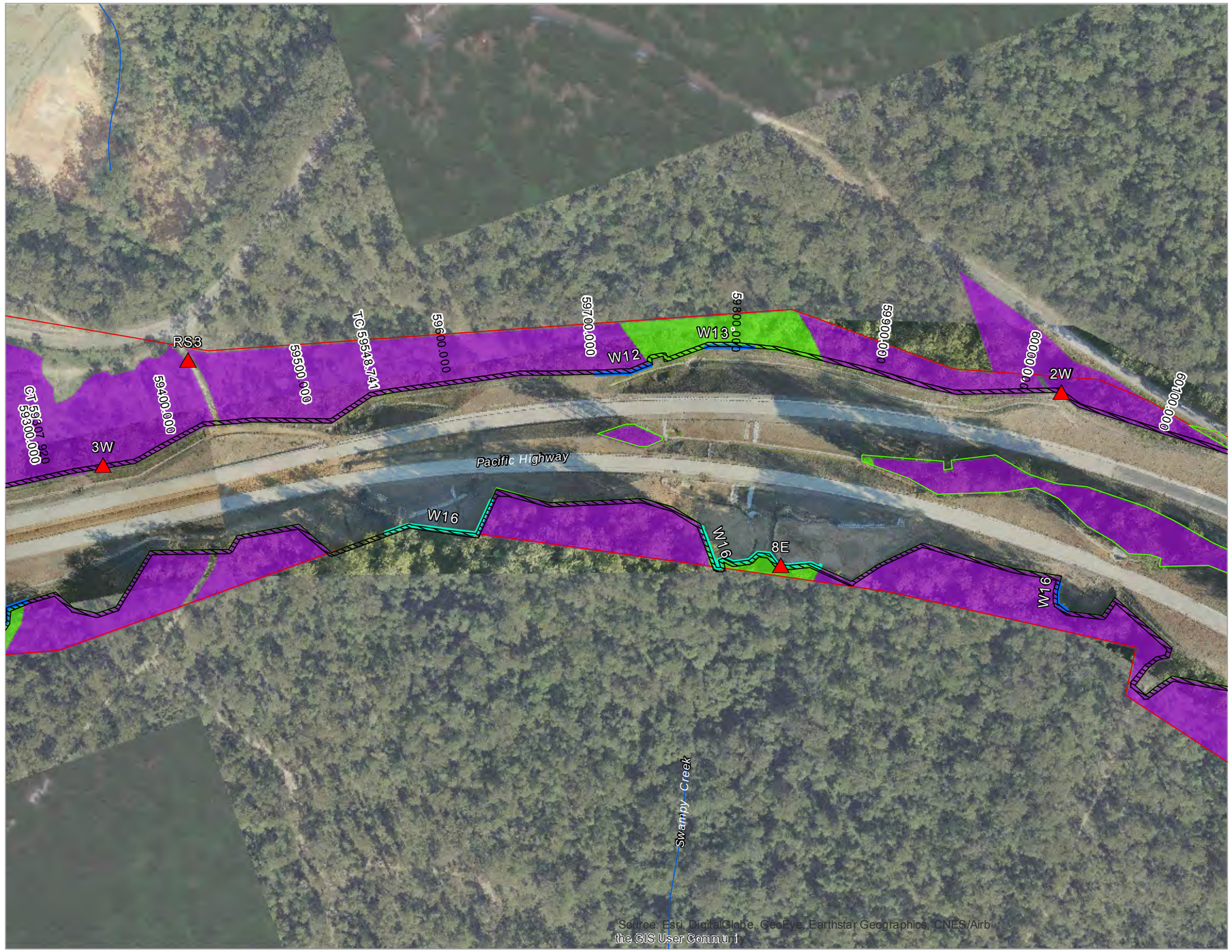
- Blackbutt Open Forest
- Moist Open Forest - Flooded Gum

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 31/07/2018
Source of base data: ESRI and AFJV



LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2A GBFF weed survey area
- Fixed photo point

Weed Site (Abundance)

- Low
- N/A

Vegetation

- Blackbutt Open Forest
- Moist Open Forest - Flooded Gum

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 31/07/2018
Source of base data: ESRI and AFJV

LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2A GBFF weed survey area
- Fixed photo point

Weed Site (Abundance)

- Low

Vegetation

- Blackbutt Open Forest

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 31/07/2018
Source of base data: ESRI and AFJV

LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2A GBFF weed survey area

Weed Site (Abundance)

- N/A

Vegetation

- Blackbutt Open Forest

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Appendix B

GHFF Food Trees Species List

GHFF primary food tree species (blossom diet)			
Banksia integrifolia	Coastal Banksia	*Eucalyptus robusta*	Swamp Mahogany
Corymbia gummifera	Red Bloodwood	*Eucalyptus saligna*	Sydney Blue Gum
Corymbia intermedia	Pink Bloodwood	*Eucalyptus siderophloia*	Northern Grey Ironbark
Corymbia maculata	Spotted Gum	*Eucalyptus tereticornis*	Forest Red Gum
Corymbia variegata	Spotted Gum	*Grevillea robusta*	Silky Oak
Castanospermum australe	Black Bean	*Melaleuca quinquenervia*	Broad-leaved Paperbark
Eucalyptus pilularis	Blackbutt	*Syncarpia glomulifera*	Turpentine
GHFF secondary food tree species (blossom diet)			
Angophora costata	Smooth-barked Apple	*Eucalyptus grandis*	Flooded Gum
Angophora floribunda	Rough-barked Apple	*Eucalyptus propinqua*	Grey Gum
Eucalyptus acmenoides	White Mahogany	*Eucalyptus resinifera*	Red Mahogany
GHFF food tree species (fruit diet)			
Acmena smithii	Lilly Pilly	*Hedycarya angustifolia*	Native Mulberry
Alphitonia excelsa	Red Ash	*Livistona australis*	Cabbage Palm
Archontophoenix cunninghamiana	Bangalow Palm	*Maclura cochinchinensis*	Cockspur Thorn
Avicennia marina	Grey Mangrove	*Melia azedarach*	White Cedar
Cissus hypogaluca	Five-leaf Water Vine	*Melodinus australis*	Southern Melodinus
Dendrocnide excelsa	Giant Stinging Tree	*Morinda jasminoides*	Morinda
Dendrocnide photinophylla	Shining-lved Stinging Tree	*Pennantia cunninghamii*	Brown Beech
Diospyros pentamera	Myrtle Ebony	*Pittosporum undulatum*	Sweet Pittosporum
Diploglottis australis	Native Tamarind	*Planchonella australis*	Black Apple
Eucalyptus reticulatus	Blueberry Ash	*Podocarpus elatus*	Plum Pine
Ehretia acuminata	Koda	*Polyosma cunninghamii*	Featherwood
Elaeocarpus obovatus	Hard Quandong	*Rauwenhoffia leichardtii*	Zig Zag Vine
Ficus coronata	Creek Sandpaper Fig	*Rhodamnia argentea*	Malletwood
Ficus fraseri	Sandpaper Fig	*Syzygium australe*	Brush Cherry
Ficus macrophylla	Moreton Bay Fig	*Syzygium corynanthum*	Sour Cherry
Ficus obliqua	Small-leaved Fig	*Syzygium crebrinerve*	Purple Cherry
Ficus rubiginosa	Rusty Fig	*Syzygium luehmanii*	Riberry
Ficus superba	Deciduous Fig	*Syzygium. oleosum*	Blue Lilly Pilly
Ficus watkinsiana	Strangler Fig	*Schizomeria ovata*	Crabapple

Appendix C

Fixed Photo Point Results

Table C1 Rehabilitation Site Photo Points

Photo Monitoring Point Location	*Site Rehabilitation Summer Monitoring Event – February 2018*	*Site Rehabilitation Autumn Monitoring Event – May 2018*	*Site Rehabilitation Winter Monitoring Event – July 2018*
CH: 60800 West - Photo Point RS1 – view to the south (W:497272, N:6610243)			
CH: 60800 West - Photo Point RS2 – view to the north-east (E:497260, N:6610256)			
CH: 60800 West - Photo Point RS2 – view to the south-west (E:497260, N:6610256)			

Photo Monitoring Point Location	*Site Rehabilitation Summer Monitoring Event – February 2018*	*Site Rehabilitation Autumn Monitoring Event – May 2018*	*Site Rehabilitation Winter Monitoring Event – July 2018*
CH: 59450 East - Photo Point RS3 - view to the east (E:496443, N:6609093), no rehabilitation works started at time of monitoring.			
CH: 59450 East - Site reference photo view to the west (E:496443, N:6609093), looking towards Photo Point #3, no rehabilitation works started at time of monitoring.			
CH: 60800 East - Photo Point RS4 (E:497440, N:6610248) - view to the west (no peg installed)			

Table C2 Weed Monitoring Fixed Photo Points (Stage 2A)

*Photo Point ID **	*Photo Point GPS Coordinates^*	*February 2018 photograph*	*May 2018 photograph*	*July 2018 photograph*
1E	491906, 6598292			
1W	492671, 6600507			
2E	492372, 6599033			

*Photo Point ID **	*Photo Point GPS Coordinates^*	*February 2018 photograph*	*May 2018 photograph*	*July 2018 photograph*
2W	496675, 6609675			
3E	492778, 6600567			
3W	496494, 6609010			

Photo Point ID *	Photo Point GPS Coordinates^	February 2018 photograph	May 2018 photograph	July 2018 photograph
4E	494575, 6605139			
4W	496131, 6608279			
5E	494960, 6606206			

*Photo Point ID **	*Photo Point GPS Coordinates^*	*February 2018 photograph*	*May 2018 photograph*	*July 2018 photograph*
5W	495668, 6607684			
6E	495433, 6607052			
6W	494890, 6606346			

*Photo Point ID **	*Photo Point GPS Coordinates^*	*February 2018 photograph*	*May 2018 photograph*	*July 2018 photograph*
7E	496240, 6608213			
7W	494355, 6604185			
8E	496724, 6609444			

* number + side of alignment heading north: E=east, W=west.

Table C3 Weed Monitoring Fixed Photo Points (Stage 2B)

*Photo Point ID**	*Photo Point GPS Coordinates^*	*July 2018 photograph*
1BE	489545, 6594390	
1BW	490778, 6596540	
2BE	488766, 6593840	

*Photo Point ID**	*Photo Point GPS Coordinates^*	*July 2018 photograph*
2BW	489407, 6594440	
3BE	490153, 6595330	
3BW	489268, 6594420	

Appendix 4: Spring 2018 Stage 2A and Stage 2B monitoring report.

ABN 79 896 839 729
ACN 101 084 557

Return address:
PO Box 119
LENNOX HEAD
NSW 2478

LENNOX HEAD
T 02 6687 7666
F 02 6687 7782

COFFS HARBOUR
T 02 6651 7666

ARMIDALE
T 0488 677 666

LISMORE
T 02 6621 6677

www.geolink.net.au

16 November 2018
Ref No: 2692-1156

Roads and Maritime Service
124 Albert Drive
DONNELLYVILLE NSW 2447

Attention: Mr Kris Hincks

Dear Kris

WC2NH Stage 2A and 2B GHFF Habitat Monitoring – Spring 2018 (Issue 2)

Introduction

This report presents the habitat monitoring results of Grey-Headed Flying-fox (GHFF) habitat adjacent to the Warrell Creek to Nambucca Heads Highway Upgrade (WC2NH) project for:

- Stage 2A: the fourth and final quarterly monitoring event (spring 2018); and
- Stage 2B: the second quarterly monitoring event (spring 2018).

Quarterly GHFF habitat monitoring is required for Stage 2A (chainage 47700 to 61300) and Stage 2B (chainage 41700 to 47700) (refer to **Appendix A**) for up to one year after the opening of these sections of WC2NH to traffic. Quarterly GHFF habitat monitoring is undertaken in accordance with the *Warrell Creek to Urunga Pacific Highway Upgrade Ecological Monitoring Program – Stage 2: Warrell Creek to Nambucca Heads* (Benchmark Environmental Management, 2014).

The *Warrell Creek to Nambucca Heads Flying-fox Management Plan* (Sinclair Knight Merz, 2017) recognised that the quality of vegetation adjacent to the Project area could be detrimentally affected by invasion of noxious and environmental weeds. A main goal identified for management during operation of the Project is '*no reduction of the quality of flying-fox habitats adjacent to the Project corridor due to the operation of the Project and to minimise the impact of edge effects'* (Sinclair Knight Merz, 2017).

Methodology

The monitoring of Grey-headed Flying-fox habitat includes the following components:

1. Monitoring of identified revegetation/ rehabilitation areas to ensure the establishment/ restoration of seedlings and plants.
2. Monitoring both revegetation/ rehabilitation areas and other habitat areas adjacent to the Project to manage invasion of noxious and environmental weeds.

Urban and Regional Planning | Environmental Engineering | Civil Design | Environmental Impact Assessment | Ecological Surveys and Monitoring | Landscape Architecture | Urban Design |

quality solutions **sustainable** future

For brevity, component 1 is henceforth referred to as 'rehabilitation site monitoring', and component 2 is referred to as 'weed monitoring'.

Field surveys were undertaken by GeoLINK ecologists Grant McLean and Frank Makin on:

- 30 October 2018 between 7.00 am to 4.00 pm; and
- 31 October 2018 between 7.30 am to 2.30 pm.

Rehabilitation Site Monitoring

The locations of the GHFF habitat areas requiring revegetation/ rehabilitation are listed in **Table 1** and correspond with Stage 2A of the Project. Monitoring of these areas aims to assess the effectiveness of rehabilitation of GHFF habitat areas cleared during the construction of the Project.

Table 1 Location of GHFF Habitat Rehabilitation Sites

Habitat Type	*Location*	*Site*
Open Forest - Blackbutt	CH: 59450 East	15c ancillary compound
Open Forest - Blackbutt	CH: 60800 East	Old Coast Rd Temporary Deviation

The following data was recorded for each location:

- Date and time of monitoring.
- Weed abundance and composition.
- Evidence of management and control of noxious and environmental weeds.
- Evidence of any progressive revegetation/ rehabilitation during the construction phase using collected topsoil and seed at specific sites and to develop different successional stages of rehabilitation.
- Evidence of native plant establishment of seedlings.
- Identification of any of the GHFF food tree plants referred to in **Appendix B**.

Photos were also taken at the four fixed photo points associated with the rehabilitation sites (refer to **Table 2**).

Table 2 Locations of Fixed Photo Points for Rehabilitation Sites

Photo Point ID	*Photo Point GPS Coordinates**	*Corresponding Rehabilitation Site*
RS1	497272, 6610243	Old Coast Road temporary deviation (west)
RS2	497260, 6610256	Old Coast Road temporary deviation (west)
RS3	496443, 6609093	15c ancillary compound
RS4	497440, 6610248	Old Coast Road temporary deviation (east)

** UTM eastings, northings; Zone 56J*

Weed Monitoring

The Project *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) approval defined GHFF habitat as habitat consisting of:

- Swamp Forest - Swamp Mahogany/ Paperbark.
- Moist Open Forest - Flooded Gum.
- Moist Open Forest - White Mahogany/ Grey Gum/ Ironbark.
- Mixed Floodplain Forest.
- Open Forest - Blackbutt.

All instances of the above plant communities occurring along the outside of the Project clearing corridor were targeted during the field surveys. Within two metres of the cleared edge of these habitat areas the following data was recorded in relation to weeds:

- Date and time of monitoring.
- Weed abundance and composition.
- Evidence of management and control of noxious and environmental weeds.

Weed abundance for individual species was measured using modified Braun-Blanquet cover classes between 1 and 5: 1 (<5%), 2 (6-25%), 3 (26-50%), 4 (51-75%), and 5 (76-100%). Abundance scores for identified weed sites were classified based on the categories in **Table 3**. Priority weed sites for management were identified based on species present and the percentage cover, prioritising *Biosecurity Act 2015* listed species and weeds with potential to degrade flying-fox foraging habitat values.

Table 3 Weed Abundance Classification for Weed Sites

Noxious/ Environmental Weed Cover (%)	*Weed Abundance Classification*
0-10	NA
11-39	Low
40-69	Medium
70-100	High

Photos were taken at the fixed photo points established during the Summer 2018 weed monitoring for Stage 2A and at fixed photo points established during the Winter 2018 weed monitoring for Stage 2B. Locations of the fixed photo points are listed in **Table 4**.

Table 4 Locations of Fixed Photo Points

Stage	*Photo Point ID**	*Photo Point GPS Coordinates^*	*Notes on Photo Direction*	*Vegetation Type*	*Corresponding Weed Infestation*
2A	1E	491906, 6598292	Looking north	Moist Open Forest - White Mahogany/ Grey Gum/ Ironbark	W28
2A	1W	492671, 6600507	Looking north north-east	Swamp Forest - Swamp Mahogany/ Paperbark	W1b
2A	2E	492372, 6599033	Looking north-east	Moist Open Forest - Flooded Gum	W25

Stage	Photo Point ID*	Photo Point GPS Coordinates^	Notes on Photo Direction	Vegetation Type	Corresponding Weed Infestation
2A	2W	496675, 6609675	Looking north-east	Open Forest - Blackbutt	Not applicable
2A	3E	492778, 6600567	Looking south-west	Swamp Forest - Swamp Mahogany/ Paperbark	W21
2A	3W	496494, 6609010	Looking south	Open Forest - Blackbutt	Not applicable
2A	4E	494575, 6605139	Looking north north-east	Swamp Forest - Swamp Mahogany/ Paperbark	Not applicable
2A	4W	496131, 6608279	Looking north-east	Moist Open Forest – Flooded Gum	W9
2A	5E	494960, 6606206	Looking south south-west	Open Forest - Blackbutt	W17
2A	5W	495668, 6607684	Looking north-east	Moist Open Forest – Flooded Gum	Not applicable
2A	6E	495433, 6607052	Looking north	Open Forest - Blackbutt	Not applicable
2A	6W	494890, 6606346	Looking south south-west	Open Forest - Blackbutt	W7
2A	7E	496240, 6608213	Looking west	Moist Open Forest – Flooded Gum	W16
2A	7W	494355, 6604185	Looking north	Moist Open Forest - White Mahogany/ Grey Gum/ Ironbark	Not applicable
2A	8E	496724, 6609444	Looking south south-west	Moist Open Forest – Flooded Gum	W16
2B	1BE	489545, 6594390	Looking north	Moist Open Forest - Flooded Gum	2BW9
2B	1BW	490778, 6596540	Looking south	Moist Open Forest - Flooded Gum	2BW3
2B	2BE	488766, 6593840	Looking south-west	Mixed Floodplain Forest	2BW18
2B	2BW	489407, 6594440	Looking north-east	Mixed Floodplain Forest	2BW8
2B	3BE	490153, 6595330	Looking south	Moist Open Forest - Flooded Gum	Not applicable
2B	3BW	489268, 6594420	Looking south	Mixed Floodplain Forest	2BW11

** number plus side of alignment heading north: E=east, W=west.*

^ UTM eastings, northings; Zone 56J.

Results and Discussion

Rehabilitation Site Monitoring

The results of the rehabilitation site monitoring are provided in **Table 5**. Photos from the four fixed photo points are shown in **Appendix C**. Plantings and/ or seeding at these sites are either young or have not been undertaken (in the case of the rehabilitation site at the 15c ancillary compound).

Native seed germination is evident at the Old Coast Road Temporary Deviation (CH60800) with a number of native species recorded growing from the native seed mix applied on both sides of the highway alignment. However native species growth has remained stagnant and cover is minimal.

Table 5 Rehabilitation Site Monitoring

Rehabilitation Site	***Old Coast Rd Temporary Deviation (CH: 60800 West)***	***Old Coast Rd Temporary Deviation (CH: 60800 East)***	***15c Ancillary Compound (CH: 59450 East)***
Photo Point GPS Coordinates (UTM eastings, northings; Zone 56J)	Photo Point RS1: 497272, 6610243 Photo Point RS2: 497260, 6610256	Photo Point RS4: 497440, 6610248	Photo Point RS3: 496443, 6609093
Date and time of survey	Spring: 30/10/2018 – 11:57 am	Spring: 30/10/2018 – 11:40 am	Spring: 31/10/2018 – 1:22 pm
Weed Abundance and Composition	No weed infestations were observed within the newly landscaped area. No change from winter 2018 survey.	No weed infestations were observed within trimmed, top-soiled and hydroseeded batter. No change from winter 2018 survey	The northern boundary of this area has <5% intrusion of Whiskey Grass (*Andropogon virginicus*), Broadleaf Paspalum (*Paspalum mandiocanum*), Lantana* *(Lantana camara*) and Blue Billygoat Weed (*Ageratum houstonianum*). A minor reduction in Fireweed (*Senecio madagascariensis*) and Cobblers Pegs (*Bidens pilosa*) was evident when compared to the winter 2018 survey.
Evidence of management and control of noxious and environmental weeds	No weeds present. No change from winter 2018 survey.	No weeds present. No change from winter 2018 survey.	No evidence of weed management observed.
Evidence of any progressive revegetation/ rehabilitation during the construction phase using collected topsoil and seed at specific sites and to develop different successional stages of rehabilitation	No observed progressive revegetation or successional stages of rehabilitation. No weeds present. No change from winter 2018 survey.	No observed progressive revegetation or successional stages of rehabilitation. No weeds present. No change from winter 2018 survey.	A mulch layer has been applied to the site that was not previously evident during the winter 2018 survey.
Evidence of native establishment of seedlings and plants	Establishment of Hickory Wattle (*Acacia falcata*) and Large-leaf Hop-bush (*Dodonaea triquetra*) to 30 cm	No change from Winter 2018 survey. Some encroachment (<1% cover) from the edge of the cleared area was	Areas with recently applied mulch (since the winter 2018 monitoring) continue to show no evidence of native establishment of seedlings and plants.

Rehabilitation Site	Old Coast Rd Temporary Deviation (CH: 60800 West)	Old Coast Rd Temporary Deviation (CH: 60800 East)	15c Ancillary Compound (CH: 59450 East)
	on the southern drain embankment. No other changes from Winter 2018 survey. Semi established native plant species that have been planted as part of rehabilitation include Water Gum (*Tristaniopsis laurina*) to ~ 1 m height and Tea Tree (*Leptospermum brachyandrum*) to ~ 2 m height. Native regeneration species account for <2% cover with maximum plant height to 35 cm. Identifiable species include: ■ Dusky Coral Pea (*Kennedia rubicunda*) ■ Purple Coral Pea (*Hardenbergia violacea*) ■ Pink Kunzea (*Kunzea capitata*) ■ Green Wattle (*Acacia irrorata*) ■ White Sally Wattle (*Acacia floribunda*) ■ Austral indigo (*Indigofera australis*) ■ *Goodenia sp.* (likely *G. heterophylla*). The hydroseeded grass cover crop has remained died off.	recorded with Bracken Fern (*Pteridum esculentum*) and Blady Grass (*Imperata cylindrica*) beginning to recolonise the disturbed area. Very minor (<1%) native regeneration of bushland regeneration hydroseed mix are regenerating to maximum height of 20 cm. Identifiable species include: ■ Dusky Coral Pea ■ Purple Coral Pea ■ Green Wattle. ■ White Sally Wattle. The hydroseeded grass cover crop has remained died off.	Minor natural regrowth <5% was observed of Blackbutt (*Eucalyptus pilularis*), Sally Wattle (*Acacia melanoxylon*), Blady Grass, Water Vine (*Cissus hypoglauca*), Bracken Fern and Kangaroo Grass (*Themeda triandra*) on the northern edge of the site where no mulch has been applied.
Identification of any of the GHFF food tree species (refer to Appendix B)	No change from winter 2018 survey. Applied landscape seed mixes have	No change from winter 2018 survey. No landscape plantings had been	No evidence of GHFF food tree recruitment from landscaping at the time of monitoring. Minor natural regeneration on

Rehabilitation Site	*Old Coast Rd Temporary Deviation (CH: 60800 West)*	*Old Coast Rd Temporary Deviation (CH: 60800 East)*	*15c Ancillary Compound (CH: 59450 East)*
	included species identified within **Appendix B** (Alex Dwyer {Pacifico Environmental Manager} email 8/03/2018). No regeneration of GHFF food tree species has been detected to date.	undertaken at the time of monitoring. It appears that no landscape plantings are proposed for this area of the Old Coast Road temporary deviation rehabilitation. Applied landscape seed mixes have included species identified within **Appendix B** (Alex Dwyer {Pacifico Environmental Manager} email 8/03/2018). No regeneration of GHFF food tree species has been detected to date.	the northern end includes Blackbutt, a GHFF food tree species.

* Denotes *Biosecurity Act 2015* listed priority weed species.

Weed Monitoring

Stage 2A

Occurrence of noxious and/ or environmental weeds was recorded at 27 sites (identified as low, medium or high) within the edge of GHFF habitat adjacent to the Project area. These weed occurrences are shown in **Appendix A** and listed in **Table 6**. Photographs of GHFF habitat areas taken from the fixed photo points are shown in **Appendix C**.

Only very minor changes to weed densities and composition were observed during the subject spring 2018 monitoring event compared to the previous monitoring event (winter 2018). Cool and wet weather conditions (178 mm total rainfall for October) were experienced in the month leading up to the survey (BOM, 2018). Observed changes include:

- Five additional weed sites (W2a, W19a, W19b, W19c and W19d) were observed during the spring 2018 survey and comprise low weed management priority areas.
- Additional weed species were recorded at eleven sites: W1a, W1b, W2, W5, W6, W12, W20, W22, W23, W24 and W25.
- Weed abundance at site W19 and W26 has reduced to Low. Weed abundance at sites W8, W11, W12 and W16 (in several sections) and W19 has reduced to NA.
- An increase in the weed cover of individual species was recorded at sites W20 (Setaria) and W21 (Salvinia - *Salvinia molesta*).
- A decrease in weed infestation extent was observed at site W19, reducing the northern extent by approximately 170 m to south.

A total of 27 noxious and environmental weed species were recorded. Lantana, Salvinia, Fireweed and Blackberry (*Rubus fruticosus*) were recorded on-site and are listed as priority weed species for the North Coast of NSW under the *Biosecurity Act 2015*. The primary management duty for these is they '*must not be imported into the state or sold*'.

Broadleaf Paspalum and Lantana were recorded within GHFF habitat areas at the highest density, and were also the dominant weed species in those GHFF areas that recorded a 'high' weed abundance level (refer to **Table 6**).

One weed site (site W25) was considered to have a high weed management priority, while seven weed sites were considered to have a medium weed management priority (sites W18, W19 {part}, W20, W22, W23, W24 and W28). These areas should be targeted during weed management works.

A reduction in weeds and general vegetative cover was observed at fixed photo point monitoring site 1E attributed to disturbance associated with fencing installation. No other obvious changes were recorded between the winter 2018 and spring 2018 fixed photo point monitoring sites (refer to **Appendix C**).

No increase in the densities of the exotic vines Mile-a-minute (*Ipomoea cairica*) or Morning Glory (*Ipomoea indica*) were recorded during the spring 2018 habitat monitoring. Both of these species have potential to inhibit native regeneration and smother the canopy of intact GHFF habitat.

Table 6 Abundance and Composition of Noxious and/ or Environmental Weeds Sites for Stage 2A

Weed Site Ref.	*Chainage (side of highway)*	*Spring 2018 Weed Composition (Cover Class^)*	*GHFF Habitat Type (Plant Community)*	*Summer 2018 Weed Abundance^^*	*Autumn 2018 Weed Abundance^^*	*Winter 2018 Weed Abundance^^*	*Spring 2018 Weed Abundance^^*	*Comments*	*Evidence of Management and Control*	*Weed Management Priority*
Date and time: ■ 30 October 2018 between 7.00 am to 4.00 pm. ■ 31 October 2018 between 7.30 am to 2.30 pm.										
W1a	48400 to 48700 (west)	Lantana* (2), Camphor Laurel (1), Broadleaf Paspalum (2), Blackberry* (1), Blue Billygoat Weed	Moist Open Forest - White Mahogany/ Grey Gum/ Ironbark	NA	Low	Low	Low	**Additional weeds recorded: Blue Billygoat Weed**	No evidence of weed control	Low
W1b	49790 - 50100 (west)	Setaria (*Setaria sphacelata*) **(1),** Annual Ragweed (*Ambrosia artemisiifolia*) (1), Broadleaf Paspalum (2), Fireweed* (1), Blue Billygoat Weed (1) Balloon Cotton Bush (*Gomphocarpus physocarpus*) (1), **Paddy's Lucerne (1), Purple Top (1).**	Swamp Forest - Swamp Mahogany/ Paperbark	Low	Low	Low	Low	Majority of weed infestation concentrated on batter edge. Blue Water Lily (on swamp fringe) 40% cover in concentrated areas of open water. **Minor reduction in Setaria cover recorded from 2 in Winter 2018 to 1 in Spring 2018. Additional weeds recorded:**	No evidence of weed control	Low

Weed Site Ref.	Chainage (side of highway)	Spring 2018 Weed Composition (Cover Class^)	GHFF Habitat Type (Plant Community)	Summer 2018 Weed Abundance^^	Autumn 2018 Weed Abundance^^	Winter 2018 Weed Abundance^^	Spring 2018 Weed Abundance^^	Comments	Evidence of Management and Control	Weed Management Priority
								Paddy's Lucerne (1), Purple Top (1).		
W2	51010 - 51165 (west)	Salvinia* (within open water area – approx. chainage 51020) (2), **Paddy's Lucerne (1), Purple top (1).**	Swamp Forest - Swamp Mahogany/ Paperbark	Low	Low	Low	Low	Very minor Flax-leaf Fleabane (*Conyza bonariensis*), Broadleaf Paspalum and Annual Ragweed on fauna fence edge. **Additional weeds recorded: Paddy's Lucerne (1), Purple Top (1).**	No evidence of weed control	Low (this species would have minimal impact on GHFF habitat value).
W2a	**53580 - 53700**	**Lantana (1), Mickey Mouse Plant (*Ochna serrulata*) (1)**	**Moist Open Forest - White Mahogany/ Grey Gum/ Ironbark**	**Not recorded**	**Not recorded**	**Not recorded**	**NA**	**Minor new weed infestation with Lantana and Mickey Mouse Plant growth detected in Spring 2018 survey.**	**No evidence of weed control**	**Low**
W3	53750 - 53840 (west)	Broadleaf Paspalum (2), Annual Ragweed (1), White Passionflower (*Passiflora*	Moist Open Forest - White Mahogany/ Grey Gum/	Low	Low	Low	Low	Additional weeds recorded: Wild Tobacco Bush and Fireweed*.	No evidence of weed control	Low

Weed Site Ref.	Chainage (side of highway)	Spring 2018 Weed Composition (Cover Class^)	GHFF Habitat Type (Plant Community)	Summer 2018 Weed Abundance^^	Autumn 2018 Weed Abundance^^	Winter 2018 Weed Abundance^^	Spring 2018 Weed Abundance^^	Comments	Evidence of Management and Control	Weed Management Priority
		subpeltata) (1), Paddy's Lucerne (*Sida rhombifolia*) (1), Purple-top (*Verbena bonariensis*) (1), Fireweed* (1), Wild Tobacco Bush (*Solanum mauritianum*) (1).	Ironbark							
W4	54120 - 54150 (west)	Broadleaf Paspalum (2), Lantana* (1) Winter Senna (*Senna septemtrionalis*) (1), Blue Billygoat Weed (1)	Open Forest - Blackbutt	Low	Low	Low	Low	Setaria, Flax-leaf Fleabane and Purple-top present in very low abundance.	No evidence of weed control	Low
W5	54480 - 54530, (west)	Broadleaf Paspalum (3), Lantana* (1), Wild Tobacco Bush (1), Flaxleaf Fleabane (*Conyza bonariensis*) (1), **Setaria (1)**	Open Forest - Blackbutt	Medium	Medium	Medium	Medium	**Additional weeds recorded: Setaria (1)**	No evidence of weed control	**Low**
W6	55220 - 55260 (west)	Setaria (1), **Broadleaf Paspalum (1)**	Open Forest - Blackbutt	Low	NA	NA	NA	**Additional weeds recorded: Broadleaf Paspalum (1)**	Weed control has not yet commenced	Low
W7	56160 -	Broadleaf Paspalum	Open Forest -	Low	Low	Low	Low	Lantana* present	Weed control	Low

Weed Site Ref.	Chainage (side of highway)	Spring 2018 Weed Composition (Cover Class^)	GHFF Habitat Type (Plant Community)	Summer 2018 Weed Abundance^^	Autumn 2018 Weed Abundance^^	Winter 2018 Weed Abundance^^	Spring 2018 Weed Abundance^^	Comments	Evidence of Management and Control	Weed Management Priority
	56360 (west)	(2), Setaria (1), Lantana* (1)	Blackbutt					in low abundance on fringe	has not yet commenced **Evidence of weed management on adjacent property.**	
W8	57370 – 57450 (west)	Lantana* (1), Broadleaf Paspalum (1)	Open Forest - Blackbutt	Low	Low	Low	**NA**	**Weed abundance has reduced from Low to NA.**	No evidence of weed control	Low
W9	58440 - 58550 (west)	Broadleaf Paspalum (2), Lantana* (1)	Moist Open Forest - Flooded Gum	Low	Low	Low	Low	-	No evidence of weed control	Low
W10	58850 – 58940 (west)	Lantana* (1)	Open Forest - Blackbutt	Low	Low	Low	Low	-	No evidence of weed control	Low
W11	59200 - 59250, (west)	Broadleaf Paspalum (1)	Open Forest - Blackbutt	Low	Low	Low	**NA**	**Weed abundance has reduced from Low to NA.**	No evidence of weed control	Low
W12	59700 - 59740 (west)	**Broadleaf Paspalum (1), Lantana (1)**	Open Forest - Blackbutt	Low	Low	Low	**NA**	**Weed abundance has reduced from Low to NA.** **Additional weeds recorded:**	No evidence of weed control	Low

Weed Site Ref.	*Chainage (side of highway)*	*Spring 2018 Weed Composition (Cover Class^)*	*GHFF Habitat Type (Plant Community)*	*Summer 2018 Weed Abundance^^*	*Autumn 2018 Weed Abundance^^*	*Winter 2018 Weed Abundance^^*	*Spring 2018 Weed Abundance^^*	*Comments*	*Evidence of Management and Control*	*Weed Management Priority*
								Lantana (1)		
W13	59780 - 59810 (west)	Broadleaf Paspalum (2)	Flooded Gum Moist Open Forest	Low	Low	Low	Low	-	Weed control has not yet commenced	Low
W14	60400 - 60540, 60640 – 60665 (west)	Broadleaf Paspalum (2), Morning Glory (1), Rhodes Grass (*Chloris gayana*) (1), Winter Senna (1), Blue Billygoat Weed (1), **Crofton (1)**	Open Forest - Blackbutt	Low	Low	Low	Low	Some sections without GHFF habitat (old hardstand area and stockpile site).	No evidence of weed control	Low
W15	61240 – 61260 (east)	Lantana* (1)	Open Forest - Blackbutt	Low	NA	NA	NA	-	No evidence of weed control	Low
W16	60570 - 60600	**Lantana* (1),** Broadleaf Paspalum (1)	Flooded Gum Moist Open Forest	Medium	Low	Low	**NA**	**Weed cover has reduced in several chainage sections due to a reduction in per cent of foliage cover of Lantana*.**	No evidence of weed control	Low
	60300 - 60400	Lantana* (1)		NA	Medium	Low	**NA**			Low
	60040 - 60060	Lantana* (1)		NA	Low	Low	**NA**			Low
	59780 - 59850	Lantana* (1)		Medium	Low	NA	NA			Low
	59550 - 59610	Lantana* (1)		Medium	Low	NA	NA			Low
	59200 - 59260	Lantana* (1)		Medium	Low	Low	NA			Low

Weed Site Ref.	Chainage (side of highway)	Spring 2018 Weed Composition (Cover Class^)	GHFF Habitat Type (Plant Community)	Summer 2018 Weed Abundance^^	Autumn 2018 Weed Abundance^^	Winter 2018 Weed Abundance^^	Spring 2018 Weed Abundance^^	Comments	Evidence of Management and Control	Weed Management Priority
	59000 - 59080	Broadleaf Paspalum (1)		Medium	Low	NA	NA			Low
	58470 – 58550	Lantana* (1), Whiskey Grass (1)		Medium	Low	NA	NA			Low
	58050 - 58110	Lantana* (1)		Medium	Low	NA	NA			Low
	57650 - 57770	None		Medium	Low	NA	NA			Low
	57210 - 57250 (east)	Lantana* (1)		Medium	Low	Low	Low			Low
W16a	56950	Lantana* (2), Broadleaf Paspalum (2)	Open Forest - Blackbutt	Not recorded	Not recorded	Low	Low	-	No evidence of weed control	Low
W17	56100 – 56420 (east)	Broadleaf Paspalum (3), **Lantana* (1)**	Open Forest - Blackbutt Flooded Gum Moist Open Forest	Low	Low	Low	Low	Mostly intact native canopy but more scattered trees around big house in north. Lower weed cover in south. **Reduction in Lantana weed composition cover.**	No evidence of weed control	Low
W18	56420 – 56580 (east)	Broadleaf Paspalum (4), **Lantana* (1)**	Open Forest - Blackbutt	Medium	Medium	Medium	Medium	Very weedy understorey in north around big house. Very	No evidence of weed control	Medium

Weed Site Ref.	Chainage (side of highway)	Spring 2018 Weed Composition (Cover Class^)	GHFF Habitat Type (Plant Community)	Summer 2018 Weed Abundance^^	Autumn 2018 Weed Abundance^^	Winter 2018 Weed Abundance^^	Spring 2018 Weed Abundance^^	Comments	Evidence of Management and Control	Weed Management Priority
								weedy north section. **Reduction in Lantana weed composition cover.**		
W19	**55800 - 56080**	Lantana* (2), Broadleaf Paspalum (2), Setaria (1)	Open Forest - Blackbutt	Low	Medium	Medium	**Low**	**Reduction in site length of approximately 170 m.**	**Slashing along fence line evident.**	Medium
	55620 - 55800 (east)			Low	Low	Low	**NA**			Low
W19a	**55350**	**Broadleaf Paspalum (1)**	**Open Forest - Blackbutt**	**Not recorded**	**Not recorded**	**Not recorded**	**NA**	**New weed site.**	**No evidence of weed control**	**Low**
W19b	**55350**	**Broadleaf Paspalum (1), Lantana (1), Setaria (1)**	**Open Forest - Blackbutt**	**Not recorded**	**Not recorded**	**Not recorded**	**NA**	**New weed site.**	**No evidence of weed control**	**Low**
W19c	**55200**	**Setaria (1), Whisky Grass (1)**	**Open Forest - Blackbutt**	**Not recorded**	**Not recorded**	**Not recorded**	**NA**	**New weed site.**	**No evidence of weed control**	**Low**
W19d	**53550-53590**	**Setaria (2), Broadleaf Paspalum (2)**	Swamp Forest - Swamp Mahogany/ Paperbark	**Not recorded**	**Not recorded**	**Not recorded**	**Low**	**New weed site.**	**No evidence of weed control**	**Low**
W20	52980 – 53040 (east)	Lantana* (**2**), Mile a Minute (**2**), Annual Ragweed (1), **Setaria (3),** Rhodes	Swamp Forest - Swamp Mahogany/	Medium	Medium	Medium	Medium	**Setaria cover has increased from cover class 1 in winter**	No evidence of weed control	Medium

Weed Site Ref.	*Chainage (side of highway)*	*Spring 2018 Weed Composition (Cover Class^)*	*GHFF Habitat Type (Plant Community)*	*Summer 2018 Weed Abundance^^*	*Autumn 2018 Weed Abundance^^*	*Winter 2018 Weed Abundance^^*	*Spring 2018 Weed Abundance^^*	*Comments*	*Evidence of Management and Control*	*Weed Management Priority*
		Grass (1), Blue Billygoat Weed (1), Winter Senna (1), **Tobacco Bush (*Solanum mauritianum*)**	Paperbark					**2018 to 3 in spring 2018. Overall weed abundance has remained medium. Additional weeds recorded: Tobacco Bush**		
W21	49830 - 50220 (east)	Setaria (on batter edge) (2), **Salvinia* (within open water area along swamp edge) (3), Blue Water Lily (1), and Fireweed* on batter edge (1)**	Swamp Forest - Swamp Mahogany/ Paperbark	Low	Low	Low	Low	Forest is overall in good condition including the understorey except for some sections with Blue Water Lily **and Salvinia*. There are also some minor incursions of exotic grasses and herbs along fence.** **Salvinia cover has increased from cover class 2 in winter 2018 to 3 in spring 2018.**	No evidence of weed control	Low (these weeds would have minimal impact on GHFF habitat value).

Weed Site Ref.	Chainage (side of highway)	Spring 2018 Weed Composition (Cover Class^)	GHFF Habitat Type (Plant Community)	Summer 2018 Weed Abundance^^	Autumn 2018 Weed Abundance^^	Winter 2018 Weed Abundance^^	Spring 2018 Weed Abundance^^	Comments	Evidence of Management and Control	Weed Management Priority
								Overall weed abundance has remained medium.		
W22	49560 – 49670 (east)	Broadleaf Paspalum (4), Lantana* (1), Balloon Cotton Bush (1), **Camphor Laurel (1), Mickey Mouse Plant (1), Tobacco Bush (1), Fireweed (1) and Paddy's Lucerne**	Moist Open Forest - White Mahogany/ Grey Gum/ Ironbark	Medium	Medium	Medium	Medium	**Additional weeds: Camphor Laurel (1), Mickey Mouse Plant (1), Tobacco Bush (1), Fireweed (1) and Paddy's Lucerne**	No evidence of weed control	Medium
W23	49030 - 49070 (east)	Broadleaf Paspalum (5), Camphor Laurel (1) Balloon Cotton Bush (1), **Blue Billygoat Weed (1).**	Flooded Gum Moist Open Forest	High	High	High	High	Scattered native overstorey of Hard Quandong (*Elaeocarpus obovatus*), Foam Bark Tree (*Jagera pseudorhus*), Broad-leaved Paperbark (*Melaleuca quinquenervia*), with few shrubs and groundcover dominated by Broadleaf Paspalum. **Additional**	No evidence of weed control	Medium

Weed Site Ref.	Chainage (side of highway)	Spring 2018 Weed Composition (Cover Class^)	GHFF Habitat Type (Plant Community)	Summer 2018 Weed Abundance^^	Autumn 2018 Weed Abundance^^	Winter 2018 Weed Abundance^^	Spring 2018 Weed Abundance^^	Comments	Evidence of Management and Control	Weed Management Priority
								weeds: Blue Billygoat Weed		
W24	48430 - 48550 (east)	Broadleaf Paspalum (5), **Lantana (1)**	Moist Open Forest - Flooded Gum	High	High	High	High	Scattered overstorey of Flooded Gum (*Eucalyptus grandis*), Guioa (*Guioa semiglauca*), Broad-leaved Paperbark (*Melaleuca quinquenervia*), but lack of shrub layer and ground cover dominated by Broadleaf Paspalum. **Additional weeds: Lantana**	No evidence of weed control	Medium
W25	48260 – 48380 (east)	Lantana* (5), Broadleaf Paspalum (2), **Setaria (2),** Mile a Minute (1), Winter Senna (1).	Moist Open Forest - Flooded Gum	High	High	High	High	Mostly intact overstorey dominated by Flooded Gum with some River Oak (*Casuarina cunninghamiana*) on edge creek. Understorey dominated by weeds mostly	No evidence of weed control	High

Weed Site Ref.	Chainage (side of highway)	Spring 2018 Weed Composition (Cover Class^)	GHFF Habitat Type (Plant Community)	Summer 2018 Weed Abundance^^	Autumn 2018 Weed Abundance^^	Winter 2018 Weed Abundance^^	Spring 2018 Weed Abundance^^	Comments	Evidence of Management and Control	Weed Management Priority
								Lantana*. **Additional weeds: Setaria**		
W26	47800 – 47832 (east)	Lantana* (2), Wild Tobacco Bush (2), Setaria (1), White Passionflower (1), **Winter Senna (1).**	Open Forest - Blackbutt	Medium	Medium	Medium	**Low**	-	No evidence of weed control	**Low**
W27	47510 – 47530 (east)	Broadleaf Paspalum (3), Camphor Laurel (2), Purple Top (2), Wild Tobacco Bush (2)	Moist Open Forest – White Mahogany – Grey Gum	Medium	Medium	Medium	Medium	-	**Recently cleared for fence installation.**	**Low**
W28	47450 – 47490 (east)	Camphor Laurel (2), Broadleaf Paspalum (2), Lantana* (2), Blackberry* (1), Narrow-leaved Privet (*Ligustrum sinense*) (1)	Moist Open Forest - White Mahogany/ Grey Gum/ Ironbark	Medium	Medium	Medium	Medium	**-**	**Recently cleared for fence installation.**	Medium

^ *Modified Braun-Blanquet cover classes of 1=<5%, 2=6-25%, 3=26-50%, 4=51-75%, and 5=76-100%*

^^ Refer to Table 3.

* Denotes *Biosecurity Act 2015* listed priority weed species. Lantana, Fireweed, Blackberry and Salvinia are listed as Weeds of National Significance and as priority weed species for the North Coast of NSW. They must not be imported into the State or sold.

Bold text denotes change from winter 2018 monitoring event.

Stage 2B

Occurrence of noxious and/ or environmental weeds was recorded at 20 sites (identified as low, medium or high) within the edge of GHFF habitat adjacent to the Project area. These weed occurrences are shown in **Appendix A** and listed in **Table 7**. Photographs of GHFF habitat areas taken from the fixed photo points are shown in **Appendix C.**

A total of 21 noxious and environmental weed species were recorded. Blackberry, Fireweed and Lantana were recorded on-site and are listed as priority weed species for the North Coast of NSW under the *Biosecurity Act 2015*. The primary management duty for these is they '*must not be imported into the state or sold*'.

Broadleaf Paspalum, Setaria, and Large-leaved Privet (*Ligustrum lucidum*) were recorded within GHFF habitat areas at the highest density, and were also the dominant weed species in those GHFF areas that recorded a 'Medium' or 'High' weed abundance level (refer to **Table** 6**7**).

One weed site (2BW8a) has a high weed management priority. Two weed sites (sites 2BW1 and 2BW16) were considered to have a medium weed management priority. These areas should be targeted during weed management works.

No exotic vines with the potential to inhibit native regeneration and smother the canopy of intact GHFF habitat were observed.

Table 7 Abundance and Composition of Noxious and/or Environmental Weeds Sites for Stage 2B

Weed Site No.	*Chainage (side of highway)*	*Spring 2018 Weed Composition (Cover Class^)*	*GHFF Habitat Type (Plant Community)*	*Winter 2018 Weed Abundance^^*	*Spring 2018 Weed Abundance^^*	*Comments*	*Evidence of Management and Control*	*Weed Management Priority*
2BW1	46180 – 46190 (east)	**Setaria (4),** Camphor Laurel (1)	Open Forest - Blackbutt	High	**Medium**	**Spring 2018 weed composition has changed from the Winter 2018 survey. Setaria is present in Spring as opposed to Broadleaf Paspalum in winter. Broadleaf Paspalum cover in Winter 2018 is considered a typographical error and has been rectified. Overall weed abundance has been reduced to medium.**	No evidence of weed control	Medium
2BW2	45440 – 45450 (east)	Broadleaf Paspalum (2), Camphor Laurel (1), Setaria (1)	Moist Open Forest - Flooded Gum	Low	Low	Small creek and riparian zone within survey area.	**No evidence of weed control.**	Low
2BW3	45170 – 45280 (west)	Broadleaf Paspalum (3), Camphor Laurel (2),	Moist Open Forest - Flooded	Medium	Medium	**Additional weeds**	No evidence of weed control	Low

Weed Site No.	Chainage (side of highway)	Spring 2018 Weed Composition (Cover Class^)	GHFF Habitat Type (Plant Community)	Winter 2018 Weed Abundance^^	Spring 2018 Weed Abundance^^	Comments	Evidence of Management and Control	Weed Management Priority
		Setaria (1), **Blackberry (1), Small-leaved Privet (1), Lantana (1).**	Gum			**recorded: Blackberry, Small-leaved Privet, Lantana**.		
2BW4	44100 – 44200 (east)	Broadleaf Paspalum (3), **Purple Top (1), Rhodes Grass (1), Camphor Laurel (1), Whisky Grass (1).**	Open Forest - Blackbutt	Medium	**Low**	**Spring 2018 weed composition has increased from the Winter 2018 survey however overall weed abundance has been reduced to low.**	No evidence of weed control	Low
2BW5	43960 – 44030 (east)	Broadleaf Paspalum (3), Balloon Cotton Bush (1), Crofton Weed (*Ageratina adenophora*) (1), Fireweed* (1)	Moist Open Forest - Flooded Gum	Medium	Medium	-	No evidence of weed control	Low
2BW6	43050 – 43090 (east)	**Lantana* (1),** Broadleaf Paspalum (1)	Moist Open Forest - Flooded Gum	Low	Low	**Slight reduction in Lantana cover form 2 in Winter 2018 to 1 Spring 2018 within weed composition.**	No evidence of weed control	Low
2BW7	42980 – 42990 (west)	Lantana* (2), Large-leaved Privet (1), Broadleaf Paspalum (1)	Mixed Floodplain Forest	Low	Low	-	No evidence of weed control	Low

Weed Site No.	*Chainage (side of highway)*	*Spring 2018 Weed Composition (Cover Class^)*	*GHFF Habitat Type (Plant Community)*	*Winter 2018 Weed Abundance^^*	*Spring 2018 Weed Abundance^^*	*Comments*	*Evidence of Management and Control*	*Weed Management Priority*
2BW7a	**42800 - 42900**	**Lantana (1)**	**Moist Open Forest - Flooded Gum**	**Not recorded**	**NA**	**Lantana growth detected in Spring 2018 survey.**	**No evidence of weed control**	**Low**
2BW8	**42700** – 42880 (west)	Lantana* (3), Large-leaved Privet (3), Camphor Laurel (1), Winter Senna (1), Wild Tobacco Bush (1), Broadleaf Paspalum (1), Setaria (1).	Mixed Floodplain Forest	Medium	Medium	**2BW8 has been split into 2 sections (see 2BW8a below) to identify area of high weed activity.**	No evidence of weed control	Medium
2BW8a	**42650 - 42700**	**Large-leaved Privet (4), Lantana (3), Tobacco Bush (2).**	**Mixed Floodplain Forest**	**Medium**	**High**	**2BW8 has been split into 2 sections to identify area of high weed activity.** **Weed abundance has increased from Winter 2018 survey.**	**No evidence of weed control**	**High**
2BW9	42770 – 42800 (east)	Broadleaf Paspalum (2), Lantana* (1), **Blue Billygoat Weed (1)**	Moist Open Forest - Flooded Gum	Low	Low	**Additional weeds: Blue Billygoat Weed**	No evidence of weed control	Low
2BW10	42620-42630 (east)	**Setaria (3),** Cobblers Pegs (1), Wild Tobacco Bush (1)	Mixed Floodplain Forest	Medium	Medium	**Slight reduction in Setaria cover from 4 in Winter 2018 to 3 Spring 2018 within weed**	Evidence of weed control.	Low

Weed Site No.	Chainage (side of highway)	Spring 2018 Weed Composition (Cover Class^)	GHFF Habitat Type (Plant Community)	Winter 2018 Weed Abundance^^	Spring 2018 Weed Abundance^^	Comments	Evidence of Management and Control	Weed Management Priority
						composition.		
2BW11	42500 – 42600 (west)	Broadleaf Paspalum (3), Lantana* (1), **Tobacco Bush (1)**	Mixed Floodplain Forest	Medium	Medium	**Additional weeds: Tobacco Bush**	No evidence of weed control	Low
2BW12	42600 – 42610 (west)	Lantana* (3), Broadleaf Paspalum (2), Wild Tobacco Bush (1), Setaria (1)	Mixed Floodplain Forest	Low	Low	-	No evidence of weed control	Low
2BW13	42500 – 42510 (west)	Large-leaved Privet (2), Lantana* (2), Narrow-leaved Privet (1)	Mixed Floodplain Forest	Low	Low	-	No evidence of weed control	Low
2BW14	42570 – 42600 (east)	Large-leaved Privet (2), **Broadleaf Paspalum (1)**	Mixed Floodplain Forest	Low	Low	**Additional weeds: Broadleaf Paspalum**	No evidence of weed control	Low
2BW15	42530 – 42600 (east)	Lantana* (2), Large-leaved Privet (2), Narrow-leaved Privet (2), Broadleaf Paspalum (1), **Camphor Laurel (saplings) (1)**	Mixed Floodplain Forest	Low	Low	**Additional weeds: Camphor Laurel**	No evidence of weed control	Low
2BW16	42090 – 42220, 42290, 42390 (east)	Broadleaf Paspalum (4), Setaria (2), Lantana* (1), Camphor Laurel (1), Fireweed* (1), Wild Tobacco Bush (1).	Mixed Floodplain Forest	High	High	-	No evidence of weed control	Medium
2BW17	**41900 – 41920 (east)**	**Small-leaved Privet (2), Setaria (2), Lantana (1), Paddy's Lucerne (1), Tobacco Plant (1)**	**Mixed Floodplain Forest**	**Not recorded**	**Low**	**New site**	**No evidence of weed control**	**Low**

Weed Site No.	*Chainage (side of highway)*	*Spring 2018 Weed Composition (Cover Class^)*	*GHFF Habitat Type (Plant Community)*	*Winter 2018 Weed Abundance^^*	*Spring 2018 Weed Abundance^^*	*Comments*	*Evidence of Management and Control*	*Weed Management Priority*
2BW18	**41830 – 41880 (east)**	**Lantana (2), Camphor Laurel (2), Paddy's Lucerne (1), White Passionflower (1)**	**Mixed Floodplain Forest**	**Not recorded**	**Low**	**New site**	**No evidence of weed control**	**Low**
2BW19	**41560 – 41620 (east)**	**Blackberry (2), Lantana (2), Broadleaf Paspalum (2), Paddy's Lucerne (2), Annual Ragweed (1), Tobacco Bush (1)**	**Mixed Floodplain Forest**	**Not recorded**	**Low**	**New site**	**No evidence of weed control**	**Low**

^ *Modified Braun-Blanquet cover classes of 1=<5%, 2=6-25%, 3=26-50%, 4=51-75%, and 5=76-100%.*

^^ Refer to Table 3.

* Denotes *Biosecurity Act 2015* listed priority weed species. Lantana and Fireweed are listed as Weeds of National Significance and as priority weed species for the North Coast of NSW. They must not be imported into the State or sold.

Bold text denotes change from winter 2018 monitoring event.

Stage 2A Annual Monitoring Findings

Discussion

Comparison with previous results

In general, the weed monitoring results have remained fairly consistent, with only minor changes in abundance (refer to **Table 8**). The total number of weed species has steadily increased over the monitoring period generally attributed to small scale weed growth comprising <5% weed abundance. One weed occurrence area (site 25) was classified as high weed abundance and high management priority over the duration of the four quarterly monitoring events. Nine areas were considered to have a medium weed management priority (sites 5, 16, 18, 22, 23, 24, 26, 27 and 28) the first quarterly (Summer 2018) monitoring event as opposed to seven sites (sites W18, W19 {part}, W20, W22, W23, W24 and W28) in final Spring 2018. Site differences are attributed to seasonal and species variations. No significant differences in sites identified as high or medium weed management priority were observed over the monitoring period.

Eighteen weed occurrence areas were identified as a low weed management priority during the first quarterly (Summer 2018) monitoring event. This increased to 26 low management priority areas in Spring 2018. Additional low weed management priority sites are mainly attributed to new environmental weed growth such as Broadleaf Paspalum and Setaria as well as small scale Lantana occurrences comprising <10% weed abundance.

Lantana, Broad-leaved Paspalum (*Paspalum mandiocanum*) and Camphor Laurel (*Cinnamomum camphora*) were recorded within GHFF habitat areas at the highest density and were also the dominant weed species in those GHFF areas that recorded a Medium weed infestation level across all survey periods.

Table 8 Comparison of Weed Abundance and Composition

Weed Abundance (km2)	***Summer 2018***	***Autumn 2018***	***Winter 2018***	***Spring 2018***
High	0.61	0.61	0.61	0.61
Medium	2.51	1.79	1.26	1.20
Low	5.65	6.89	6.59	5.32
Total	8.78	9.30	8.46	7.13
Total number of weed species	19	21	23	27

Recommendations and Conclusions

Rehabilitation Site Monitoring

Limited regeneration has established to date at all rehabilitation sites. This has been observed throughout the monitoring program. The monitoring results indicate that rehabilitation goals in line with the Project landscape plans have not been achieved and a review of the regeneration efforts is required.

Weed Monitoring

Weed sites W25, W19, W20, W23, W24, W28 are important target weed management areas to reduce degradation to GHFF habitat. At these sites, there is the potential for Lantana to alter community structure and inhibit regeneration.

Management of the weeds at these sites would be consistent with the key objectives of the WC2NH *Weed and Pathogen Management Plan* (GeoLINK 2015) which is to '*ensure the Project avoids, suppresses and controls the spread of all weeds, plant pathogens and invasive species to ensure that impacts to the environment are minimised.*'

Weed sites primarily with dense Broadleaf Paspalum (sites W5, W17, W18, W22, W23, W24 and W27) should be considered somewhat lower priorities for management than sites comprising medium infestations of Lantana for the following reasons:

- There may be a lower likelihood of weed management success (it is difficult to remove this species successfully from degraded communities that have a suitable semi-shaded understorey environment); and
- Being an understorey weed species that occurs in disturbed environments and edges, Broadleaf Paspalum has a low potential to alter either the forest structure or regeneration potential, and hence the quality of relatively intact GHFF habitat.

No significant increase in the density of the exotic vines (including Morning Glory and Mile-a-minute) which have the potential to inhibit native regeneration and smother the canopy of intact GHFF habitat was observed over the monitoring period.

Conclusion: Project Success

In relation to weed monitoring, the *Warrell Creek to Nambucca Heads Flying-fox Management Plan* (Sinclair Knight Merz, 2017) identifies the main goal for management during the duration of the Project as '*no reduction of the quality of flying-fox habitats adjacent to the Project corridor due to the operation of the Project and to minimise the impact of edge effects'*. The performance threshold by which this is measured is '*Deterioration in the quality of adjacent habitat vegetation as a result of the Project (as determined by qualified ecologist*)' (Sinclair Knight Merz, 2017). Potential indicators of success as listed in the *Warrell Creek to Urunga Pacific Highway Upgrade Ecological Monitoring Program – Stage 2: Warrell Creek to Nambucca Heads* (Benchmark Environmental Management, 2014) include '*No deterioration in the quality of adjacent habitat vegetation as a result of the Project'*.

The following limitations must be considered when interpreting the data:

- Limited dataset (short survey period of four survey events contained within one year) making it challenging to observe weed impacts over time.
- Natural seasonal variations in species growth / dieback.

Notwithstanding, based on the results to date '*deterioration in the quality of adjacent habitat vegetation as a result of the Project'* has not been detected and the main goal of '*no reduction of the quality of flying-fox habitats adjacent to the Project corridor due to the operation of the Project and to minimise the impact of edge effects'* has been observed.

In relation to rehabilitation efforts, the monitoring results indicate that rehabilitation goals in line with the Project landscape plans have not been achieved and a review of the regeneration efforts is required.

Recommendations and Conclusions

Weed sites 2BW8 and 2BW8a are important target weed management areas to reduce degradation to GHFF habitat. At these sites, there is the potential for Lantana and Large-leaved Privet to alter community structure and inhibit regeneration. Management of the weeds at these sites would be consistent with the key objectives of the WC2NH *Weed and Pathogen Management Plan* (GeoLINK 2015) which is to '*ensure the Project avoids, suppresses and controls the spread of all weeds, plant pathogens and invasive species to ensure that impacts to the environment are minimised.*'

Weed sites primarily with dense Setaria and Broadleaf Paspalum (sites 2BW1, 2BW3, 2BW5, 2BW10, 2BW11 and 2BW16) should be considered somewhat lower priorities for management than sites comprising medium infestations of Lantana and/ or Large-leaved Privet for the following reasons:

- There may be a lower likelihood of weed management success (it is difficult to remove this species successfully from degraded communities that have a suitable semi-shaded understorey environment); and
- Being an understorey weed species that occurs in disturbed environments and edges, Broadleaf Paspalum and Setaria have a low potential to alter either the forest structure or regeneration potential, and hence the quality of relatively intact GHFF habitat.

Future monitoring should identify any incursions of exotic vines (including Morning Glory and Mile-a-minute) which have the potential to inhibit native regeneration and smother the canopy of intact GHFF habitat. None have been observed to date during Stage 2B monitoring.

Please contact the undersigned if require any further information.

Yours sincerely
GeoLINK

Grant McLean
Ecologist

References

Benchmark Environmental Management (2014). *Warrell Creek to Urunga Pacific Highway Upgrade Ecological Monitoring Program. Stage 2: Warrell Creek to Nambucca Heads*. Report to Roads and Maritime Services.

Bureau of Meteorology (2018). Daily rainfall. [ONLINE] Available at: http://www.bom.gov.au/jsp/ncc/cdio/wData/wdata?p_nccObsCode=136&p_display_type=dailyDataFile&p_stn_num=059150&p_startYear= . [Accessed 13 November 2018].

GeoLINK (2015). *Weed and Pathogen Management Plan: Warrell Creek to Nambucca Heads Upgrade of the Pacific Highway.* Unpublished report to Acciona and Ferrovial Joint Venture/ Roads and Maritime Services. GeoLINK Consulting, Coffs Harbour.

Sinclair Knight Merz (2017). *Warrell Creek to Nambucca Heads Upgrade of the Pacific Highway; Flying-fox Management Plan.* Report to Roads and Maritime Services.

Issue Log

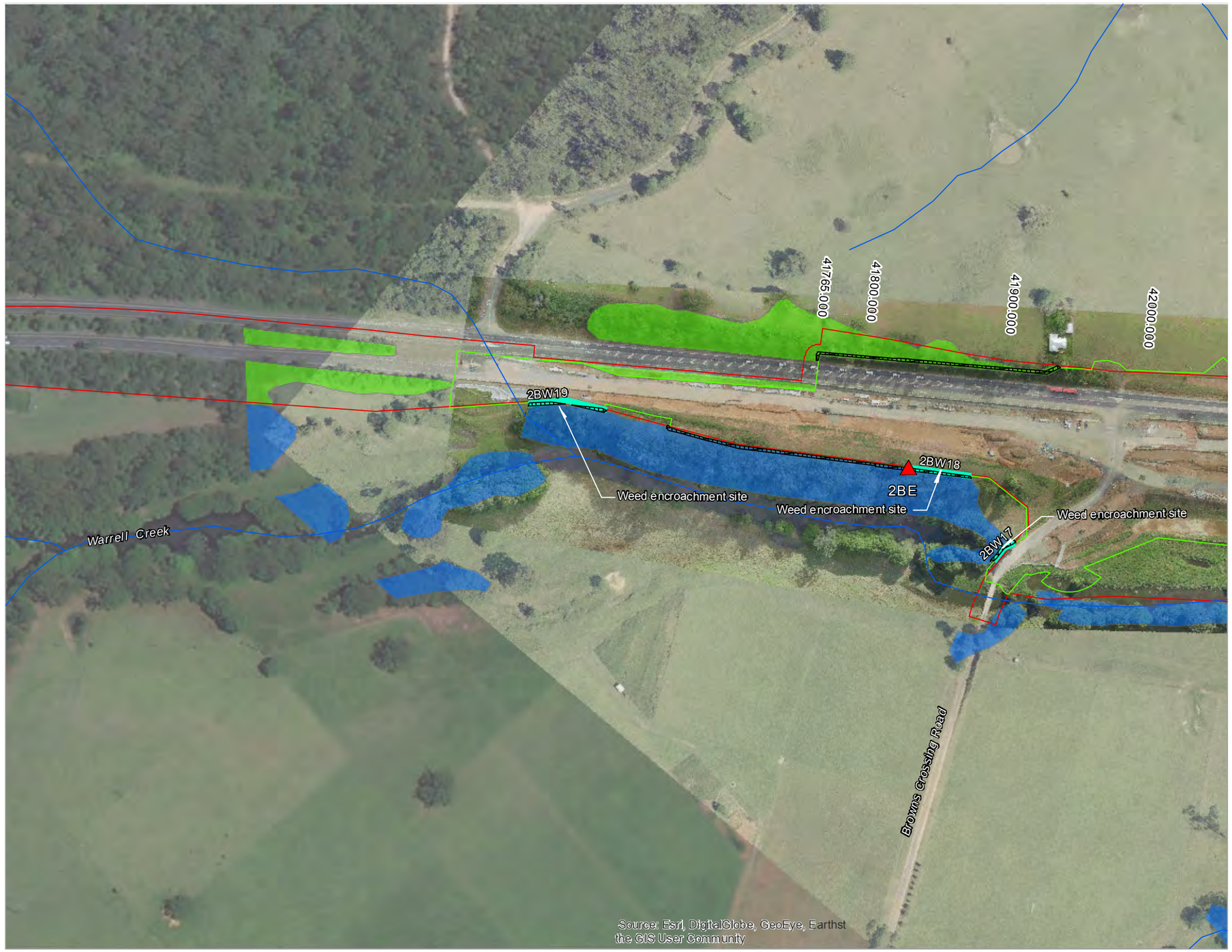
UPR	*Description*	*Date issued*	*Issued By*
2692-1153	First issue (draft)	14/11/2018	Grant McLean
2692-1156	Second issue (final)	16/11/2018	Grant McLean

Appendix A

GHFF Weed Survey Areas and Weed Infestation Levels (Spring 2018)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 14/11/2018
Source of base data: ESRI and AFJV



LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2B GHFF weed survey area
- Fixed photo point

Vegetation

- Mixed Floodplain Forest (EEC)
- Moist Open Forest - Flooded Gum

Weed Site (Abundance)

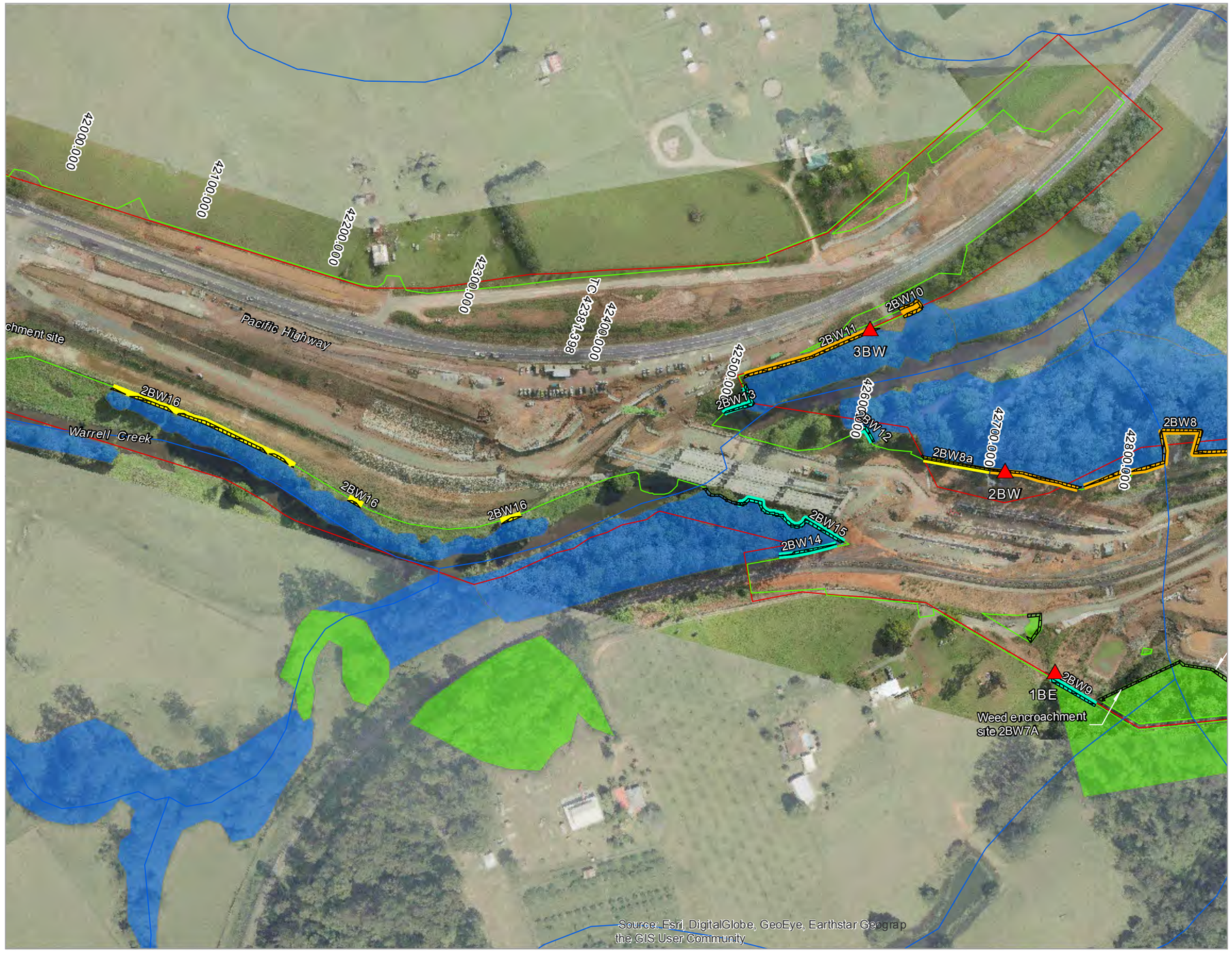
- Low

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 14/11/2018
Source of base data: ESRI and AFJV



LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2B GHFF weed survey area
- Fixed photo point

Vegetation

- Mixed Floodplain Forest (EEC)
- Moist Open Forest - Flooded Gum

Weed Site (Abundance)

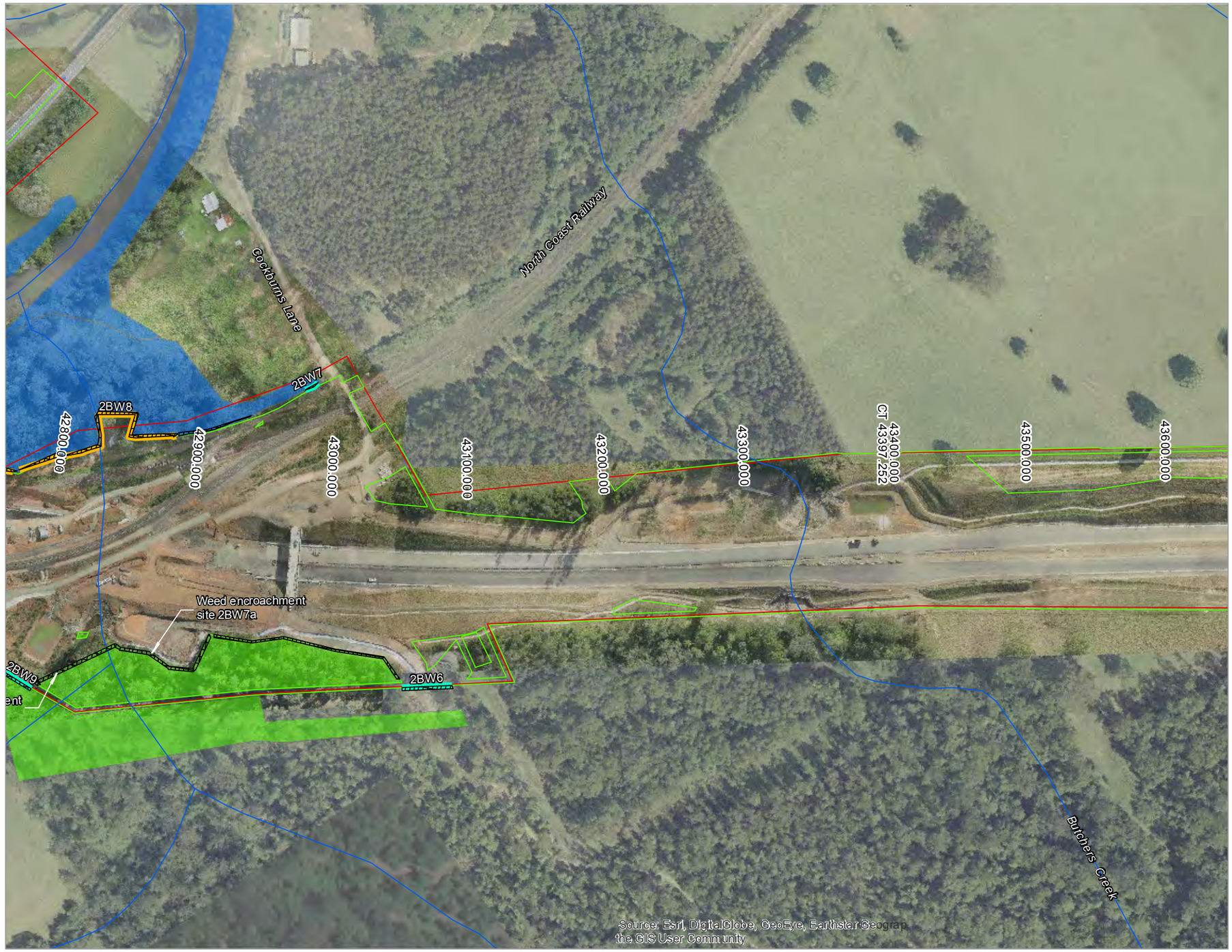
- High
- Medium
- Low

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 14/11/2018
Source of base data: ESRI and AFJV



LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2B GHFF weed survey area

Vegetation

- Mixed Floodplain Forest (EEC)
- Moist Open Forest - Flooded Gum

Weed Site (Abundance)

- Medium
- Low

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 14/11/2018
Source of base data: ESRI and AFJV

LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2B GHFF weed survey area
- Fixed photo point

Vegetation

- Blackbutt Open Forest
- Moist Open Forest - Flooded Gum

Weed Site (Abundance)

- Medium
- Low

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 14/11/2018
Source of base data: ESRI and AFJV

LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2B GHFF weed survey area

Vegetation

- Blackbutt Open Forest
- Moist Open Forest - Flooded Gum

Weed Site (Abundance)

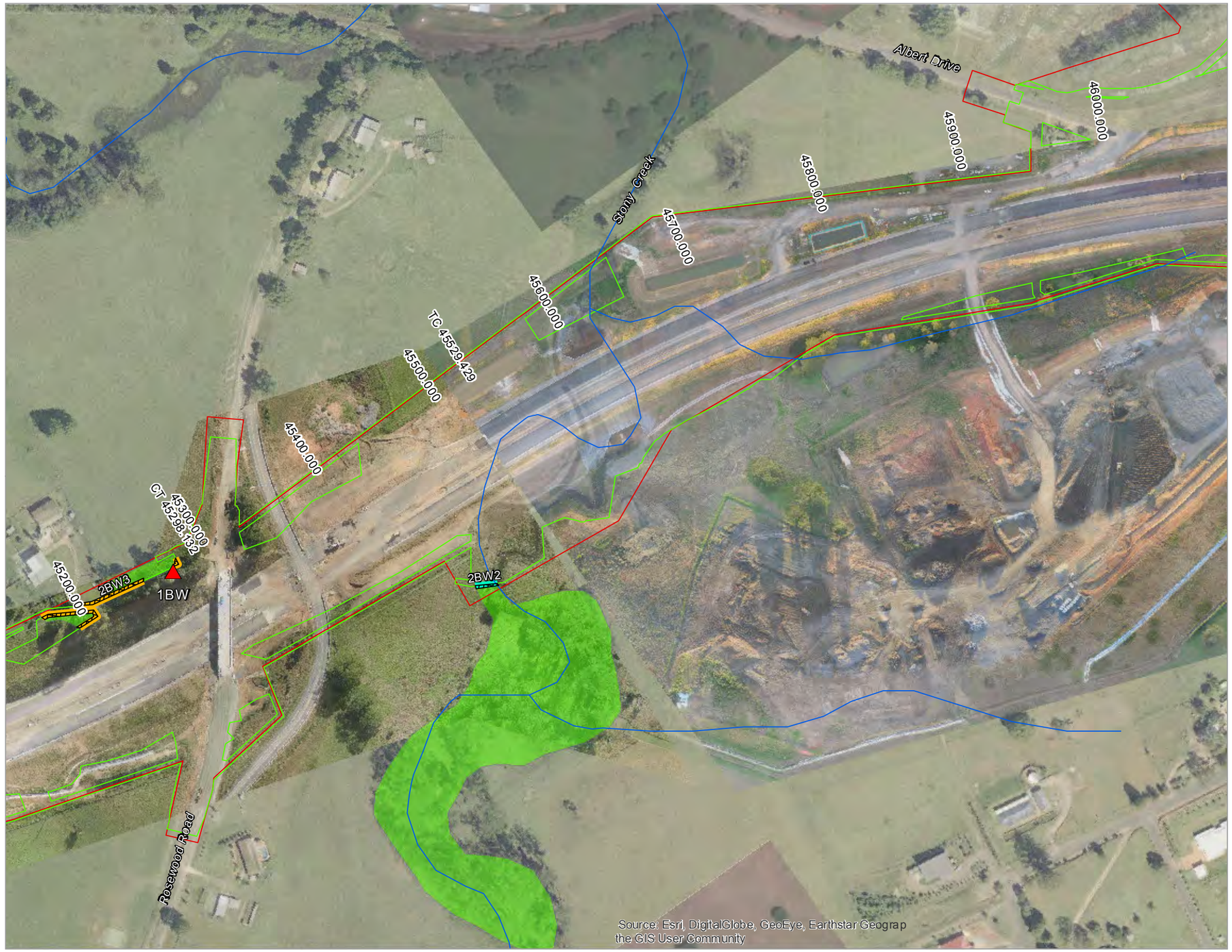
- Medium

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 14/11/2018
Source of base data: ESRI and AFJV



LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2B GHFF weed survey area
- Fixed photo point

Vegetation

- Moist Open Forest - Flooded Gum

Weed Site (Abundance)

- Medium
- Low

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 14/11/2018
Source of base data: ESRI and AFJV

LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2B GHFF weed survey area

Vegetation

- Blackbutt Open Forest

Weed Site (Abundance)

- Medium

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 14/11/2018
Source of base data: ESRI and AFJV

LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2A GBFF weed survey area
- Fixed photo point

Vegetation

- Moist Open Forest - White Mahogany / Grey Gum / Ironbark

Weed Site (Abundance)

- Medium

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 14/11/2018
Source of base data: ESRI and AFJV

LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2A GBFF weed survey area
- Fixed photo point

Vegetation

- Moist Open Forest - White Mahogany / Grey Gum / Ironbark

Weed Site (Abundance)

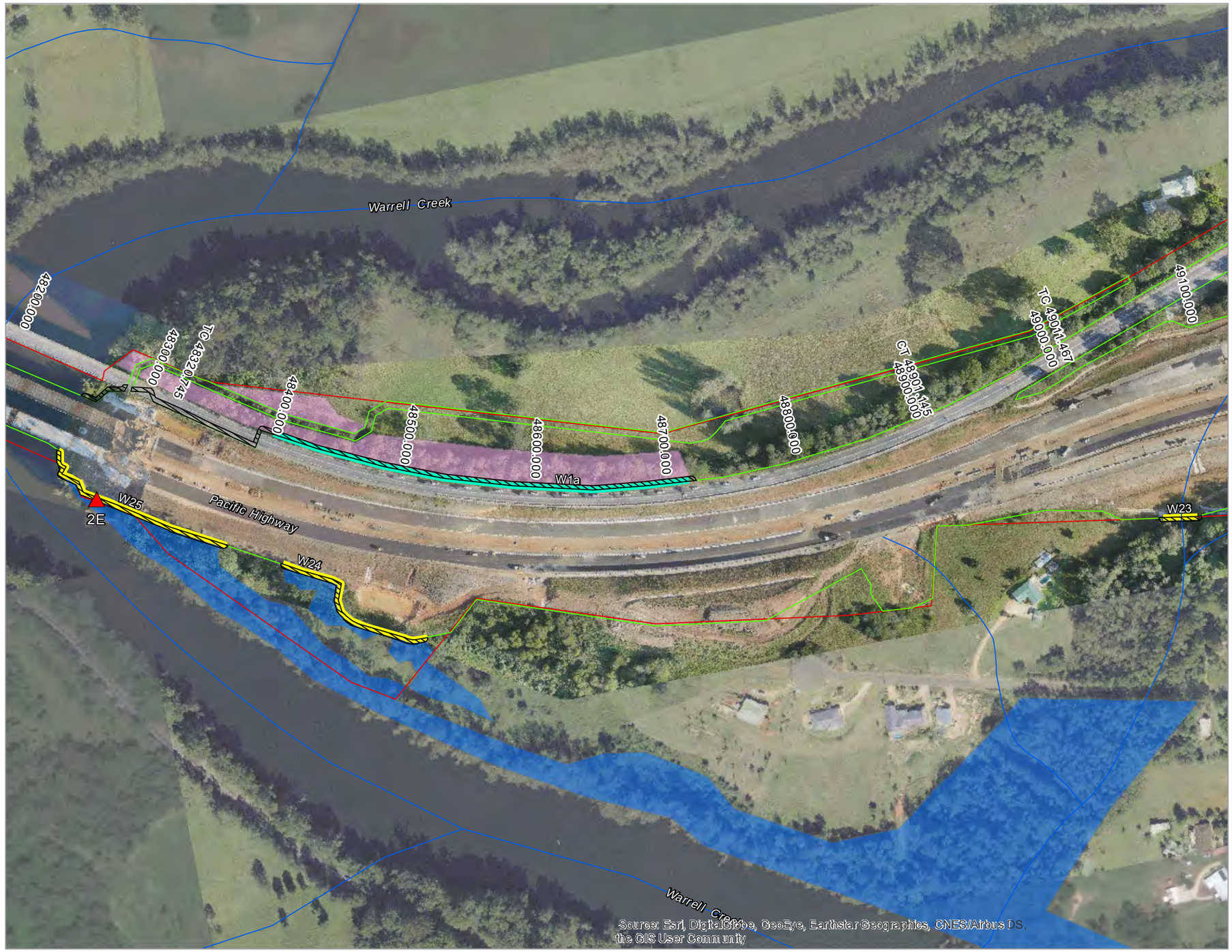
- Medium
- Low

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 14/11/2018
Source of base data: ESRI and AFJV



LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2A GBFF weed survey area
- Fixed photo point

Vegetation

- Mixed Floodplain Forest (EEC)
- Moist Open Forest - White Mahogany / Grey Gum / Ironbark

Weed Site (Abundance)

- High
- Low

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 14/11/2018
Source of base data: ESRI and AFJV

LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2A GBFF weed survey area
- Fixed photo point

Vegetation

- Mixed Floodplain Forest (EEC)
- Moist Open Forest - White Mahogany / Grey Gum / Ironbark
- Swamp Forest - Swamp Mahogany/ Paperbark (EEC)

Weed Site (Abundance)

- High
- Medium
- Low

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 14/11/2018
Source of base data: ESRI and AFJV

LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2A GBFF weed survey area

Vegetation

- Swamp Forest - Swamp Mahogany/ Paperbark (EEC)

Weed Site (Abundance)

- Low

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 14/11/2018
Source of base data: ESRI and AFJV

LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2A GBFF weed survey area

Vegetation

- Swamp Forest - Swamp Mahogany/ Paperbark (EEC)

Weed Site (Abundance)

- Low

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 14/11/2018
Source of base data: ESRI and AFJV

LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2A GBFF weed survey area

Vegetation

- Mixed Floodplain Forest (EEC)

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 14/11/2018
Source of base data: ESRI and AFJV

LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2A GBFF weed survey area

Vegetation

- Moist Open Forest - White Mahogany / Grey Gum / Ironbark
- Swamp Forest - Swamp Mahogany/ Paperbark (EEC)

Weed Site (Abundance)

- Medium

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 14/11/2018
Source of base data: ESRI and AFJV

LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2A GBFF weed survey area
- Fixed photo point

Vegetation

- Blackbutt Open Forest
- Moist Open Forest - White Mahogany / Grey Gum / Ironbark
- Swamp Forest - Swamp Mahogany/ Paperbark (EEC)

Weed Site (Abundance)

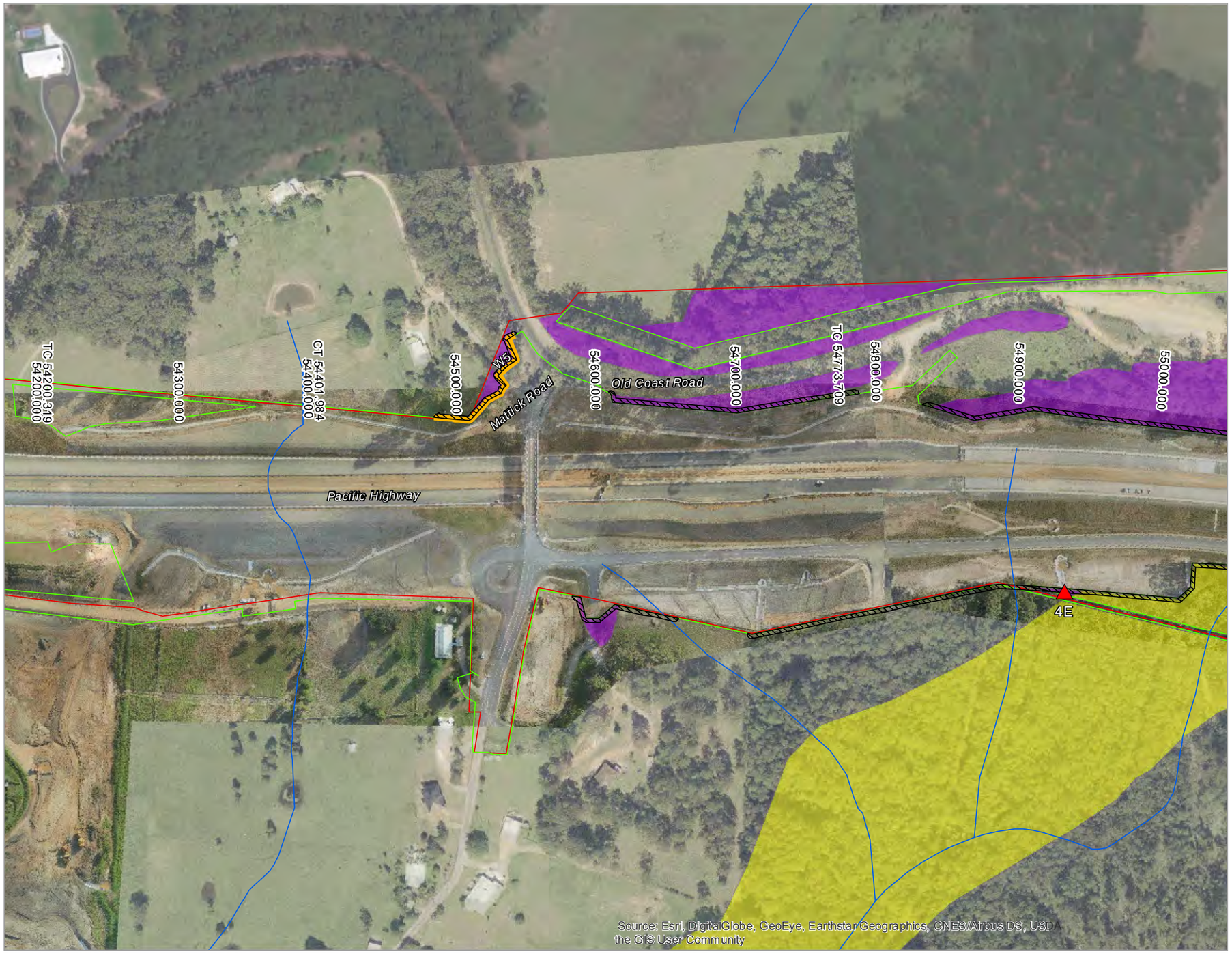
- Low

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 14/11/2018
Source of base data: ESRI and AFJV



LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2A GBFF weed survey area
- Fixed photo point

Vegetation

- Blackbutt Open Forest
- Swamp Forest - Swamp Mahogany/ Paperbark (EEC)

Weed Site (Abundance)

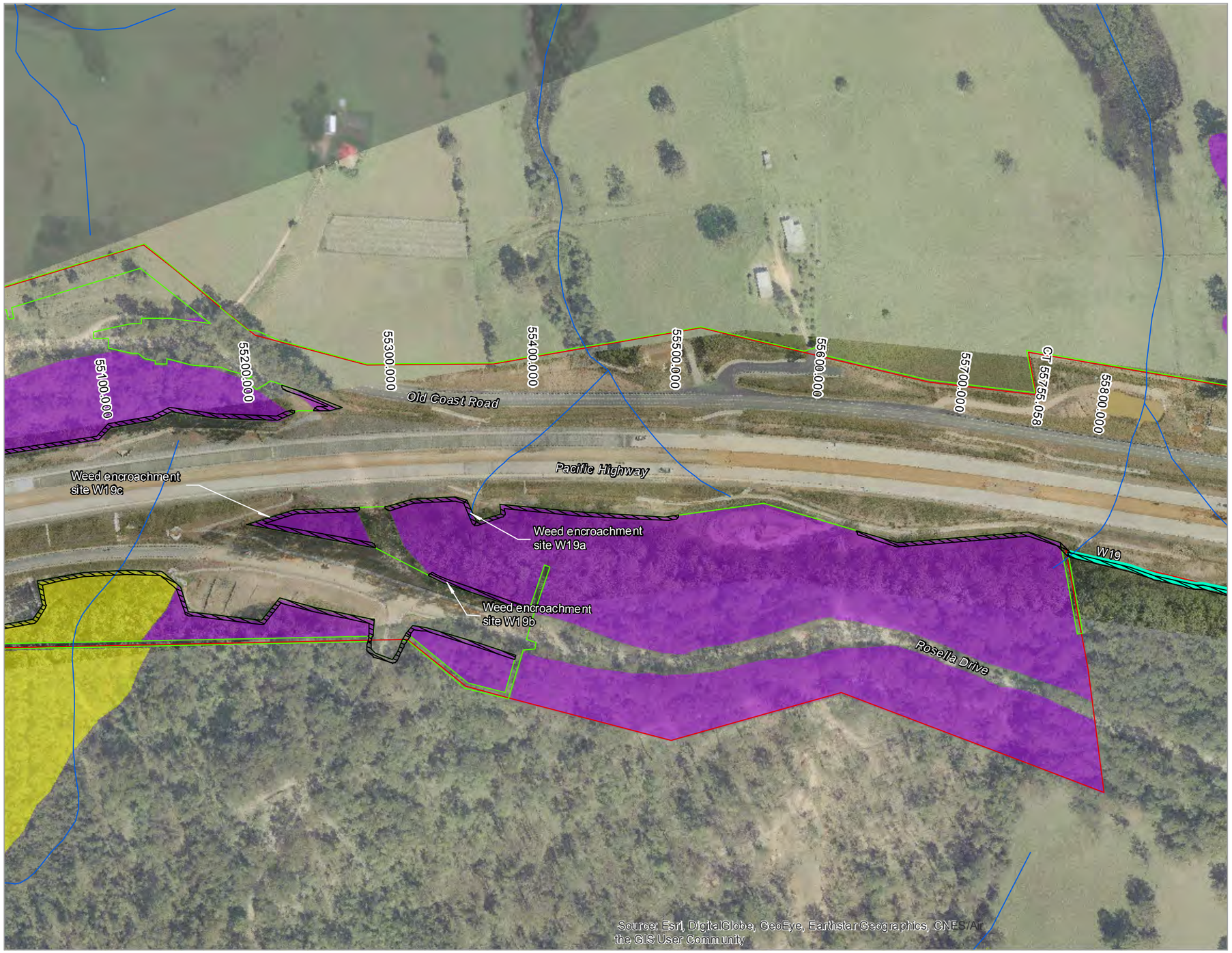
- Medium

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 14/11/2018
Source of base data: ESRI and AFJV



LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2A GBFF weed survey area

Vegetation

- Blackbutt Open Forest
- Swamp Forest - Swamp Mahogany/ Paperbark (EEC)

Weed Site (Abundance)

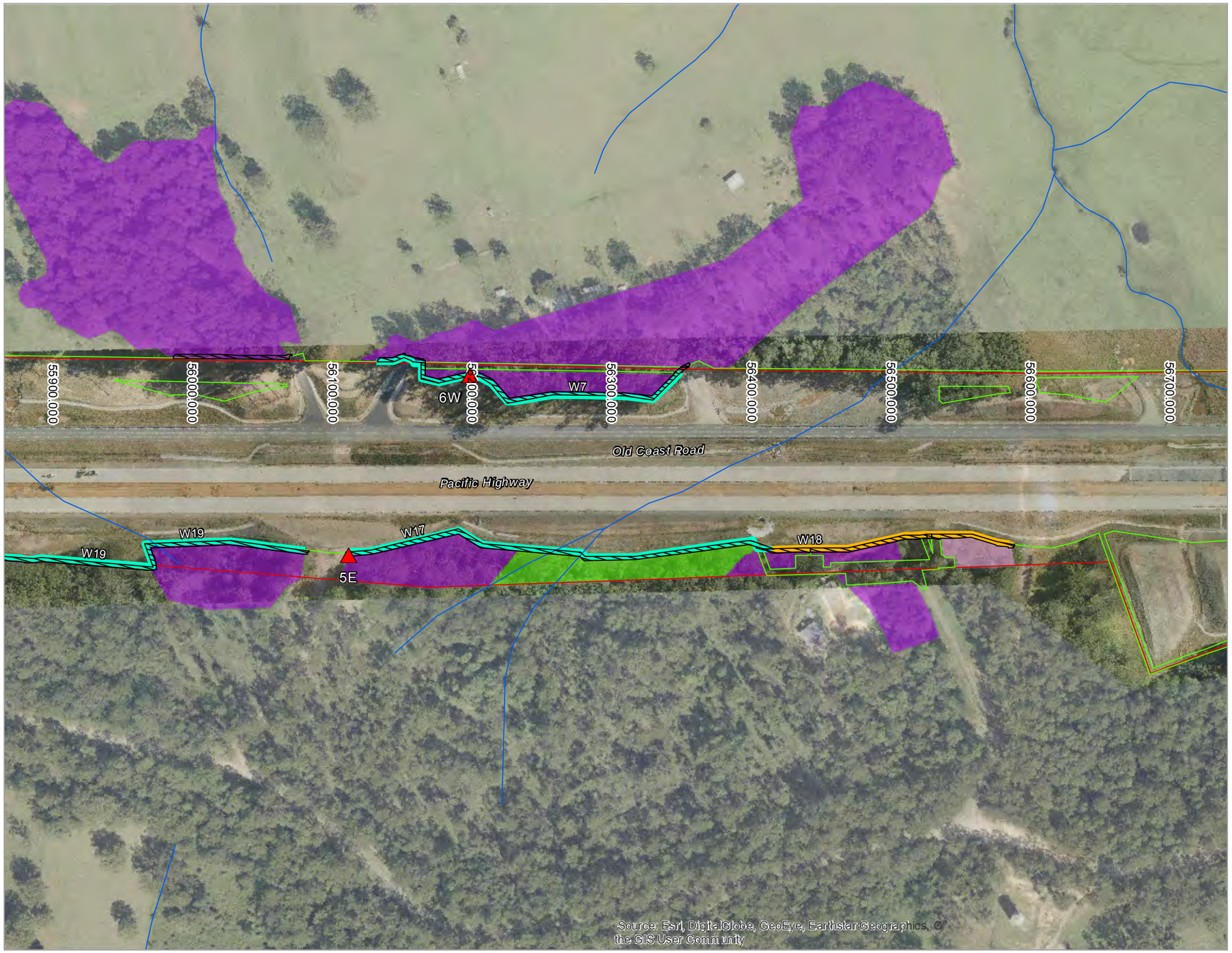
- Low

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 14/11/2018
Source of base data: ESRI and AFJV



LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2A GBFF weed survey area
- Fixed photo point

Vegetation

- Blackbutt Open Forest
- Moist Open Forest - Flooded Gum
- Moist Open Forest - White Mahogany / Grey Gum / Ironbark

Weed Site (Abundance)

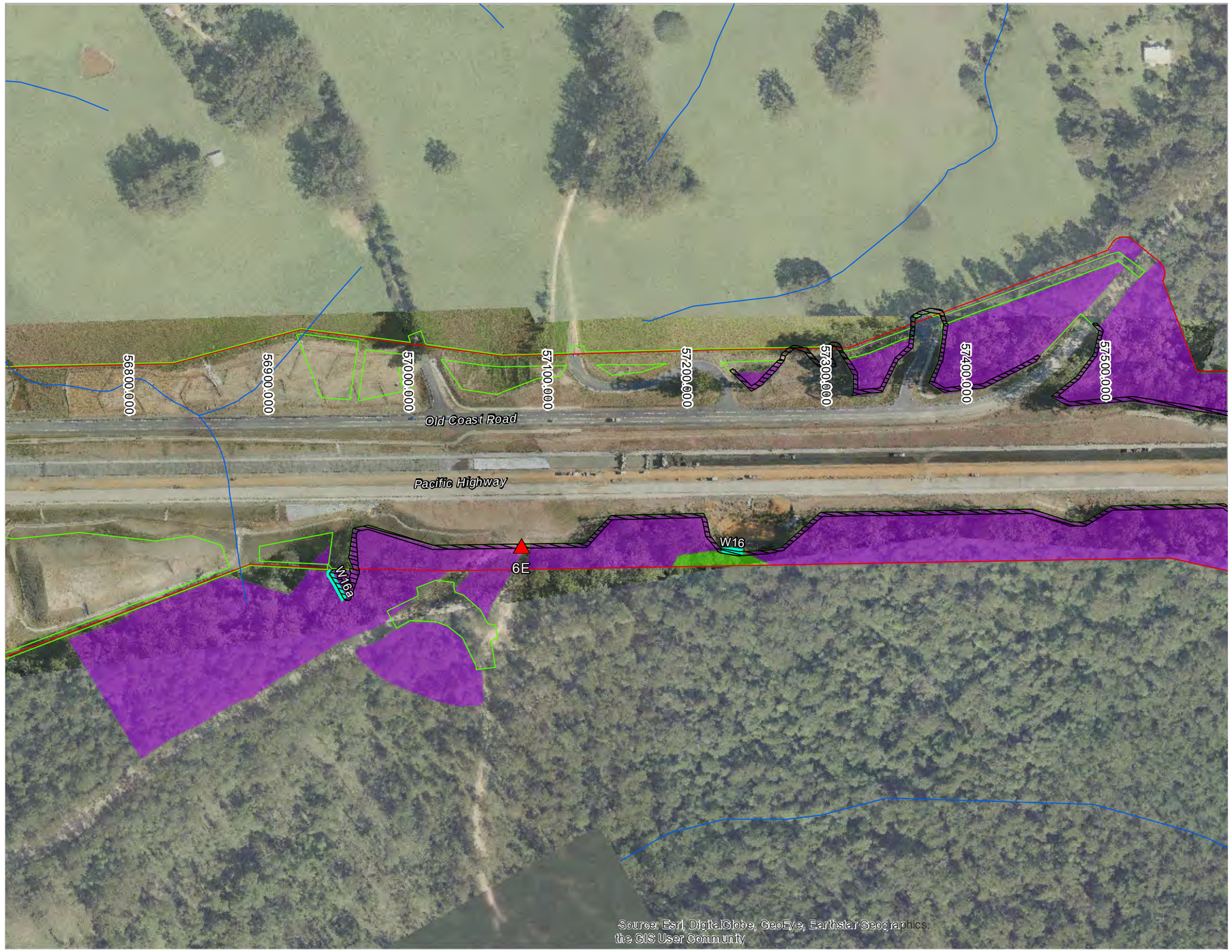
- Medium
- Low

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 14/11/2018
Source of base data: ESRI and AFJV



LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2A GBFF weed survey area
- Fixed photo point

Vegetation

- Blackbutt Open Forest
- Moist Open Forest - Flooded Gum

Weed Site (Abundance)

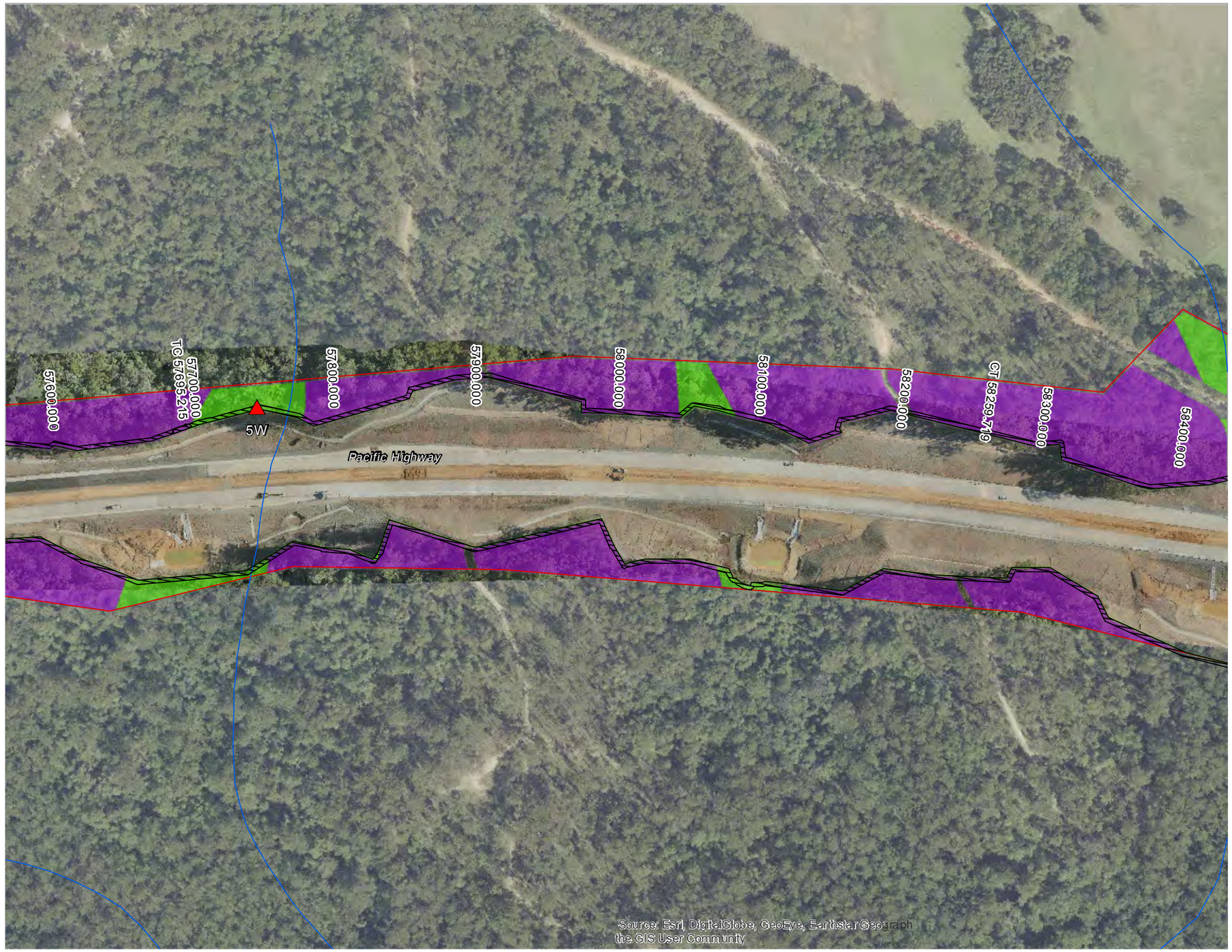
- Low

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 14/11/2018
Source of base data: ESRI and AFJV



LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2A GBFF weed survey area
- Fixed photo point

Vegetation

- Blackbutt Open Forest
- Moist Open Forest - Flooded Gum

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 14/11/2018
Source of base data: ESRI and AFJV

LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2A GBFF weed survey area
- Fixed photo point

Vegetation

- Blackbutt Open Forest
- Moist Open Forest - Flooded Gum

Weed Site (Abundance)

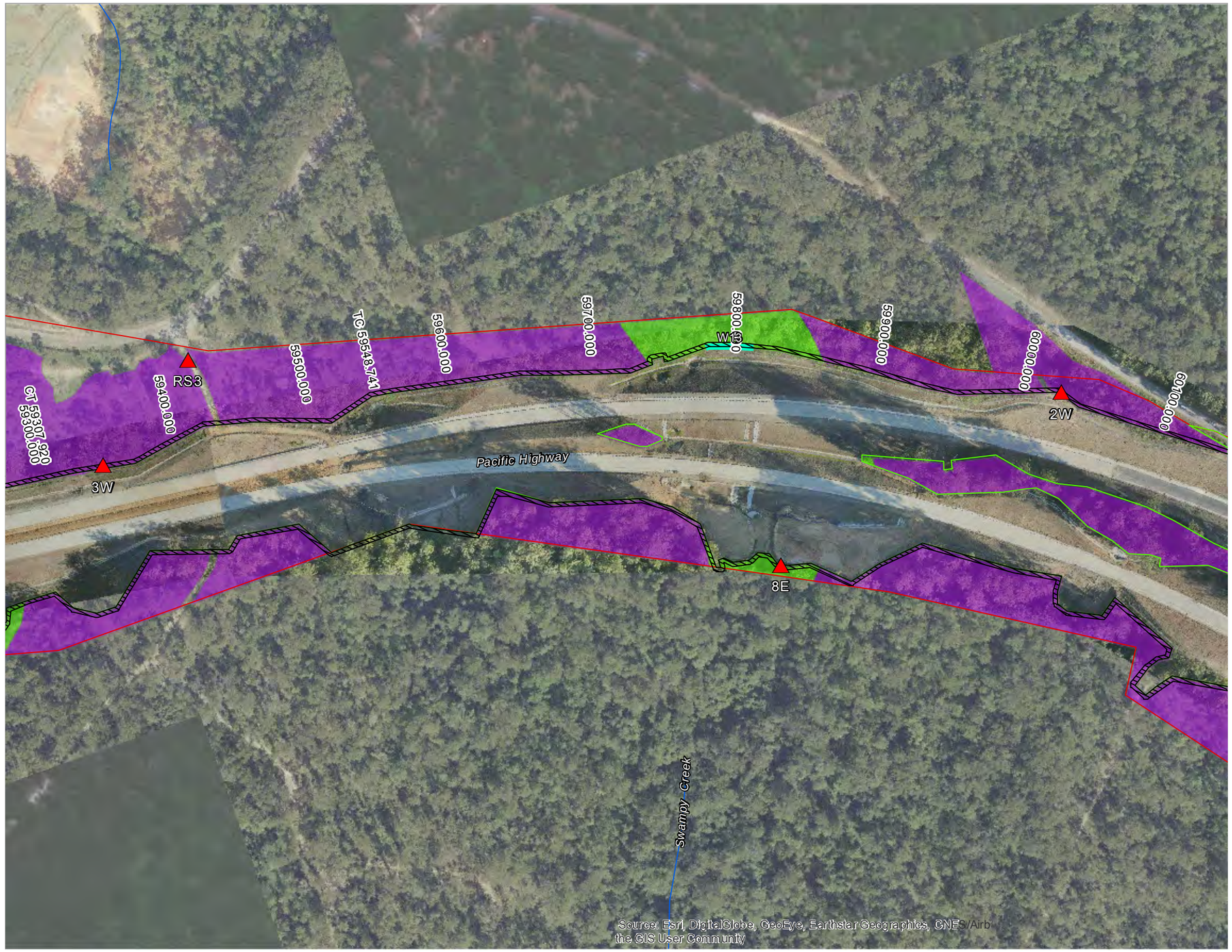
- Low

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 14/11/2018
Source of base data: ESRI and AFJV



LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2A GBFF weed survey area
- Fixed photo point

Vegetation

- Blackbutt Open Forest
- Moist Open Forest - Flooded Gum

Weed Site (Abundance)

- Low

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 14/11/2018
Source of base data: ESRI and AFJV

LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2A GBFF weed survey area
- Fixed photo point

Vegetation

- Blackbutt Open Forest

Weed Site (Abundance)

- Low

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: GJM Date: 14/11/2018
Source of base data: ESRI and AFJV

LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2A GBFF weed survey area

Vegetation

- Blackbutt Open Forest

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stages 2A and 2B)

Appendix B

GHFF Food Trees Species List

GHFF primary food tree species (blossom diet)			
Banksia integrifolia	Coastal Banksia	*Eucalyptus robusta*	Swamp Mahogany
Corymbia gummifera	Red Bloodwood	*Eucalyptus saligna*	Sydney Blue Gum
Corymbia intermedia	Pink Bloodwood	*Eucalyptus siderophloia*	Northern Grey Ironbark
Corymbia maculata	Spotted Gum	*Eucalyptus tereticornis*	Forest Red Gum
Corymbia variegata	Spotted Gum	*Grevillea robusta*	Silky Oak
Castanospermum australe	Black Bean	*Melaleuca quinquenervia*	Broad-leaved Paperbark
Eucalyptus pilularis	Blackbutt	*Syncarpia glomulifera*	Turpentine
GHFF secondary food tree species (blossom diet)			
Angophora costata	Smooth-barked Apple	*Eucalyptus grandis*	Flooded Gum
Angophora floribunda	Rough-barked Apple	*Eucalyptus propinqua*	Grey Gum
Eucalyptus acmenoides	White Mahogany	*Eucalyptus resinifera*	Red Mahogany
GHFF food tree species (fruit diet)			
Acmena smithii	Lilly Pilly	*Hedycarya angustifolia*	Native Mulberry
Alphitonia excelsa	Red Ash	*Livistona australis*	Cabbage Palm
Archontophoenix cunninghamiana	Bangalow Palm	*Maclura cochinchinensis*	Cockspur Thorn
Avicennia marina	Grey Mangrove	*Melia azedarach*	White Cedar
Cissus hypogaluca	Five-leaf Water Vine	*Melodinus australis*	Southern Melodinus
Dendrocnide excelsa	Giant Stinging Tree	*Morinda jasminoides*	Morinda
Dendrocnide photinophylla	Shining-lved Stinging Tree	*Pennantia cunninghamii*	Brown Beech
Diospyros pentamera	Myrtle Ebony	*Pittosporum undulatum*	Sweet Pittosporum
Diploglottis australis	Native Tamarind	*Planchonella australis*	Black Apple
Eucalyptus reticulatus	Blueberry Ash	*Podocarpus elatus*	Plum Pine
Ehretia acuminata	Koda	*Polyosma cunninghamii*	Featherwood
Elaeocarpus obovatus	Hard Quandong	*Rauwenhoffia leichardtii*	Zig Zag Vine
Ficus coronata	Creek Sandpaper Fig	*Rhodamnia argentea*	Malletwood
Ficus fraseri	Sandpaper Fig	*Syzygium australe*	Brush Cherry
Ficus macrophylla	Moreton Bay Fig	*Syzygium corynanthum*	Sour Cherry
Ficus obliqua	Small-leaved Fig	*Syzygium crebrinerve*	Purple Cherry
Ficus rubiginosa	Rusty Fig	*Syzygium luehmanii*	Riberry
Ficus superba	Deciduous Fig	*Syzygium. oleosum*	Blue Lilly Pilly
Ficus watkinsiana	Strangler Fig	*Schizomeria ovata*	Crabapple

Appendix C

Fixed Photo Point Results

Table C1 Rehabilitation Site Photo Points

Photo Monitoring Point Location	*Site Rehabilitation Summer Monitoring Event – February 2018*	*Site Rehabilitation Autumn Monitoring Event – May 2018*	*Site Rehabilitation Winter Monitoring Event – July 2018*	*Site Rehabilitation Winter Monitoring Event – October 2018*
CH: 60800 West - Photo Point RS1 – view to the south (W:497272, N:6610243)				
CH: 60800 West - Photo Point RS2 – view to the north-east (E:497260, N:6610256)				
CH: 60800 West - Photo Point RS2 – view to the south-west (E:497260, N:6610256)				

Photo Monitoring Point Location	*Site Rehabilitation Summer Monitoring Event – February 2018*	*Site Rehabilitation Autumn Monitoring Event – May 2018*	*Site Rehabilitation Winter Monitoring Event – July 2018*	*Site Rehabilitation Winter Monitoring Event – October 2018*
CH: 59450 East - Photo Point RS3 - view to the east (E:496443, N:6609093), no rehabilitation works started at time of monitoring.				
CH: 59450 East - Site reference photo view to the west (E:496443, N:6609093), looking towards Photo Point #3, no rehabilitation works started at time of monitoring.				
CH: 60800 East - Photo Point RS4 (E:497440, N:6610248) - view to the west (no peg installed)				

Table C2 Weed Monitoring Fixed Photo Points (Stage 2A)

*Photo Point ID **	*Photo Point GPS Coordinates^*	*February 2018 photograph*	*May 2018 photograph*	*July 2018 photograph*	*October 2018 photograph*
1E	491906, 6598292				
1W	492671, 6600507				
2E	492372, 6599033				

Photo Point ID *	Photo Point GPS Coordinates^	February 2018 photograph	May 2018 photograph	July 2018 photograph	October 2018 photograph
2W	496675, 6609675				
3E	492778, 6600567				
3W	496494, 6609010				

Photo Point ID *	Photo Point GPS Coordinates^	February 2018 photograph	May 2018 photograph	July 2018 photograph	October 2018 photograph
4E	494575, 6605139				
4W	496131, 6608279				
5E	494960, 6606206				

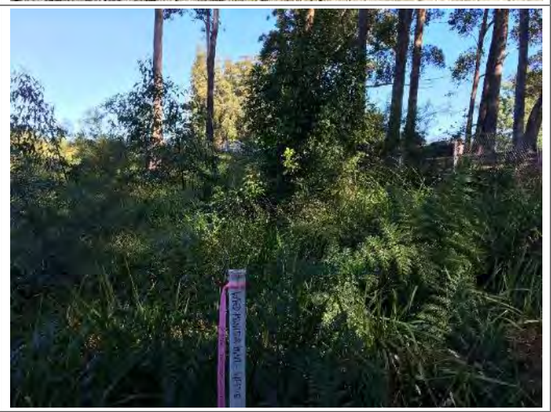
Photo Point ID *	Photo Point GPS Coordinates^	February 2018 photograph	May 2018 photograph	July 2018 photograph	October 2018 photograph
5W	495668, 6607684				
6E	495433, 6607052				
6W	494890, 6606346				

Photo Point ID *	Photo Point GPS Coordinates^	February 2018 photograph	May 2018 photograph	July 2018 photograph	October 2018 photograph
7E	496240, 6608213				
7W	494355, 6604185				
8E	496724, 6609444				

* number + side of alignment heading north: E=east, W=west.

Table C3 Weed Monitoring Fixed Photo Points (Stage 2B)

*Photo Point ID**	*Photo Point GPS Coordinates^*	*July 2018 photograph*	*October 2018 photograph*
1BE	489545, 6594390		
1BW	490778, 6596540		
2BE	488766, 6593840		

*Photo Point ID **	*Photo Point GPS Coordinates^*	*July 2018 photograph*	*October 2018 photograph*
2BW	489407, 6594440		
3BE	490153, 6595330		
3BW	489268, 6594420		

Appendix 5: Summer 2019 Stage 2B monitoring report.

GeoLINK environmental management and design

ABN 79 896 839 729
ACN 101 084 557

Return address:
PO Box 119
LENNOX HEAD
NSW 2478

LENNOX HEAD
T 02 6687 7666
F 02 6687 7782

COFFS HARBOUR
T 02 6651 7666

ARMIDALE
T 0488 677 666

LISMORE
T 02 6621 6677

www.geolink.net.au

1 February 2019
Ref No: 2692-1161

Roads and Maritime Service
Sent via Email to: Kris.HINCKS@rms.nsw.gov.au

Attention: Mr Kris Hincks

Dear Kris

WC2NH Stage 2B GHFF Habitat Monitoring – Summer 2019

Introduction

This report presents the results of the third quarterly (summer 2019) Grey-Headed Flying-fox (GHFF) habitat monitoring event for Stage 2B (chainage 41700 to 47700 - refer to **Appendix A**) of Warrell Creek to Nambucca Heads Highway Upgrade (WC2NH or the Project). Quarterly GHFF habitat monitoring is required for one year after the opening of each section of WC2NH to traffic in accordance with the *Warrell Creek to Urunga Pacific Highway Upgrade Ecological Monitoring Program – Stage 2: Warrell Creek to Nambucca Heads* (Benchmark Environmental Management, 2014).

The *Warrell Creek to Nambucca Heads Flying-fox Management Plan* (Sinclair Knight Merz, 2017) recognised that the quality of vegetation adjacent to the Project area could be detrimentally affected by invasion of noxious and environmental weeds. A main goal identified for management during operation of the Project is '*no reduction of the quality of flying-fox habitats adjacent to the Project corridor due to the operation of the Project and to minimise the impact of edge effects'* (Sinclair Knight Merz, 2017).

Methodology

The WC2NH GHFF habitat monitoring includes the following components:

1. Monitoring of identified revegetation/ rehabilitation areas to ensure the establishment/ restoration of seedlings and plants.
2. Monitoring both revegetation/ rehabilitation areas and other habitat areas adjacent to the Project to manage invasion of noxious and environmental weeds.

Urban and Regional Planning | Environmental Engineering | Civil Design | Environmental Impact Assessment | Ecological Surveys and Monitoring | Landscape Architecture | Urban Design |

There are no GHFF revegetation/ rehabilitation areas associated with Stage 2B, therefore the subject monitoring event exclusively related to the second component of the monitoring program (henceforth referred to as 'weed monitoring').

Weed Monitoring

The Project *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) approval defined GHFF habitat as habitat consisting of:

- Swamp Forest - Swamp Mahogany/ Paperbark.
- Moist Open Forest - Flooded Gum.
- Moist Open Forest - White Mahogany/ Grey Gum/ Ironbark.
- Mixed Floodplain Forest.
- Open Forest - Blackbutt.

All instances of the above plant communities occurring along the outside of the Stage 2B Project clearing corridor were targeted during the field surveys. Within two metres of the cleared edge of these habitat areas the following data was recorded in relation to weeds:

- Date and time of monitoring.
- Weed abundance and composition.
- Evidence of management and control of noxious and environmental weeds.

Weed abundance for individual species was measured using modified Braun-Blanquet cover classes between 1 and 5: 1 (<5%), 2 (6-25%), 3 (26-50%), 4 (51-75%), and 5 (76-100%). Abundance scores for identified weed sites were classified based on the categories in **Table 1**. Priority weed sites for management were identified based on species present and the percentage cover, prioritising *Biosecurity Act 2015* listed species and weeds with potential to degrade flying-fox foraging habitat values. The field surveys were undertaken by GeoLINK ecologists Jessica O'Leary and Frank Makin on 22 January 2019 between 8:00 am to 12:00 pm (eight person hours in total).

Table 1 Weed Abundance Classification for Weed Sites

Noxious/ Environmental Weed Cover (%)	*Weed Abundance Classification*
0-10	NA
11-39	Low
40-69	Medium
70-100	High

Photos were taken at the fixed photo points established during the winter 2018 weed monitoring for Stage 2B. Locations of the fixed photo points are listed in **Table2**.

Table 2 Locations of Fixed Photo Points

*Photo Point ID**	*Photo Point GPS Coordinates^*	*Notes on Photo Direction*	*Vegetation Type*	*Corresponding Weed Infestation*
1BE	489545, 6594390	Looking north	Moist Open Forest - Flooded Gum	2BW9
1BW	490778, 6596540	Looking south	Moist Open Forest - Flooded Gum	2BW3
2BE	488766, 6593840	Looking south-west	Mixed Floodplain Forest	2BW18
2BW	489407, 6594440	Looking north-east	Mixed Floodplain Forest	2BW8
3BE	490153, 6595330	Looking south	Moist Open Forest - Flooded Gum	Not applicable
3BW	489268, 6594420	Looking south	Mixed Floodplain Forest	2BW11

** number plus side of alignment heading north: E=east, W=west.*

^ UTM eastings, northings; Zone 56J

Results and Discussion

Occurrence of noxious and/or environmental weeds was recorded at 23 sites (identified as low, medium or high) within the edge of GHFF habitat adjacent to the Project area. These weed occurrences are shown in **Appendix A** and listed in **Table 3**. Photographs of GHFF habitat areas taken from the fixed photo points are shown in **Appendix B.**

A total of 21 noxious and environmental weed species were recorded. Blackberry (*Rubus fruticosus*), Fireweed (*Senecio madagascariensis*) and Lantana (*Lantana camara*) were recorded on-site and are listed as priority weed species for the North Coast of NSW under the *Biosecurity Act 2015*. The primary management duty for these is they '*must not be imported into the state or sold*'.

Overall the summer 2019 monitoring event has recorded an increase in weed species presence and abundance within the exiting weed survey areas. This is consistent with the expected summer growth period for the mid-north coast region. Two new weed infestation areas were recorded (2BW4a and 2BW20) which contain low weed abundance infestations.

Broad-leaved Paspalum (*Paspalum mandiocanum*), Setaria (*Seteria sphacelata*), Lantana and Large-leaved Privet (*Ligustrum lucidum*) were recorded within GHFF habitat areas at the highest density. They were also the dominant weed species in at infestations with 'Medium' or 'High' weed abundance levels (refer to Error! Reference source not found.**3**).

One weed survey area was nominated as a 'High' priority weed management area and four sites were nominated as 'Medium' weed management priority areas. Weed management priority areas are listed below and shown in **Appendix C**:

- 2BW8a - High weed management priority
- 2BW1 - Medium weed management priority
- 2BW8 - Medium weed management priority
- 2BW13 - Medium weed management priority
- 2BW16 - Medium weed management priority.

The summer 2019 monitoring event has recorded a slight increase from three medium management priority sites, recorded during the spring 2018 monitoring event, to four within the current monitoring event. These areas should be targeted during weed management works. To date, no management of weed infestation areas has be recorded during field surveys.

No significant change to the structure or composition of GHFF habitat has been recorded during fixed photo point monitoring. No exotic vines with the potential to inhibit native regeneration and smother the canopy of intact GHFF habitat were observed.

Table 3 Abundance and Composition of Noxious and/or Environmental Weeds Infestations at Stage 2B

Weed Site No.	*Chainage (side of highway)*	*Summer 2019 Weed Composition (Cover Class^)*	*GHFF Habitat Type (Plant Community)*	*Winter 2018 Weed Abundance^^*	*Spring 2018 Weed Abundance^^*	*Summer 2019 Weed Abundance^^*	*Comments*	*Evidence of Management and Control*	*Weed Management Priority*
2BW1	46180 – 46190 (east)	**Setaria (2),** Camphor Laurel (1), **Lantana (1), Tobacco Bush (1), Broad-leaved Paspalum (2)**	Open Forest - Blackbutt	High	Medium	Medium	**Additional weed species present to those recorded during the previous monitoring event (spring 2018).**	No evidence of weed control	Medium
2BW2	45440 – 45450 (east)	Broad-leaved Paspalum (2), Camphor Laurel (1), **Setaria (3)**	Moist Open Forest - Flooded Gum	Low	Low	Low	Small creek and riparian zone within survey area. **Increase in abundance of Setaria since the previous monitoring event (spring 2018).**	No evidence of weed control.	Low
2BW3	45170 – 45280 (west)	**Broad-leaved Paspalum (2),** Camphor Laurel (2), **Setaria (2),** Blackberry (1), Small-leaved Privet (1), Lantana (1), **Fleabane**	Moist Open Forest - Flooded Gum	Medium	Medium	Medium	**Changes from the previous monitoring event (spring 2018) include:** ▪ **A decrease in Broad-leaved Paspalum cover.** ▪ **An increase in Setaria cover.** ▪ **Additional weed species recorded.**	No evidence of weed control	Low

Weed Site No.	*Chainage (side of highway)*	*Summer 2019 Weed Composition (Cover Class^)*	*GHFF Habitat Type (Plant Community)*	*Winter 2018 Weed Abundance^^*	*Spring 2018 Weed Abundance^^*	*Summer 2019 Weed Abundance^^*	*Comments*	*Evidence of Management and Control*	*Weed Management Priority*
		(1), Balloon Cotton Bush (1)							
2BW4a	**44230 – 44280 (west)**	**Camphor Laurel (1), Lantana (1), Setaria (1)**	**Open Forest - Blackbutt**	**Not recorded**	**Not recorded**	**Low**	**New weed infestation area with low abundance of weeds**	**N/A**	**Low**
2BW4**b**	44100 – 44200 (east)	Broad-leaved Paspalum (3), Purple Top (1), Rhodes Grass (1), Camphor Laurel (1), Whisky Grass (1), **Setaria (1)**	Open Forest - Blackbutt	Medium	Low	Low	**Seteria now recorded during summer 2019 (not previously recorded for this site)**	No evidence of weed control	Low
2BW5	43960 – 44030 (east)	Broad-leaved Paspalum (3), Balloon Cotton Bush (1), Crofton Weed (1), Fireweed* (1), **Setaria (1)**	Moist Open Forest - Flooded Gum	Medium	Medium	Medium	No GHFF habitat vegetation exists immediately adjacent to the weed survey area. The weeds recorded within 2BW5 pose low risk of encroachment into the retained Moist Open Flooded Gum Forest which is 15 m from the weed infestation area.	No evidence of weed control	Low
2BW6	43050 – 43090	Lantana* (1), Broad-	Moist Open Forest -	Low	Low	Low	No change since the previous monitoring	No evidence of weed	Low

Weed Site No.	Chainage (side of highway)	Summer 2019 Weed Composition (Cover Class^)	GHFF Habitat Type (Plant Community)	Winter 2018 Weed Abundance^^	Spring 2018 Weed Abundance^^	Summer 2019 Weed Abundance^^	Comments	Evidence of Management and Control	Weed Management Priority
	(east)	leaved Paspalum (1)	Flooded Gum				event (spring 2018)	control	
2BW7	42980 – 42990 (west)	Lantana* (2), Large-leaved Privet (1), Broad-leaved Paspalum (1)	Mixed Floodplain Forest	Low	Low	Low	No change since the previous monitoring event (spring 2018)	No evidence of weed control	Low
2BW7a	42800 - 42900	Lantana (1)	Moist Open Forest - Flooded Gum	Not recorded	Low	Low	No change since the previous monitoring event (spring 2018)	No evidence of weed control	Low
2BW8	42700 – 42880 (west)	Lantana* (3), Large-leaved Privet (3), Camphor Laurel (1), Winter Senna (1), Wild Tobacco Bush (1), Broad-leaved Paspalum (1), Setaria (1), **Rhodes Grass (1), Annual Ragweed**	Mixed Floodplain Forest	Medium	Medium	Medium	During spring 2BW8 was split into two sections (see 2BW8a below) to identify area of high weed activity. **Additional weed species recorded during summer 2019.**	No evidence of weed control	Medium

Weed Site No.	Chainage (side of highway)	Summer 2019 Weed Composition (Cover Class^)	GHFF Habitat Type (Plant Community)	Winter 2018 Weed Abundance^^	Spring 2018 Weed Abundance^^	Summer 2019 Weed Abundance^^	Comments	Evidence of Management and Control	Weed Management Priority
		(1), Fleabane (1), Setaria (1), Spear Thistle (1), Paddy's Lucerne (1)							
2BW8a	42650 - 42700	Large-leaved Privet (4), Lantana (3), Tobacco Bush (2), **Broad-leaved Paspalum (2), Setaria (1)**	Mixed Floodplain Forest	Medium	High	High	**Additional weed species recorded during summer 2019.**	No evidence of weed control	High
2BW9	42770 – 42800 (east)	Broad-leaved Paspalum (2), Lantana* (1), Blue Billygoat Weed (1)	Moist Open Forest - Flooded Gum	Low	Low	Low	No change since the previous monitoring event (spring 2018)	No evidence of weed control	Low
2BW10	42620-42630 (east)	Setaria (3), Cobblers Pegs (1), Wild Tobacco Bush (1), **Lantana (2),**	Mixed Floodplain Forest	Medium	Medium	Medium	**Additional weed species recorded during summer 2019.**	Evidence of weed control.	Low

Weed Site No.	*Chainage (side of highway)*	*Summer 2019 Weed Composition (Cover Class^)*	*GHFF Habitat Type (Plant Community)*	*Winter 2018 Weed Abundance^^*	*Spring 2018 Weed Abundance^^*	*Summer 2019 Weed Abundance^^*	*Comments*	*Evidence of Management and Control*	*Weed Management Priority*
		Annual Ragweed (1)							
2BW11	42500 – 42600 (west)	Broad-leaved Paspalum (3), Lantana* (1), Tobacco Bush (1), **Annual Ragweed (1), Setaria (1), Paddy's Lucerne (1)**	Mixed Floodplain Forest	Medium	Medium	Medium	**Additional weed species recorded during summer 2019.**	No evidence of weed control	Low
2BW12	42600 – 42610 (west)	Lantana* (3), Broad-leaved Paspalum (2), Wild Tobacco Bush (1), **Setaria (2) Purple Top**	Mixed Floodplain Forest	Low	Low	Low	**Additional weed species recorded during summer 2019.**	No evidence of weed control	Low
2BW13	42500 – 42510 (west)	Large-leaved Privet (2), **Lantana* (3), Small-leaved Privet (2)**	Mixed Floodplain Forest	Low	Low	**Medium**	**Changes from the previous monitoring event (spring 2018) include:** ▪ **Increase in abundance of Lantana and Small-leaved Privet.** ▪ **Overall weed**	No evidence of weed control	**Medium**

Weed Site No.	Chainage (side of highway)	Summer 2019 Weed Composition (Cover Class^)	GHFF Habitat Type (Plant Community)	Winter 2018 Weed Abundance^^	Spring 2018 Weed Abundance^^	Summer 2019 Weed Abundance^^	Comments	Evidence of Management and Control	Weed Management Priority
							abundance has increased from low to medium.		
2BW14	42570 – 42600 (east)	Large-leaved Privet (2), Broad-leaved Paspalum (1)	Mixed Floodplain Forest	Low	Low	Low	No change since the previous monitoring event (spring 2018)	No evidence of weed control	Low
2BW15	42530 – 42600 (east)	Lantana* (2), Large-leaved Privet (2), Small-leaved Privet (2), Broad-leaved Paspalum (1), Camphor Laurel (saplings) (1)	Mixed Floodplain Forest	Low	Low	Low	No change since the previous monitoring event (spring 2018)	No evidence of weed control	Low
2BW16	42090 – 42220, 42290, 42390 (east)	Broad-leaved Paspalum (4), Setaria **(3)**, Lantana* (1), Camphor Laurel (1), Wild Tobacco	Mixed Floodplain Forest	High	High	High	**Changes from the previous monitoring event (spring 2018) include:** ▪ **Fireweed was not recorded during summer 2019** ▪ **Seteria has increase in abundance.**	No evidence of weed control	Medium

Weed Site No.	Chainage (side of highway)	Summer 2019 Weed Composition (Cover Class^)	GHFF Habitat Type (Plant Community)	Winter 2018 Weed Abundance^^	Spring 2018 Weed Abundance^^	Summer 2019 Weed Abundance^^	Comments	Evidence of Management and Control	Weed Management Priority
		Bush (1), **Blue Billy Goat (1), Purple Top (1), Croftons Weed (1), Fleabane (1), Cobblers Pegs (1)**					▪ **Additional weed species recorded.**		
2BW17	41900 – 41920 (east)	Small-leaved Privet (2), Setaria (2), Lantana (1), Paddy's Lucerne (1), Tobacco Plant (1)	Mixed Floodplain Forest	Not recorded	Low	Low	No change since the previous monitoring event (spring 2018)	No evidence of weed control	Low
2BW18	41830 – 41880 (east)	Lantana (2), Camphor Laurel (2), Paddy's Lucerne (1), White Passionflower (1)	Mixed Floodplain Forest	Not recorded	Low	Low	Weeds recorded at this survey area pose minimal risk of encroachment into the adjacent Mixed Floodplain Forest which is >5 m from the weed infestation area.	No evidence of weed control	Low
2BW19	41560 – 41620 (east)	Blackberry (2), Lantana (2), Broad-leaved Paspalum	Mixed Floodplain Forest	Not recorded	Low	Low	Grass species currently being grazed.	No evidence of weed control	Low

Weed Site No.	*Chainage (side of highway)*	*Summer 2019 Weed Composition (Cover Class^)*	*GHFF Habitat Type (Plant Community)*	*Winter 2018 Weed Abundance^^*	*Spring 2018 Weed Abundance^^*	*Summer 2019 Weed Abundance^^*	*Comments*	*Evidence of Management and Control*	*Weed Management Priority*
		(2), Paddy's Lucerne (2), Annual Ragweed (1), Tobacco Bush (1)							
2BW20	**41765-41960 (west)**	**Setaria (1), Lantana (1), Tobacco Bush (1)**	**Moist Open Forest - Flooded Gum**	**Not recorded**	**Not recorded**	**Low**	**New weed infestation area with low abundance of weeds**	**N/A**	**Low**

^ *Modified Braun-Blanquet cover classes of 1=<5%, 2=6-25%, 3=26-50%, 4=51-75%, and 5=76-100%.*

^^ Refer to Table 2.

* Denotes *Biosecurity Act 2015* listed priority weed species. Lantana, Blackberry and Fireweed are listed as Weeds of National Significance and as priority weed species for the North Coast of NSW. They must not be imported into the State or sold.

Bold text denotes change from spring 2018 monitoring event.

Recommendations and Conclusions

Weed sites 2BW1, 2BW8, 2BW8a, 2BW13 and 2BW16 are key target weed management areas to reduce degradation to GHFF habitat. At these sites, there is the potential for Lantana, Large-leaved Privet and Small-leaved Privet to alter community structure and inhibit regeneration. Management of the weeds at these sites would be consistent with the key objectives of the WC2NH *Weed and Pathogen Management Plan* (GeoLINK 2015) which is to '*ensure the Project avoids, suppresses and controls the spread of all weeds, plant pathogens and invasive species to ensure that impacts to the environment are minimised.*'

Weed sites primarily with dense Setaria and Broad-leaved Paspalum or lower profile herbaceous species (at sites 2BW3, 2BW5, 2BW10 and 2BW11) should be considered somewhat lower priorities for management than sites comprising medium or high infestations of Lantana and/ or Large-leaved or Small-leaved Privet for the following reasons:

- There may be a lower likelihood of weed management success (it is difficult to remove these species (particularly the grasses) successfully from degraded communities that have a suitable semi-shaded understorey environment); and
- Being understorey weed species that occur in disturbed environments, edge grass and herbaceous weed species have a low potential to alter either the forest structure or regeneration potential, and hence the quality of relatively intact GHFF habitat.

Please contact the undersigned if require any further information.

Yours sincerely
GeoLINK

Jessica O'Leary
Ecologist

References

Benchmark Environmental Management (2014). *Warrell Creek to Urunga Pacific Highway Upgrade Ecological Monitoring Program. Stage 2: Warrell Creek to Nambucca Heads*. Report to Roads and Maritime Services.

GeoLINK (2015). *Weed and Pathogen Management Plan: Warrell Creek to Nambucca Heads Upgrade of the Pacific Highway.* Unpublished report to Acciona and Ferrovial Joint Venture/ Roads and Maritime Services. GeoLINK Consulting, Coffs Harbour.

Sinclair Knight Merz (2017). *Warrell Creek to Nambucca Heads Upgrade of the Pacific Highway; Flying-fox Management Plan.* Report to Roads and Maritime Services.

Issue Log

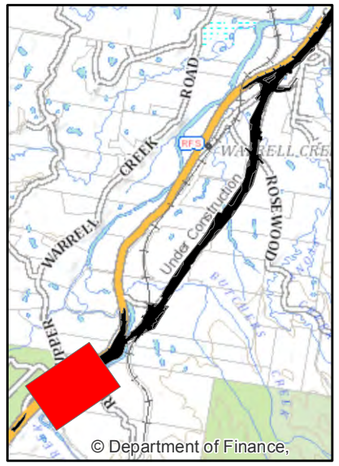
UPR	*Description*	*Date issued*	*Issued By*
2692-1161	First issue	01/02/2019	Jessica O'Leary

Appendix A

GHFF Weed Survey Areas and Weed Infestation Levels (Summer 2019)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 25/01/2019
Source of base data: ESRI and AFJV



LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2B GHFF weed survey area
- Fixed photo point

Vegetation

- Mixed Floodplain Forest (EEC)
- Moist Open Forest - Flooded Gum

Weed Site (Abundance)

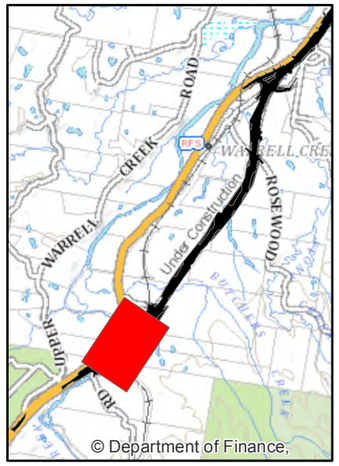
- High
- Low

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stage 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 25/01/2019
Source of base data: ESRI and AFJV



LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2B GHFF weed survey area
- Fixed photo point

Vegetation

- Mixed Floodplain Forest (EEC)
- Moist Open Forest - Flooded Gum

Weed Site (Abundance)

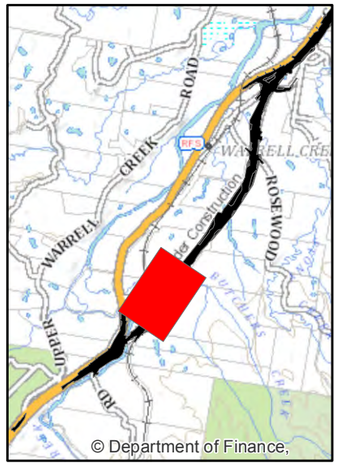
- High
- Medium
- Low

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stage 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 25/01/2019
Source of base data: ESRI and AFJV



LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2B GHFF weed survey area
- Fixed photo point

Vegetation

- Mixed Floodplain Forest (EEC)
- Moist Open Forest - Flooded Gum

Weed Site (Abundance)

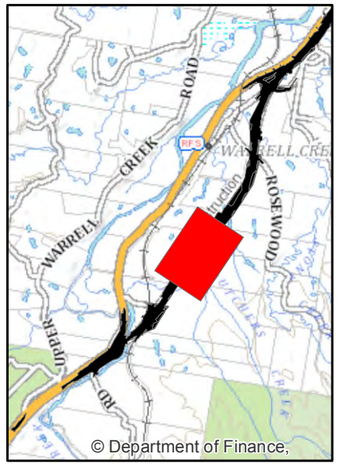
- Medium
- Low

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stage 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 25/01/2019
Source of base data: ESRI and AFJV



LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2B GHFF weed survey area
- Fixed photo point

Vegetation

- Blackbutt Open Forest
- Moist Open Forest - Flooded Gum

Weed Site (Abundance)

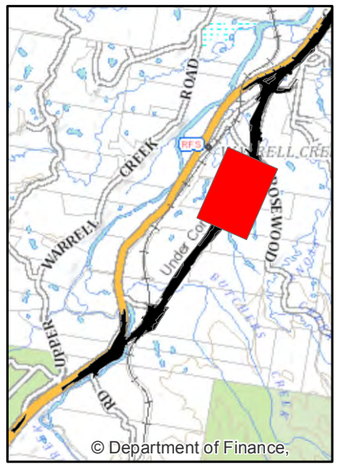
- Medium
- Low

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stage 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 25/01/2019
Source of base data: ESRI and AFJV



LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2B GHFF weed survey area

Vegetation

- Blackbutt Open Forest
- Moist Open Forest - Flooded Gum

Weed Site (Abundance)

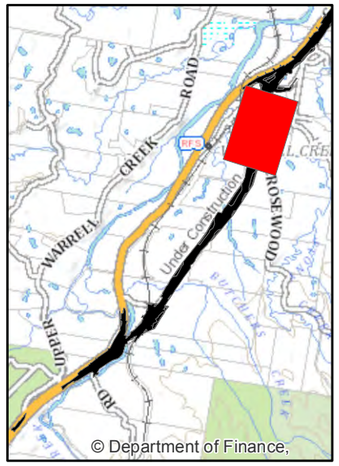
- Medium
- Low

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stage 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 25/01/2019
Source of base data: ESRI and AFJV



LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2B GHFF weed survey area
- Fixed photo point

Vegetation

- Moist Open Forest - Flooded Gum

Weed Site (Abundance)

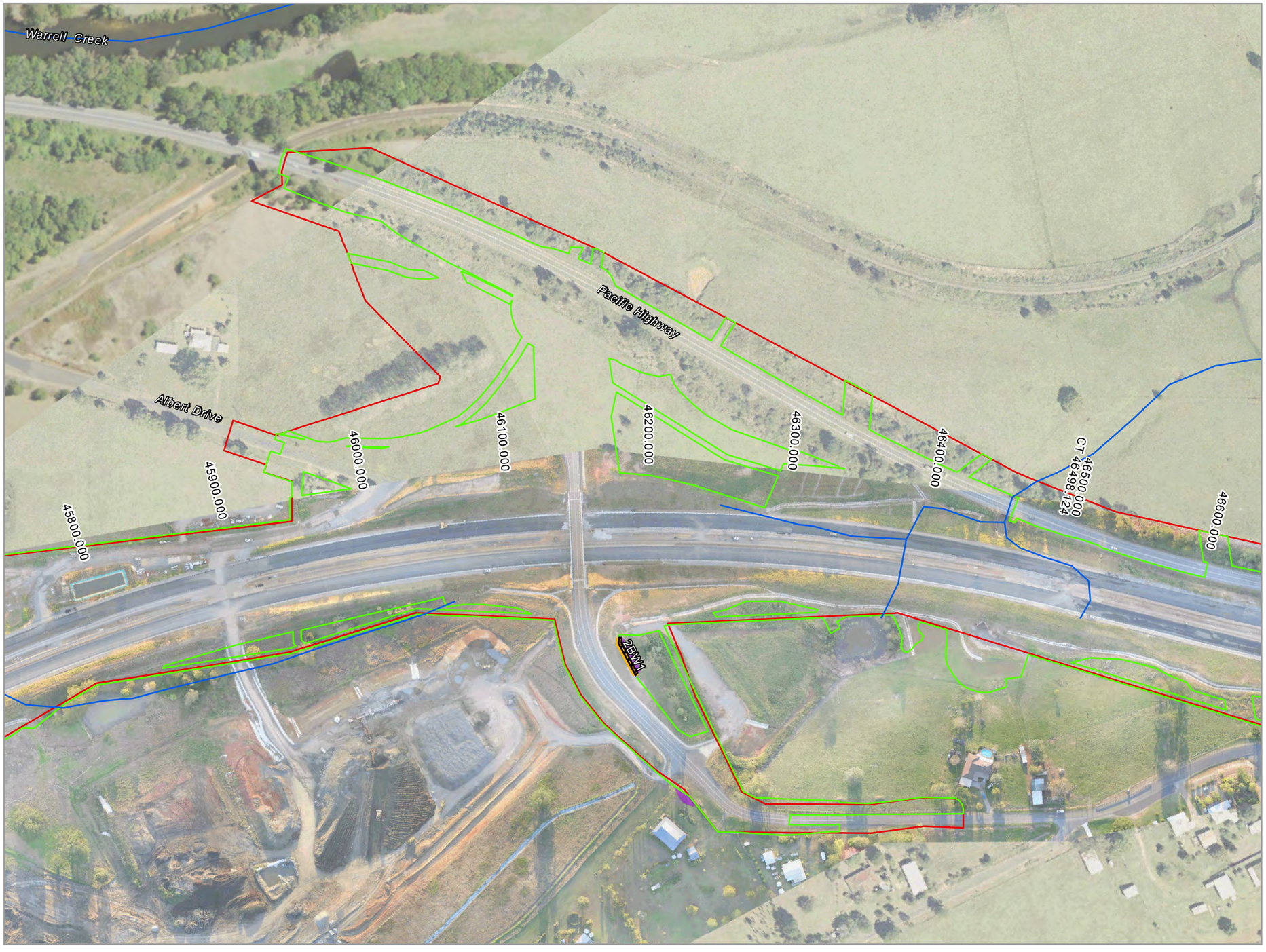
- Medium
- Low

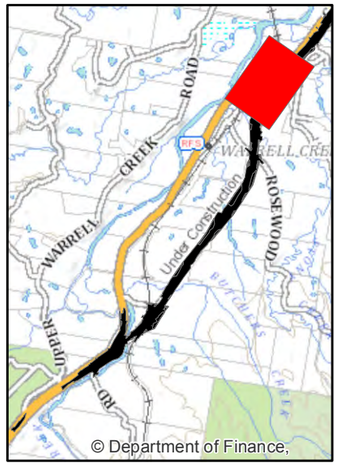
0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stage 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 25/01/2019
Source of base data: ESRI and AFJV





LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2B GHFF weed survey area

Vegetation

- Blackbutt Open Forest

Weed Site (Abundance)

- Medium

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stage 2B)

Appendix B

Fixed Photo Point Results

Table B1 Weed Monitoring Fixed Photo Points (Stage 2B)

*Photo Point ID **	*Photo Point GPS Coordinates^*	*July 2018 photograph*	*October 2018 photograph*	*January 2019 photograph*
1BE	489545, 6594390			
1BW	490778, 6596540			
2BE	488766, 6593840			

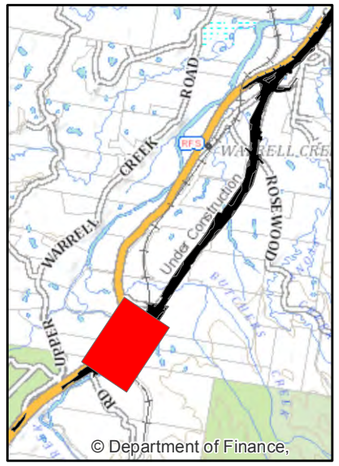
*Photo Point ID **	*Photo Point GPS Coordinates^*	*July 2018 photograph*	*October 2018 photograph*	*January 2019 photograph*
2BW	489407, 6594440			
3BE	490153, 6595330			
3BW	489268, 6594420			

Appendix C

Weed Management Priority Areas

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 25/01/2019
Source of base data: ESRI and AFJV



LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2B GHFF weed survey area
- Fixed photo point

Vegetation

- Mixed Floodplain Forest (EEC)
- Moist Open Forest - Flooded Gum

Weed Management Priority

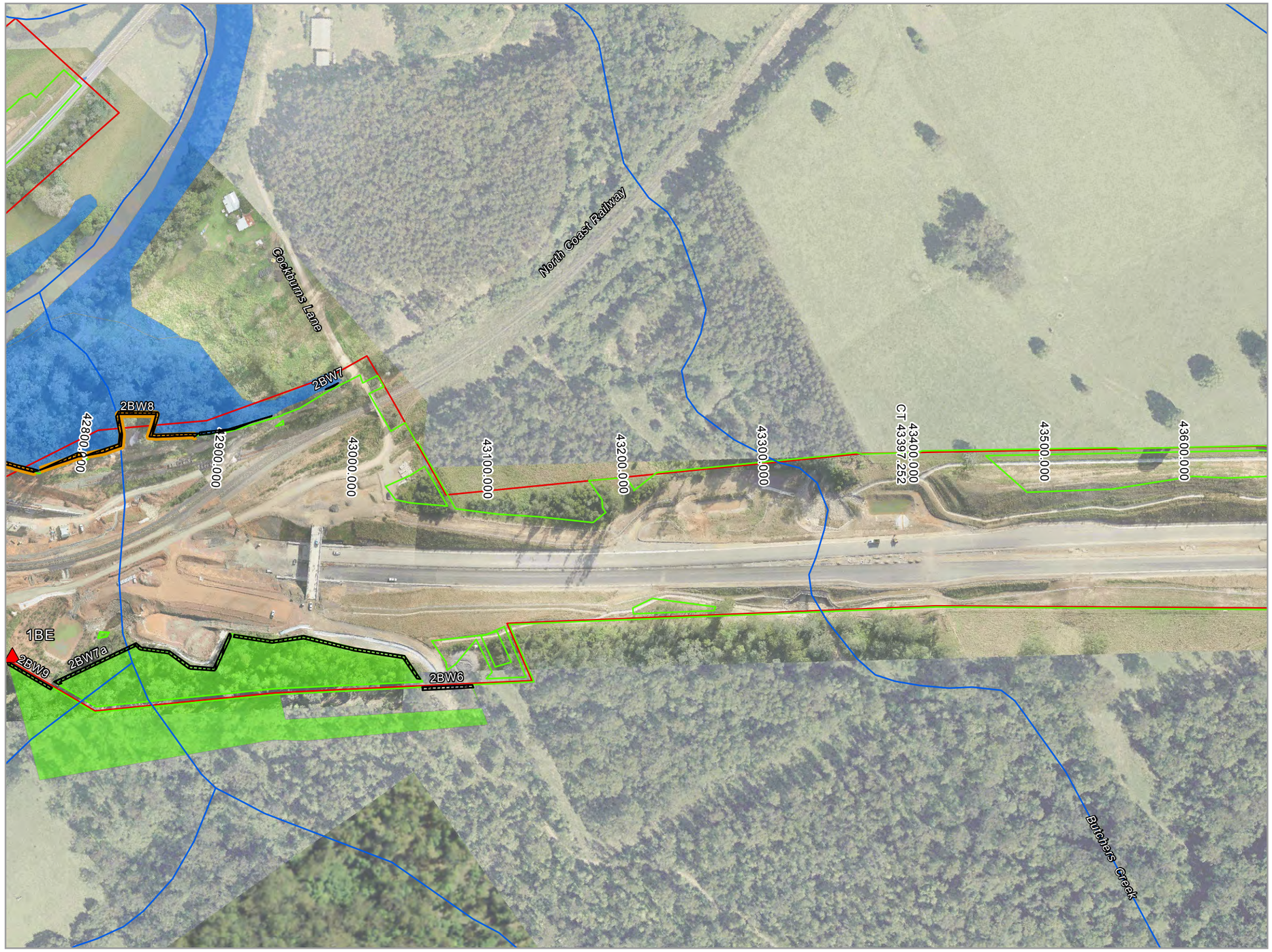
- High
- Medium

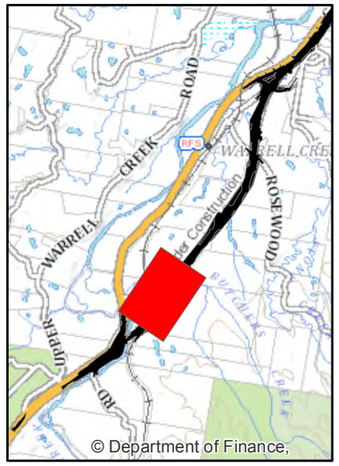
0 60

Weed Management Priority Areas (Stage 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 25/01/2019
Source of base data: ESRI and AFJV





LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2B GHFF weed survey area
- Fixed photo point

Vegetation

- Mixed Floodplain Forest (EEC)
- Moist Open Forest - Flooded Gum

Weed Management Priority

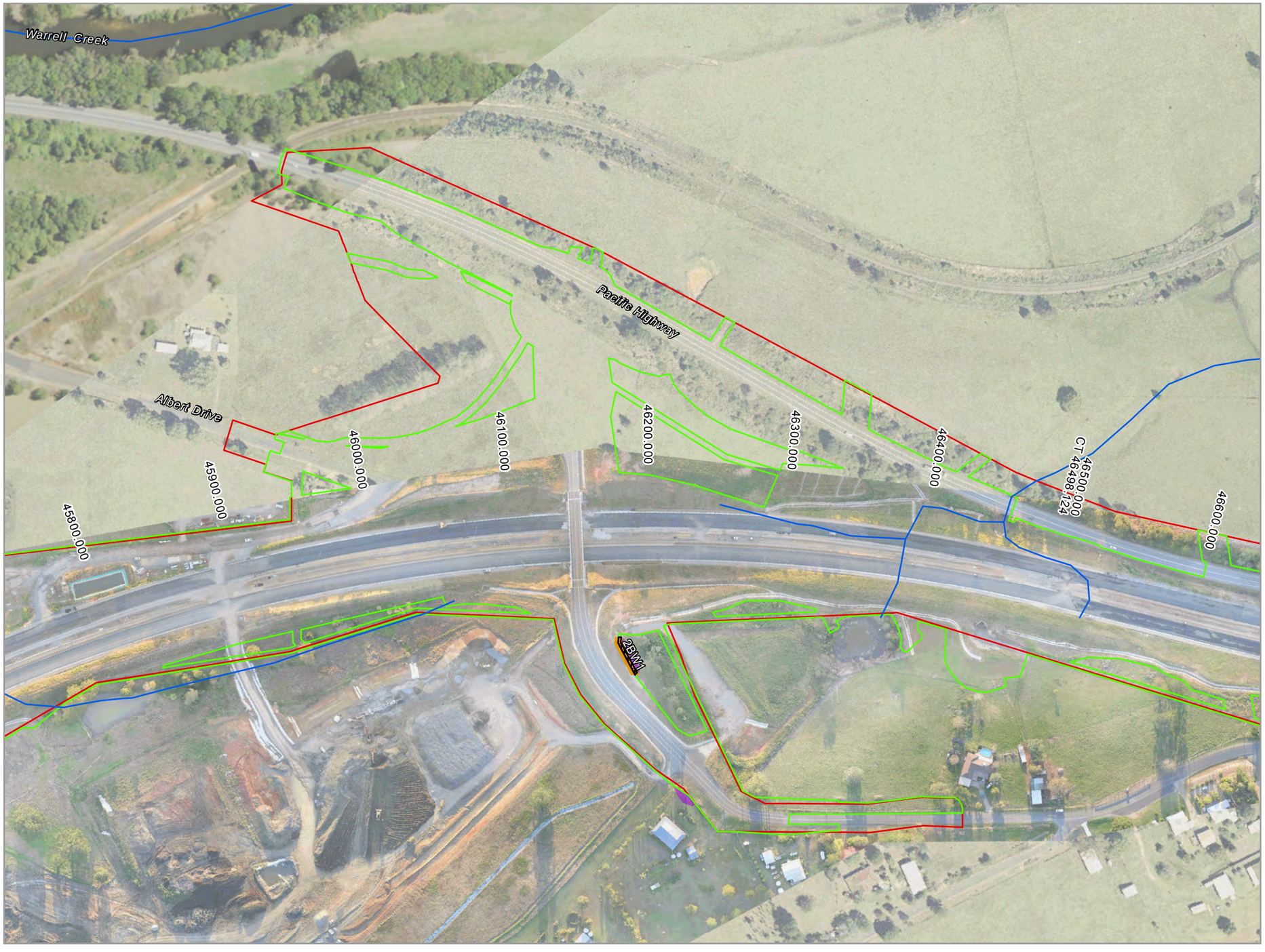
- Medium

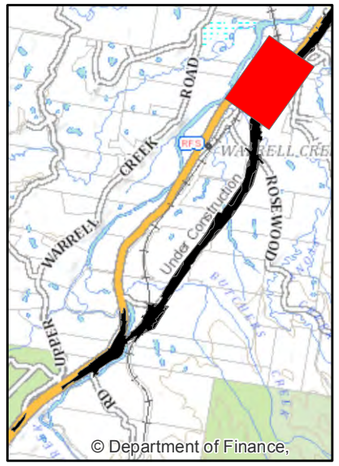
0 60

Weed Management Priority Areas (Stage 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 25/01/2019
Source of base data: ESRI and AFJV





LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2B GHFF weed survey area

Vegetation

- Blackbutt Open Forest

Weed Management Priority

- Medium

0 60

Weed Management Priority Areas (Stage 2B)

Appendix C Koala

Warrell Creek to Nambucca Heads Koala Monitoring Report- year one operational phase

Koala Monitoring Report – year one operational phase

Roads and Maritime Services | December 2018

THIS PAGE LEFT INTENTIONALLY BLANK

Document Review

Date	Version	Status	Sent to	Represent	Delivered Format	Dispatched By
12/12/2018	A	Draft	S. Hardiman	RMS	MSW	D. Rohweder

Document Distribution

Date	Version	Status	Sent to	Represent	Delivered Format	Dispatched By
14/12/2018	B	Final	S. Hardiman	RMS	PDF	D. Rohweder

Project team:

Dr D. Rohweder (project management, survey report writing)
Mr N. Priest (project management, field survey)
Mr G. McDonald (field survey)
Dr B. Barth (field survey)

Report prepared for:

Roads and Maritime Services NSW

© Sandpiper Ecological Surveys 2018
ABN: 82 084 096 828

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

Disclaimer:
This report has been prepared in accordance with the scope of services described in the contract or agreement between Sandpiper Ecological Surveys (ABN 82 084 096 828) and Pacific Complete. The report relies upon data, surveys and measurement obtained at the times and locations specified herein. The report has been prepared solely for Pacific Complete and Sandpiper Ecological Surveys accepts no responsibility for its use by other parties. Sandpiper Ecological Surveys accepts no responsibility or liability for changes in context, meaning, conclusions or omissions caused by cutting, pasting or editing the report.

Table of contents

1. Introduction 1
1.1 Background 1
1.2 Study area 2
2. Methodology 3
2.1 Transect surveys 3
2.2 Survey limitations 3
3. Results 4
3.1 Transect surveys 4
3.2 Tracks and easements 4
3.3 Habitat use and distribution 4
4. Discussion 8
4.1 Koala population 8
4.2 Habitat use and distribution 8
5. References 10

List of tables

Table 1: Location of koala scats recorded during spring 2018 transect surveys. Datum – GDA 94. 5

Table 2: Koalas recorded on tracks and easements during the spring 2018 survey. Uk = unknown; F = female.....5

Table 3: Visual assessment of health of koalas recorded during spotlight and diurnal surveys.....9

List of figures

Figure 1: Location of the WC2NH alignment..... 2

Figure 2: Location of koala records obtained between 2014 and 2018, and koala scats recorded in 2018. 7

1. Introduction

In 2015, Roads and Maritime Services (RMS) NSW, in conjunction with Acciona Ferrovial Joint Venture (AFJV), commenced the upgrade of the Pacific Highway between Warrell Creek and Nambucca Heads (WC2NH). The WC2NH project was opened to traffic in two stages: stage 2a - 13.5km section from Lower Warrell Creek Bridge to Nambucca Heads opened on 18 December 2017; and stage 2b 6.25km section from the southern end of the project to the Lower Warrell Creek bridge opened in late June 2018.

Approvals for the WC2NH upgrade required monitoring of several species and mitigation measures during the operational phase. Species and mitigation measures targeted include koala, yellow-bellied glider, giant barred frog, green-thighed frog ponds, underpasses, vegetated median, roadkill, exclusion fence, and threatened flora. Sandpiper Ecological Surveys (SES) has been contracted by RMS to deliver the WC2NH operational ecological and water quality monitoring program.

The following report details the methods and results of spring year 1 operational phase koala population monitoring. The aim of koala monitoring is to identify changes in resident koala activity (abundance, home range and movements) in response to construction of WC2NH and the effectiveness of koala habitat connectivity mitigation measures (i.e. fauna underpasses and exclusion fencing). The following report focuses on targeted koala surveys on replicate transects and includes general comment on the effectiveness of mitigation measures. Detailed analysis of koala use of underpasses will be provided in the annual koala report, which is due in August 2019.

1.1 Background

The impact of the upgrade on koala (Phascolarctos cinereus) was assessed in the Project Environmental Assessment (Sinclair Knight Merz [SKM] 2010a, SKM 2010b), and following its listing on the Environment Protection and Biodiversity Conservation Act 1999, a supplementary assessment in accordance with the *EPBC Act Policy Statement 1.1 Significant Impact Guidelines* (Geolink 2016). The supplementary assessment found that the Proposal would have negative impacts on koalas utilising the Nambucca State Forest/ Old Coast Road area, mainly through habitat removal and fragmentation.

The Project, with effective implementation of proposed mitigation measures, was found to be unlikely to result in a significant impact to the local koala population. Notwithstanding, as the Project adversely affected habitat that satisfied the SEWPaC (2012) definition of 'habitat critical to the survival of the species' (including direct removal of approximately 86.5 ha of vegetation that satisfies this criteria); the Project was considered to constitute a significant impact on the Koala as per the DSEWPaC (2012) and DoE (2013a) guidelines.

Measures implemented to minimise impacts on koalas include:

- Ecological monitoring to determine the effectiveness of mitigation measures undertaken as part of the Project.
- Installation of fauna crossings, and fauna exclusion fencing to allow for safe passage of fauna (including the koala) crossing the Pacific Highway.
- Installation of 'floppy-top' fauna exclusion fencing to minimise road strike

Prior to construction a pre-clearance baseline koala monitoring methodology was prepared and baseline surveys conducted in autumn and spring 2014 (SKM 2014). Construction phase koala monitoring surveys were conducted in spring 2015 (year 1) and spring 2017 (year 3) (Geolink 2017).

1.2 Study area

The WC2NH project covers a total length of 19.75km and extends from Warrell Creek in the south to Nambucca Heads in the north (Figure 1). The alignment bypasses the town of Macksville and the northern section traverses Nambucca State Forest.

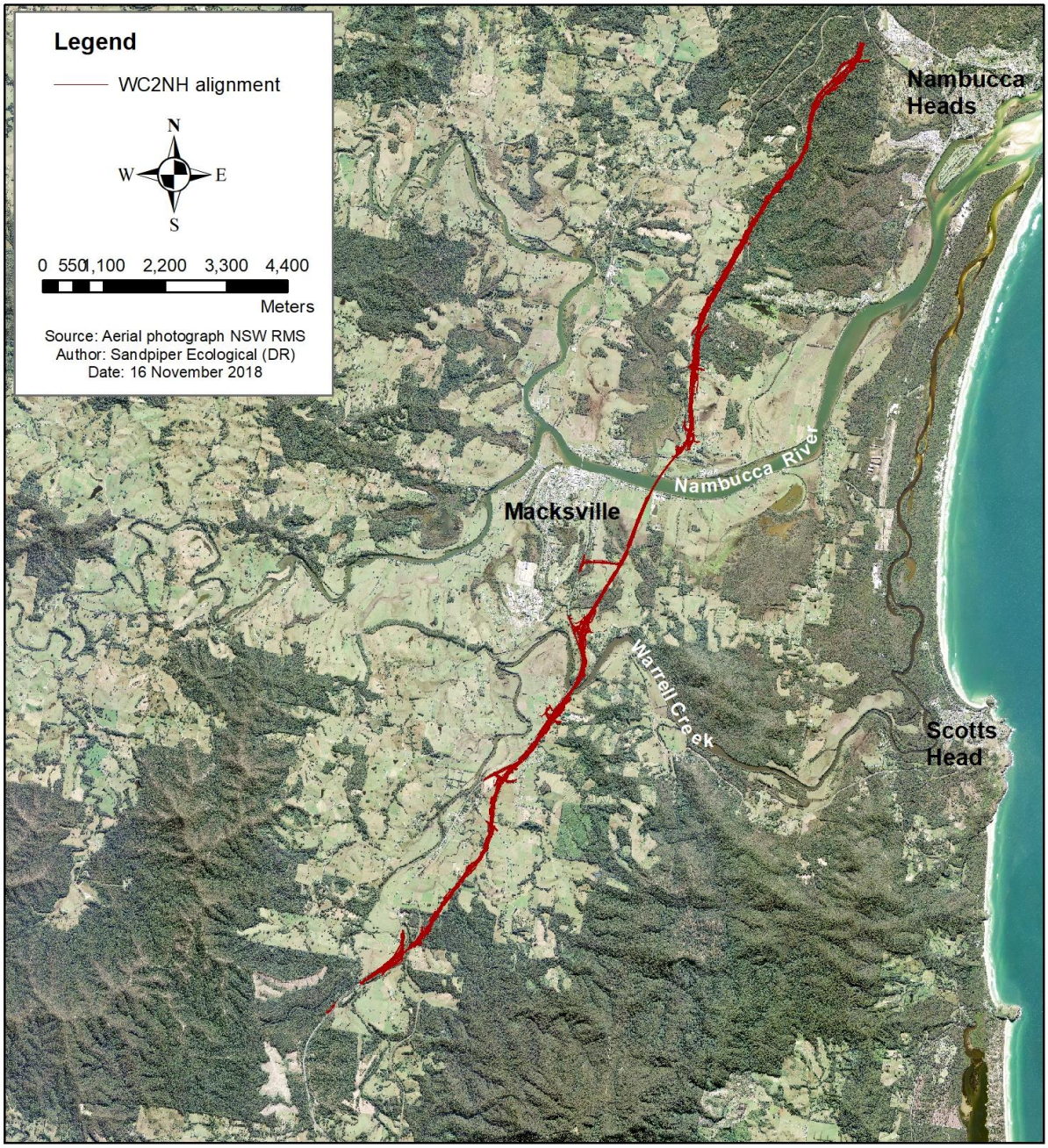


Figure 1: Location of the WC2NH alignment.

2. Methodology

2.1 Transect surveys

Twenty-five paired transects were established perpendicular to the alignment within the Nambucca State Forest/Old Coast Road area between chainages 15600 and 19500. Transects ranged in length from 500m to 34m and were approximately 150m apart (Figure 2). Shorter transects terminated at the forest edge, or at a private property boundary. Each transect was surveyed by one ecologist during the day and night. To avoid bias in koala detections the day and night survey of each transect was conducted by a different ecologist. All surveys were conducted on foot at a speed of 0.5 to 1kph. At night, the male koala call was broadcast for five minutes through an 8 watt megaphone from the approximate centre-point of each transect. Additional spotlighting was conducted along tracks and roads whilst moving between transects. All nocturnal surveys were conducted using 200 lumen spotlights. Surveys were conducted between 12 and 14 November, and on 20 and 28 November 2018. Weather conditions during the survey were suitable for sampling koalas with warm humid temperatures and light winds recorded. Survey time for 500m transects ranged from 30 to 56 minutes/transect.

The following data were collected for each koala detected:

- Location (using global positioning system GPS).
- Distance from transect (GIS).
- Occupied tree species.
- Habitat type.
- Height of occupied tree.
- Diameter at breast height of occupied tree.
- Sex.
- Behaviour.
- Evidence of disease.
- Reproductive status.

2.2 Survey limitations

The survey design has substantial limitations when considered in the context of the monitoring aim. The aim of monitoring is to identify changes in resident koala activity (abundance, home range and movements) in response to construction of WC2NH and the effectiveness of koala habitat connectivity mitigation measures (i.e. fauna underpasses and exclusion fencing). The second part of the aim “the effectiveness of koala habitat connectivity mitigation measures” is addressed in a separate component of the WC2NH operational phase monitoring program and is not a focus of population monitoring. The first part of the aim “to identify changes in resident koala activity (abundance, home range, and movements) in response to construction” is covered by the transect surveys and addressed in this report.

The survey design is unsuitable to obtain information on abundance, home range or movement. As noted by Geolink (2017) the dense mid-storey vegetation present on many transects substantially reduces koala detectability. The detection probability on some transects is likely to be less than 25%. The difficult terrain also means that a substantial amount of time is spent looking at the ground rather than the canopy. In addition, transects are not independent and there is a strong likelihood that the same koala could be recorded on several adjoining transects making estimates of abundance difficult. Individuals moving beneath the highway exacerbate this

problem. Previous surveyors noted detection limitations and sampling along tracks was included to supplement transect surveys (Geolink 2017).

3. Results

3.1 Transect surveys

One koala was recorded on transect W11 during the spring 2018 sample event (Table 1; Figure 2). An unconfirmed koala call was heard west of transect W7 on 12 November 2018 but the location of that call remains unconfirmed. Koala scats were recorded beneath three tallowwood trees (*Eucalyptus microcorys*), two on transect E10, and one on transect E19 (Table 2; Figure 2).

3.2 Tracks and easements

Two confirmed koala records were obtained during surveys of tracks and easements, one during the day between transects E18 and E19, and one at night between transects W20 and W21(Table 1; Figure 2). Two individuals appeared healthy (dry bottom and clear eyes) and diagnostic features could not be determined for the third individual. One individual was a female and the sex of the other two individuals could not be determined. The individual recorded on 13/11/2018 was recorded in the same tree during the day and night surveys.

A koala was recorded opportunistically on 28/11/2018, whilst conducting yellow-bellied glider population surveys. That individual was 124m from the female recorded on 20/11/2018 and may be the same individual.

3.3 Habitat use and distribution

Koalas were recorded using both Open Blackbutt Forest on ridges and midslope, and Flooded Gum Moist Open Forest in gullies. Occupied tree species included flooded gum (*Eucalyptus grandis*), tallowwood (*Eucalyptus microcorys*), and white mahogany (*Eucalyptus* spp). Scats were recorded beneath tallowwoods only.

In 2018, koala records occurred in the southern third and centre of the study area (Figure 2). Records near transects 19, 20 and 21 were in a similar area to records in 2017 and 2014 (Figure 2). The 2018 record on transect W11 was within 150m of a record in 2015. Koala scats recorded on E10 were near a koala record from 2017. The scats recorded at the east end of E19 may be from the individual recorded adjacent to the alignment between E18 and E19 in spring 2018 (Figure 2).

Table 1: Koalas recorded during the spring 2018 survey. Uk = unknown; F = female

Date	Easting	Northing	Time of observation	Closest transect & distance (m)	Survey type	Occupied tree	Habitat type	Tree height (m)	Tree diameter (mm)	Sex	Behaviour	Disease status	Reproductive status	Side of carriageway
12/11/2018	496198	6609663	Night	W11; 26	Transect	Flooded gum	Flooded Gum Moist Forest	35	340	Uk	Resting on lateral branch	Healthy	Uk	West
13/11/2018	496270	6608294	Day	E18; 59	Track & easement	Tallowwood	Open Blackbutt Forest	18	440	Uk	Resting – curled in tight ball; recorded during following night survey	Uk	Uk	East
20/11/2018	495941	6608102	Night	W21; 59	Track & easement	White mahogany	Open Blackbutt Forest	8	150	F	Resting on branch	Healthy	Uk	West

Table 2: Location of koala scats recorded during spring 2018 transect surveys. Datum – GDA 94.

Transect	Evidence	Distance from alignment (m)	Easting	Northing	Date
E10	Old scats beneath tallowwood	241	496903	6609380	14/11/2018
E10	Old scats beneath tallowwood	424	497068	6609298	14/11/2018
E19	Very old scats beneath tallowwood	540	496652	6607950	13/11/2018

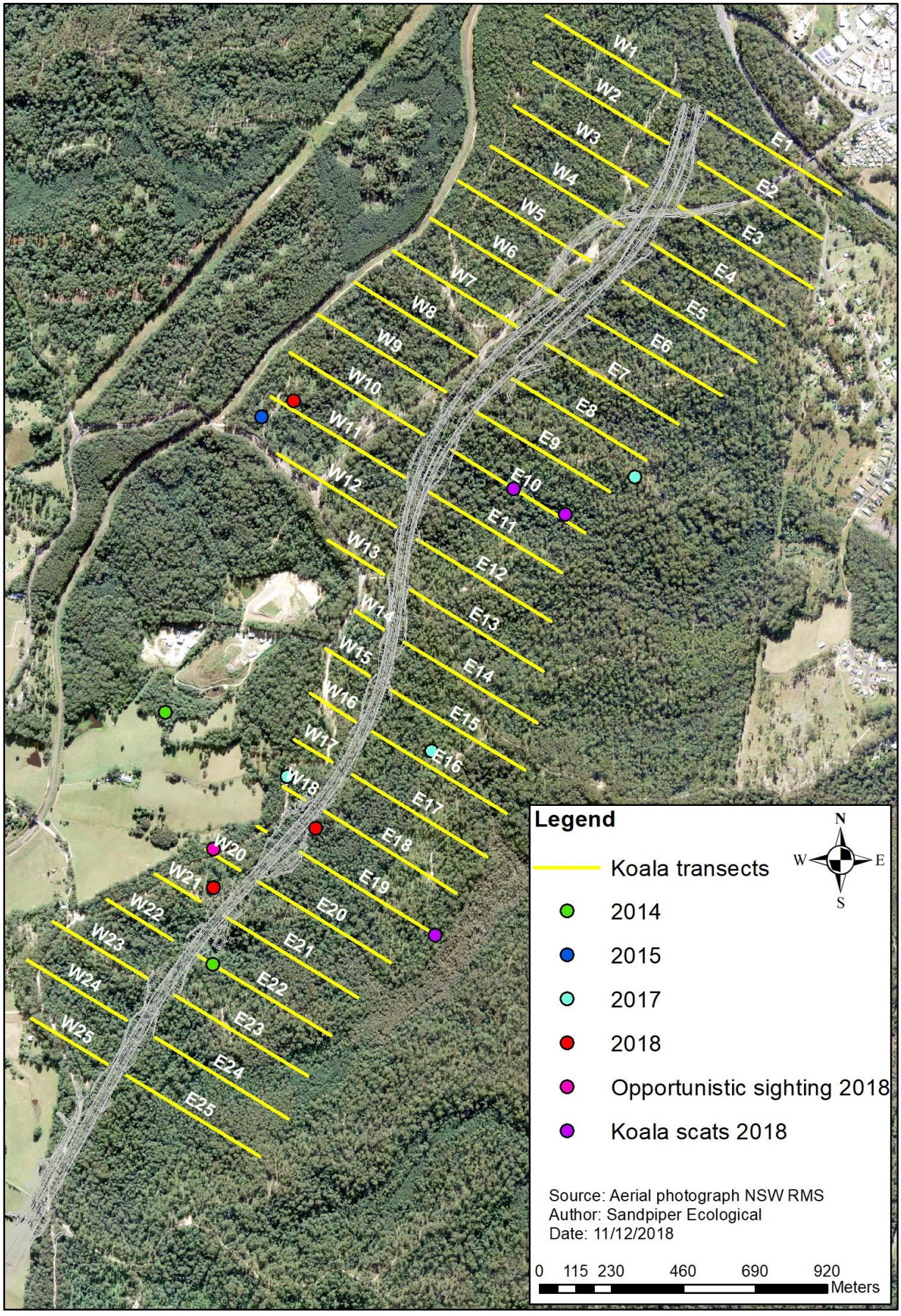


Figure 2: Location of koala records obtained between 2014 and 2018, and koala scats recorded in 2018.

4. Discussion

4.1 Koala population

The same number of koalas (3 individuals) was recorded during the spring 2018 and spring 2017 surveys. This was substantially more than the single individual recorded during baseline surveys and year one of the construction phase (Table 3). Possible variation in methods between surveys, particularly the effort expended on tracks and easements where most koalas are recorded, makes it impossible to draw conclusions on whether koala abundance has increased or decreased due to the WC2NH upgrade.

Table 3: Comparison of koala records during the baseline, construction, and operational phases of the WC2NH upgrade. * individual recorded on four occasions.

Phase & year	Transect Surveys (diurnal & nocturnal)		Track & Easement Surveys (nocturnal)	Total koalas recorded
	Koalas observed	Koala evidence (scats)	Koalas observed	
Baseline autumn 2014	0	0	1	1
Baseline spring 2014	0	0	1	1
Construction spring 2015	1	1	1	1*
Construction spring 2017	0	2	3	3
Operation spring 2018	1	3	2	3

The results show that koalas continue to reside in habitat immediately adjoining the highway and that the study area is utilised by at least three individuals. Based on the distribution of koalas in 2018 all three records are likely to be different individuals. Assuming an effective sampling width of 50m along transects and tracks the total area sampled is approximately 104ha.

Three koalas within an area of 104ha is broadly consistent with published home range estimates for males in northern NSW of 22.7ha at Bonville to 37.4ha at Lismore (Lassau *et al.* 2008; Goldingay & Dobner 2014). Home range size of koalas in Nambucca State Forest is expected to be larger than at nearby Bonville due to the lower quality of habitat present and forest management history. The presence of koalas in habitat immediately adjoining the highway and several confirmed crossings of underpasses in spring 2018 (Sandpiper Ecological unpublished data) suggests that some individuals have re-established home ranges to the new forest edge and others have home ranges that encompass the highway. The spring 2018 results support the suggestion that the study area supports a low-density koala population (Geolink 2017).

Whilst it is impossible to conclude how clearing for the upgrade has affected the local koala population the presence of individuals around the alignment suggests that impacts may have been minor. Another positive sign is that two of the three individuals observed in spring 2018 appeared healthy, and the health status of the third individual could not be determined.

4.2 Habitat use and distribution

Koala sightings and scat records obtained over the course of monitoring are beginning to reveal a pattern of koala habitation. Koalas have consistently been recorded over a 900m long area east and west of the alignment between transects 16 and 22. Evidence of koalas also occurred in the centre of the study area east and west of the alignment between transect numbers eight and 12.

5. References

DoE (2013a). *EPBC Act Policy Statement 1.1 Significant Impact Guidelines.* Department of Environment and Heritage, Canberra.

GeoLINK (2016). *Koala Management Plan. Warrell Creek to Nambucca Heads Upgrade of the Pacific Highway*. Unpublished report prepared for Acciona and Ferrovial Joint Venture and Roads and Maritime Services.

GeoLINK (2017). *Construction stage (year 3) koala monitoring. Warrell Creek to Nambucca Heads Pacific Highway Upgrade*. Report prepared for Roads and Maritime Services.

Goldingay, R. L. & Dobner, B. (2014). Home range areas of koalas in an urban area of north-east New South Wales. *Australian Mammalogy:* **36,** 74-80.

Lassau, S. A., Close, R., Ryan, B. & Pile, J. (2008). Home ranges and mortality of a roadside koala *Phascolarctos cinereus* population at Bonville, New South Wales. *Australian Zoologist:* **34,** 127-136.

SEWPAC (2012). *Interim koala referral advice for proponents*. Department of Sustainability, Environment, Water, Population and Communities, Canberra.

SKM (2014). *Draft Pre-clearance Baseline Koala Monitoring Methodology*. Unpublished report prepared for Acciona and Ferrovial Joint Venture and Roads and Maritime Services.

rms.nsw.gov.au/autorenew

13 22 13

Customer feedback
Roads and Maritime
Locked Bag 928,
North Sydney NSW 2059

December 2018

Appendix D Fauna Underpass

Transport
Roads & Maritime Services

Warrell Creek to Nambucca Heads

Interim Underpass Monitoring Report – spring / summer - year one operational phase

Roads and Maritime Services | February 2019

THIS PAGE LEFT INTENTIONALLY BLANK

Document Review

Date	Version	Status	Sent to	Represent	Delivered Format	Dispatched By
28/2/19	A	Draft	B. Taylor	Sandpiper	MSW	D. Rohweder
1/3/19	1	Draft	S. Hardiman	RMS	MSW	D. Rohweder

Document Distribution

Date	Version	Status	Sent to	Represent	Delivered Format	Dispatched By
4/3/2019	2	Final	S. Hardiman	RMS	MSW & PDF	D. Rohweder

Project team:

David Rohweder (Project management, field survey, reporting)
Nick Priest (Field survey, reporting)
Luke Andrews (Field survey)
Nirvarna Makings (Field survey)
Oska Taylor (Field survey)
Brendan Taylor (Review)

Report prepared for:

Roads and Maritime Services NSW

© Sandpiper Ecological Surveys 2019
ABN: 82 084 096 828

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

Cover Photo: NA.

Disclaimer:
This report has been prepared in accordance with the scope of services described in the contract or agreement between Sandpiper Ecological Surveys (ABN 82 084 096 828) and Pacific Complete. The report relies upon data, surveys and measurement obtained at the times and locations specified herein. The report has been prepared solely for Pacific Complete and Sandpiper Ecological Surveys accepts no responsibility for its use by other parties. Sandpiper Ecological Surveys accepts no responsibility or liability for changes in context, meaning, conclusions or omissions caused by cutting, pasting or editing the report.

Table of contents

1. Introduction 1
1.1 Background 1
1.2 Study area 2
2. Methods 2
2.1 Timing and weather conditions 2
2.2 Underpasses 4
2.2.1 Sand pads 4
2.2.2 Scat and track search 5
2.2.3 Cameras 5
2.3 Adjacent habitat 6
2.3.1 Survey design 6
2.3.2 Trapping 6
2.3.3 Diurnal active search 7
2.3.4 Nocturnal active search 7
2.3.5 Opportunistic records 7
3. Results 8
3.1 Underpasses 8
3.1.1 Sand pads 8
3.1.2 Scat and track 8
3.1.3 Cameras 9
3.2 Adjacent habitat 13
3.3 Species recorded in underpasses and adjacent habitat 15
4. Key findings 17
5. Recommendations 18
6. References 18
Appendix A – Species list 20
Appendix B – Field Data 22

List of tables

Table 1: Underpasses sampled during operational phase monitoring of the WC2NH upgrade. SQ = spotted-tailed quoll; K = koala; GBF = giant barred frog; * sites consists of dual cell 3x3m box culverts with one cell providing wet passage for aquatic fauna; P/A = presence/absence 1

Table 2: Summary of weather conditions recorded at the northern compound between 20 October and 20 December 2018. 2

Table 3: Survey effort for sampling adjacent habitat at 10 underpass sites on the WC2NH upgrade. 7

Table 4: Species and groups of fauna recorded during sand pad monitoring at 12 underpasses on the WC2NH upgrade. * possible record only. 8

Table 5: Species and fauna groups recorded during track and scat surveys of 12 underpasses on the WC2NH upgrade. 9

Table 6: Species and groups of fauna recorded by infra-red cameras at 12 underpasses on the WC2NH upgrade. C = complete crossing; IC = incomplete crossing; [I] = introduced species. 10

Table 7: Number of species and groups of fauna recorded and complete and incomplete crossings recorded at each of 12 underpasses monitored on the WC2NH upgrade. 11

Table 8: Number of complete crossings made by each species/group at each of 12 underpasses monitored on the WC2NH upgrade. NB – Sites 1 and 5 did not contain fauna furniture. [I] = introduced species 12

Table 9: Species of vertebrate recorded during surveys of habitat adjoining each side of all underpasses. [V] = vulnerable species; [E] = Endangered species; [I] = Introduced species.. 14

Table 10: Species and fauna groups recorded using underpasses by all methods and those recorded in adjacent habitat. Shading denotes a species or group not confirmed in both areas that is likely to be represented in another species/group that was recorded in both areas, for example northern brown bandicoot is likely represented by Peramelidae spp. 16

List of figures

Figure 1: Location of underpass sample sites in relation to the WC2NH alignment. 3

Figure 2: Comparison of the number of complete crossings by native and introduced species recorded at each underpass. 11

Figure 3: Complete crossings by all species on underpass floor and fauna furniture. 13

List of plates

Plate 1: Sand pad being installed in a fauna underpass on the WC2NH upgrade. 4

Plate 2: Example of a pitfall trap line installed during adjacent habitat surveys. 6

Plate 3: Koala recorded at Site 12, moving east on 22 October (left) and west of 23 October (right). 12

Plate 4: *Melomys* spp. (left) and brown antechinus (right) captured in adjacent habitat during spring 2018 monitoring. 15

1. Introduction

In 2015, Roads and Maritime Services (RMS) NSW, in conjunction with Acciona Ferrovial Joint Venture (AFJV), commenced the upgrade of the Pacific Highway between Warrell Creek and Nambucca Heads (WC2NH). The WC2NH project was opened to traffic in two stages:

- stage 2a - 13.5km section from Lower Warrell Creek Bridge to Nambucca Heads opened on 18 December 2017; and
- stage 2b - 6.25km section from the southern end of the project to the Lower Warrell Creek bridge opened on 29 June 2018.

Approvals for the WC2NH upgrade required monitoring of several species and mitigation measures during the operational phase. Species and mitigation measures targeted include koala, spotted tailed quoll, grey-headed flying-foxes, yellow-bellied glider, giant barred frog, green-thighed frog ponds, fauna underpasses, vegetated median, roadkill, exclusion fencing, and threatened flora. Sandpiper Ecological Surveys (SES) was contracted by RMS to deliver the WC2NH operational ecological and water quality monitoring program.

The objective of fauna underpass monitoring is “to assess use of underpasses by threatened and common fauna and to assess the effect of exclusion fencing on movement of small mammals, reptiles and frogs” (RMS 2018). Exclusion fence monitoring occurs annually in winter and is not reported on here.

The following interim report presents and methods and results of the spring / summer 2018 underpass and adjacent habitat surveys. The second round of monitoring in year one is scheduled for winter 2019. Due to its interim status this report does not include detailed analysis of data and results are presented as counts rather than crossings/unit of time. A detailed annual report will be prepared following the winter monitoring event. The discussion is also limited to a summary of key findings and recommendations that will be implemented in the second year one sample. A list of species names for fauna referred to in text and Tables is provided in Appendix A.

1.1 Background

The WC2NH upgrade features 23 fauna underpasses, including 13 sites with box culverts, three sites with pipe culverts and seven sites with bridges. Underpasses targeted for monitoring were specified in the WC2NH Ecological Monitoring Program (EMP; Table 1) and include eleven box culverts and one bridge. Site five includes a dual cell box culvert with one cell designated as a wet passage (for aquatic fauna) and the other as a dry cell. The dry cell includes a concrete ledge that provides dry passage for terrestrial fauna. Fauna underpasses were designed to target spotted-tailed quoll (*Dasyurus maculatus*), koala (*Phascolarctos cinereus*) and giant barred frog (*Mixophyes iteratus*). Sites 9/10, and 11/12 consist of corresponding culverts on either side of the vegetated median.

Table 1: Underpasses sampled during operational phase monitoring of the WC2NH upgrade. SQ = spotted-tailed quoll; K = koala; GBF = giant barred frog; * sites consists of dual cell 3x3m box culverts with one cell providing wet passage for aquatic fauna; P/A = presence/absence

Site	Chainage	Type	Structure	Dimensions	Fauna Furniture (P/A)	Substrate	SQ	K	GBF
1	42500	Combined	Bridge over Upper Warrell Ck		A	Soil			x
2	55120	Dedicated	Box Culvert	1 x 3000 x 3000	P	Concrete	x	x	
3	56410	Combined	Box Culvert	1 x 2400 x 2400	P	Concrete	x	x	
4	57770	Dedicated	Box Culvert	1 x 3000 x 3000	P	Mulch	x	x	
5	58510	Combined	Box Culvert	2 x 3000 x 3000*	A	Concrete	x	x	

Site	Chainage	Type	Structure	Dimensions	Fauna Furniture (P/A)	Substrate	SQ	K	GBF
6	58560	Dedicated	Box Culvert	1 x 3000 x 3000	P	Mulch	x	x	
7	59090	Dedicated	Box Culvert	1 x 3000 x 3000	P	Mulch	x	x	
8	59550	Dedicated	Box Culvert	1 x 3000 x 3000	P	Mulch	x	x	
9	59750 NB Lanes	Dedicated	Box Culvert	1 x 2400 x 2400	P	Mulch	x	x	
10	59760 SB Lanes	Dedicated	Box Culvert	1 x 2400 x 2400	P	Mulch	x	x	
11	60600 NB Lanes	Dedicated	Box Culvert	1 x 2400 x 2400	P	Mulch	x	x	
12	60610 SB Lanes	Dedicated	Box Culvert	1 x 2400 x 2400	P	Mulch	x	x	

1.2 Study area

The WC2NH project covers a total length of 19.75km and extends from Warrell Creek in the south to Nambucca Heads in the north (Figure 1). The alignment bypasses the town of Macksville and the northern section traverses Nambucca State Forest. Eleven underpasses are situated north of the Nambucca River and one (Site 1) is situated at Upper Warrell Creek near the southern extent of the project. Sites four to 12 adjoin Nambucca State Forest and sites two and three adjoin remnant vegetation on private land.

2. Methods

2.1 Timing and weather conditions

Spring / summer year one operational phase underpass monitoring was conducted between 15 October and 17 December 2018. Weather conditions over the sample period were characterised by warm humid conditions with small amounts of rain (10-30mm) occurring at regular intervals (Table 2). Rain events of 20-30mm created moist conditions in underpasses conducive to movements by amphibians. Daily weather conditions recorded at the northern compound are presented in Table B1, Appendix B.

Table 2: Summary of weather conditions recorded at the northern compound of the project site between 20 October and 20 December 2018.

Total rainfall	No. rain days	Max wind gusts	Relative Humidity	Max temp range (^{0}C)	Min temp range (^{0}C)
223mm	19	13-50kph	>70% on 90% of days	22.2-33.9	9.4-22.9

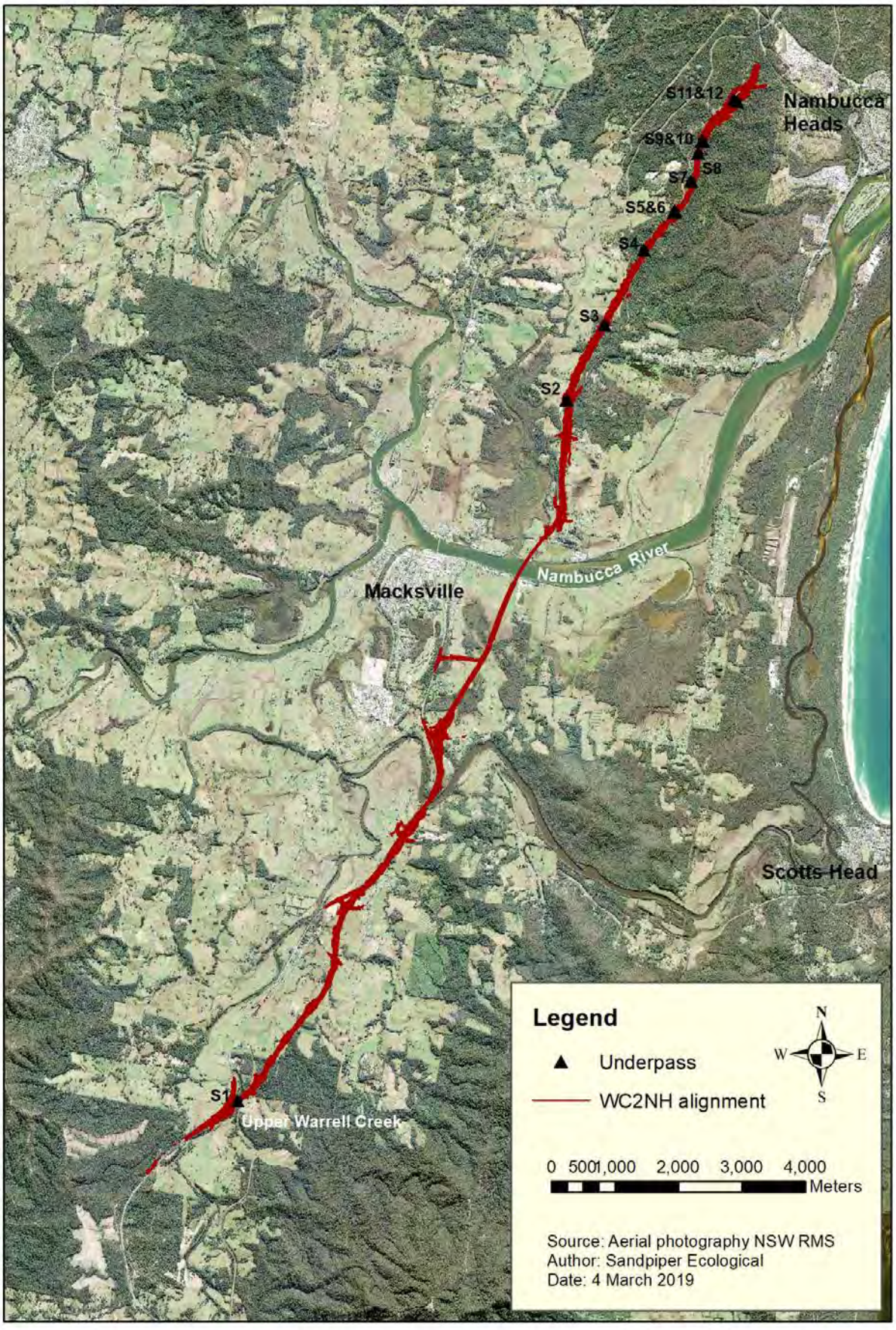


Figure 1: Location of underpass sample sites in relation to the WC2NH alignment.

2.2 Underpasses

2.2.1 Sand pads

Sand pads were installed on 30 October 2018 (sites 2-12) and 14 November 2018 (site 1). A 50:50 mix of brickies sand and washed beach sand was used. Two sand pads were installed at each site. In culverts, pads were installed 3-5m from each end, whilst at the bridge (Site 1) one pad was installed on each side of Warrell creek. Each pad was approximately 50mm deep by 1m wide and extended for the entire culvert width, or for 3m at Site 1. At sites with a concrete ledge the pad covered both the floor and ledge (Plate 1). The exception was site 5 where the pad only covered the ledge due to standing water over the culvert floor.

Sand pads were inspected on eight consecutive days, 31 October to 7 November at Sites 2-12 and 15-22 November at Site 1. Inspections were conducted by an ecologist and included a systematic scan of each pad searching for fauna tracks. A Small torch was used to illuminate the pad, if required. Information recorded included species or fauna group, number of traverses, direction of traverse and pad condition (Good, moderate, poor). Pad condition focussed on suitability of the pad for capturing good quality animal tracks. Tracks were identified with reference to Triggs (2004) and advice from senior ecologists. Tracks that could not be identified insitu were photographed and referred to a senior ecologist for identification.

Plate 1: Sand pad being installed in a fauna underpass on the WC2NH upgrade.

2.2.2 Scat and track search

Each underpass was searched by a senior ecologist for scats and tracks on two occasions during the sample period. Sites 2-12 were sampled on 17 and 31 October and Site 1 was sampled on 26 October and 8 November. The search involved a slow systematic traverse of each culvert using a hand-held spotlight (Led Lenser P14). Fauna furniture, the culvert floor, and joints were targeted. Areas of accumulated fine sediment were targeted for tracks. Tracks and scats were identified in-situ, with reference to Triggs (2004) and the ecologists' experience, or photographed and sent to colleagues for identification.

2.2.3 Cameras

Two motion activated infra-red cameras were installed centrally in each underpass except at Site one where a single camera, fixed to a star picket, was installed on each side of Warrell Creek, and Site 5 where one camera was installed centrally in each cell. In total, 24 cameras were installed. Swift Enduro cameras were used at sites 2-12 and Reconyx HC500 cameras were used at Site 1. In underpasses, both cameras were installed centrally, one on the fauna furniture, and one 300mm above the culvert floor. All cameras were oriented to the east. Swift cameras were set to take 10 seconds of video with no delay between activation. Cameras at site 1 were positioned at approximately 1m above ground level and oriented towards ground vegetation near the creek bank. Reconyx cameras were set on time-lapse mode to take a picture at 1-minute intervals between 8pm and 6am each day throughout the monitoring period. Time-lapse mode is better suited to targeting frogs and was used successfully to monitor frog pipes at Sapphire to Woolgoolga Upgrade (Sandpiper Ecological 2017a, 2018a).

Cameras were installed between 16 and 24 October and checked on 21 and 22 November. Images were downloaded and batteries replaced, if capacity was below 50%. Cameras were retrieved on 17 December 2018. Three cameras were damaged and one stolen on 14 December 2018. All damaged and stolen cameras were at Sites 9 and 10. SD cards in the three damaged cameras were readable and data were lost from the fauna furniture camera at Site 9 only.

Each underpass cameras was deployed for a minimum of 60 days. A total of 1339 recording days was recorded across all sites (Table B2, Appendix B). Nine of the 24 cameras were active for less than the 60 day minimum sample period, although two of these cameras, both at Site 5, were active for 58 days each. Of the remaining cameras four were positioned on fauna furniture, and three were on the floor. One of the furniture cameras was stolen during the second half of the spring monitoring period.

Image review

Images were uploaded to a computer and viewed using Windows Photo Viewer©. A senior ecologist or ecologist reviewed all images, with reference to standard field guides (i.e. Menkhorst & Knight 2004; Pizzey & Knight 2007; Van Dyck *et al.* undated). Input from multiple ecologists was sought to identify some images.

Animals were scored making a complete or incomplete crossing. A complete crossing was scored when an animal showed directional movement when detected by the centrally mounted underpass camera. An incomplete crossing was scored when an animal showed no directional movement (i.e. remained stationary in front of camera) or when an animal passed the camera but returned within 10 minutes. Crossing definitions are consistent with those used at other Pacific Highway monitoring sites (e.g. Sandpiper Ecological 2017b, 2018b, 2019) and crossing structure research programs (e.g. Soanes *et al.* 2015). Further, it represents a conservative approach to identification of complete crossings.

Data recorded for each active image included: site, date, time, species, accuracy (definite 90%+ certainty, probable 75-90% certainty, and possible 60-75% certainty), movement direction (east, west, no directional

movement (animal stationary, returned), number of images and image numbers. A hierarchical approach was adopted to species identification that included: species, genus or group. If a species could not be identified or assigned to a group, it was labelled as “unidentified species”.

2.3 Adjacent habitat

2.3.1 Survey design

A total of 18 sites were sampled at the 12 underpasses as part of the adjacent habitat surveys, with one site established on each side of an underpass. Vegetated median underpasses (i.e. Sites 9-10, & 11-12) were considered single sites where sampling occurred on the east and west sides of the highway and not in the median. Survey effort was reduced at Site 3 due to concern about disturbing neighbours. No Spotlighting or arboreal Elliott trapping occurred on the west side at Site 3 and the diurnal active search was restricted to a small (100m x 30m) remnant of vegetation in the road reserve.

2.3.2 Trapping

Trapping methods applied during the survey included: cage traps, ground Elliott traps (Type A), arboreal Elliott traps (Type B), pipe traps, pitfall traps, and hair funnels. Trapping occurred within a 1ha area immediately adjacent to each culvert entrance and was conducted over three nights at each site. A maximum of 10 sites were sampled concurrently and trapping was conducted between 12 and 21 November 2018.

Traps were set in a “X” formation with five ground and five arboreal traps (4 type B Elliott traps and 1 pipe trap) set at 20m intervals on one axis and two cage traps and two hair funnels set at 50m spacing on the other axis. A line of three pitfall traps with drift fence was set at the intersection of both lines (Plate 2). Pitfall traps typically followed the contour and were set near fallen logs and dense ground cover. Trap effort is summarised in Table 2.

Plate 2: Example of a pitfall trap line installed during adjacent habitat surveys.

Arboreal traps and ground Elliott traps were baited with a peanut butter, honey and oats mixture. Arboreal traps were installed 1.8m above ground and attached to a bracket. Honey water was sprayed on the trunk above each arboreal trap, and bait was replaced as required. A plastic bag was placed over the end of each trap to provide cover, and a small amount of leaf litter was placed inside the trap. Elliott and pipe traps were set on the western side of trees to provide shelter from the morning sun. Cage traps were set in a sheltered location and baited with either peanut butter, honey and oats, or sardines. All traps were checked within four hours of sunrise. Cage traps were closed following the morning inspection and re-opened in the late afternoon. Pitfall traps were checked in the morning and again in the late afternoon.

Captured fauna were identified to species or genus, and, where possible, sexed and aged. Fauna were identified with reference to standard field guides (Van Dyck *et al.* 2013; Menkhorst & Knight 2004; Wilson & Swan 2010). Fauna were not marked as the aim of sampling was to determine the range of species present in adjacent habitat.

2.3.3 Diurnal active search

Diurnal active searches were conducted by one to two ecologists and involved a meandering traverse of habitat within 100m of the culvert entrance at each sample site. Surveys involved searching leaf litter, rolling logs, observing reptile habitat (i.e. log piles, rocks, dense leaf litter) and looking for fauna signs such as scats and tracks. Each site was sampled twice during the spring sample period for a minimum of 30 person minutes each sample. Diurnal active searches were conducted between 26 October and 22 November 2018. A total of 1118 person minutes were spent conducting diurnal active searches (Table 2).

2.3.4 Nocturnal active search

Nocturnal surveys were conducted on each side of each underpass on two occasions during the sample period. Surveys were conducted by one or two ecologists for between 30 and 60 person minutes per culvert side (Table 2). Surveys were conducted using hand-held Led Lenser P14 spotlights and involved a meandering traverse of habitat within 200m of the culvert entrance. Fauna were detected by sight and call and identified to species or genus. Surveys were conducted between 8 and 22 November 2018. A total of 1148 person minutes were spent conducting nocturnal active searches (Table 2).

2.3.5 Opportunistic records

Opportunistic observations of fauna near culvert entrances made whilst doing other monitoring activities such as koala and giant barred frog monitoring were recorded. All fauna observed whilst setting up equipment were also recorded.

Table 3: Survey effort for sampling adjacent habitat at 10 underpass sites on the WC2NH upgrade.

Component	Method / culvert side	No Samples	Total effort
Arboreal Elliott traps	5 x traps @ 20m spacing (4 Type B Elliott traps and 1 pipe trap)	3 nights/site	255 trap nights
Ground Elliott traps	5 x Type A Elliott traps @ 20m spacing	3 nights/site	270 trap nights
Cage traps	2 @ 50m spacing	3 nights/site	108 trap nights
Pitfall traps	1 x line of 3 pits with drift fence	3 nights/site	162 trap nights
Hair funnels	2 @ 50m spacing	14 nights/site	504 trap nights
Active diurnal search	30 person minute meandering traverse within 100m of culvert entrance	2 sample/site	1118 person minutes
Active nocturnal search	30 person minute meandering traverse within 200m of culvert entrance	2 samples/site	1148 person minutes

3. Results

3.1 Underpasses

3.1.1 Sand pads

Seven species and 13 fauna groups were recorded during sand pad monitoring (Table 3). Two introduced species, cat and red fox, were confirmed and it is likely that at least some of the *Rattus* spp. tracks are attributable to the introduced black rat (*R. rattus*). Koala was recorded on four occasions at Site 4 (Plate 3) and a possible long-nosed potoroo (*Potorous tridactylus*) was recorded from two track sequences at Site 8. Long-nosed potoroo is listed as vulnerable by the NSW *Biodiversity Conservation Act 2016* and Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. The highest diversity of species/groups was recorded at Site 8 (nine species/groups). Cat was the most frequently recorded species with 42 track sequences, followed by red fox 29, and lace monitor with 26 (Table 3). Rattus spp. and Dasyuridae spp. were each recorded on 15 occasions and Bandicoot spp. on 13 occasions.

Table 4: Species and groups of fauna recorded during sand pad monitoring at 12 underpasses on the WC2NH upgrade. * possible record only.

Species/group	Site and number of track sequences												Total sequences
	1	2	3	4	5	6	7	8	9	10	11	12	
Small Bird	2												2
Medium Bird	1												1
Waterbird	2												2
Lace monitor				10			2	10			2	2	26
Small reptile	2				2							6	10
Medium reptile	1			2				2			2	3	10
Frog								2					2
Short-beaked echidna		10											10
Long-nosed potoroo*								2					2
Swamp wallaby							5						5
Macropodidae spp.	1												1
Dasyuridae spp		5			1	2		6	1				15
Peramelidae spp.		4	2		2			5					13
Koala				4									4
Trichosurus spp.			2										2
Cat			16	4	4	1		6	1	2	4	4	42
Red fox		2	21	2		2		2					29
Rattus spp.		2			11				2				15
Canidae spp.			1										1
Small mammal						1		2		1			4
Total species/group	6	5	5	5	5	4	2	9	3	2	3	4	

3.1.2 Scat and track

Scats, tracks and live specimens of three species, two genera, and six fauna groups were recorded during the scat and track surveys of 12 underpasses (Table 4). Species recorded inside underpasses during the scat and track survey included: two bentwing bats (*Miniopterus* spp) roosting in culvert joints at Site 3 and an eastern water dragon at Site 5. The *Miniopterus* spp. was most likely little bentwing bat (*M. australis*) which is listed as vulnerable by the *Biodiversity Conservation Act 2016*. The eastern water dragon was observed making a complete crossing of Site 5.

Plate 3: Koala tracks recorded on sand pads at Site 4.

Table 5: Species and fauna groups recorded during track and scat surveys of 12 underpasses on the WC2NH upgrade. [I] = introduced species.

Species/Group	Site											
	1	2	3	4	5	6	7	8	9	10	11	12
Macropodidae spp.	X						X					
Peramelidae spp.	X											
Trichosurus spp.							X					
Miniopterus spp.			X									
Microbat spp.					X							
Rodentia spp.	X		X		X				X			
Cat [I]										X		
Fox [I]	X								X	X		
Eastern water dragon	X				X							
Amphibian (large)	X		X									
Bird spp.			X									

3.1.3 Cameras

Species richness

Eighteen species and six fauna groups were recorded during underpass Camera monitoring (Table 5). Koala was the only threatened species recorded, with individuals detected at Sites 4, 7, 9, 11 and 12 (Table 5). Five introduced species were recorded. Cat (*Felis catis*) was recorded at 10 sites, red fox at seven sites, and black rat at five sites (Table 5). The highest fauna diversity was recorded at Sites 2 and 3 with 10 species/groups each, followed by Site 6 (nine species/groups) and Sites 7 and 8 (eight species each). The lowest diversity was recorded at Site 5 (three species), and Site 10 (four species).

Table 6: Species and groups of fauna recorded by infra-red cameras at 12 underpasses on the WC2NH upgrade. C = complete crossing; IC = incomplete crossing; [I] = introduced species.

Species/ Groups	Site and Crossing type																							
	1		2		3		4		5		6		7		8		9		10		11		12	
	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC
Short-beaked echidna	1		13													1								
Peramelidae spp.															1									
Koala							10						2				1				2		2	
Short-eared brushtail possum					1								8		16	4								1
Common brushtail possum					1																			
Trichosurus spp.	1				2										5						1			
Swamp wallaby	2	1	6	1	2	1					1		2		5	1	1							
Red-necked wallaby			1				1						2											
Eastern grey kangaroo					2								3											
Macropodidae spp.	1		2								3		1											
House mouse[I]							1				1													
Black rat [I]			5	5					3		2						1		2	1				
Rodentia spp.											1													
Cat [I]			2		68	1	8				10		4		8		6		3		11	1	12	
Red fox [I]			3		13		7				5				7		2		2					
European Hare [I]					1																			
Small mammal spp.											1							1						
Lace monitor			1				21				3		1		26		5		3		4		4	
Eastern water dragon					3	1			1	1											7		3	
Pacific black duck									2															
Pheasant coucal					1																			
Intermediate egret																						1		
Medium frog spp.	5	1		1																				

Complete and incomplete crossings

A total of 405 fauna detections were recorded in spring 2018 and included 381 complete crossings and 24 incomplete crossings. Total crossings were evenly split between native (52%) and introduced species (48%), and complete crossings were evenly split between the two groups (51% native and 49% introduced; Table 6).

Comparison of complete crossings by native and introduced species at each site highlights substantial differences in occurrence of the two groups. Native species were recorded more frequently at Sites 2, 4, 7 and 8 and introduced species at Sites 3, 6, and 10 (Figure 2). Fragmented habitat and the presence of roads may explain the higher occurrence of introduced species at Sites 3 and 6.

Fauna crossings at the split median underpasses were consistent at Sites 11 and 12 but varied between Sites 9 and 10 (Table 6). Variation at Sites 9 and 10 is most likely due to theft of the Site 9 floor camera in the second half of the spring monitoring period.

Table 7: Number of species and groups of fauna recorded and complete and incomplete crossings recorded at each of 12 underpasses monitored on the WC2NH upgrade.

Site	Diversity			No crossings			
	No. Species/Groups	Native Sp/Gr	Introduced Sp/Gr	Complete		Incomplete	
				Native	Intro	Native	Intro
1	5	5	0	10	0	2	0
2	10	7	3	23	10	2	5
3	10	7	3	12	82	2	1
4	6	3	3	32	16	0	0
5	3	2	1	3	3	1	0
6	9	5	4	9	18	0	0
7	8	7	1	19	4	0	0
8	8	6	2	53	15	6	0
9	7	4	3	7	9	1	0
10	4	1	3	3	7	0	1
11	6	5	1	14	11	1	1
12	5	4	1	9	12	1	0
Total				194	187	16	8

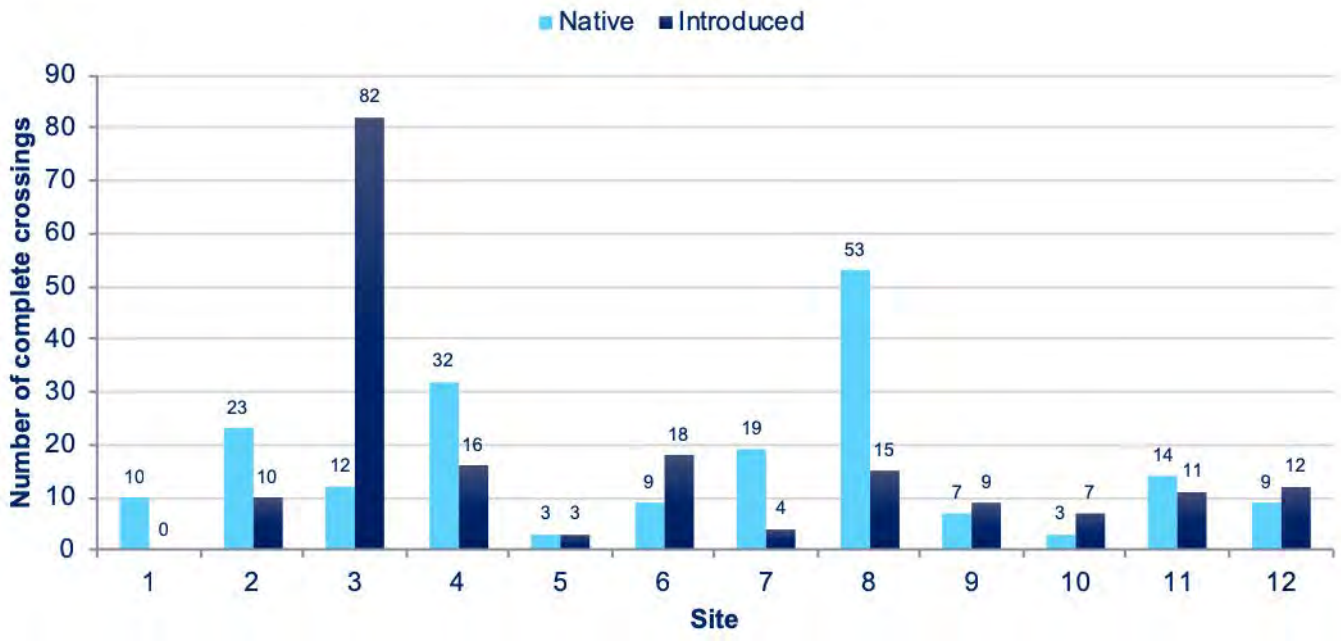


Figure 2: Comparison of the number of complete crossings by native and introduced species recorded at each underpass.

Use of floor and furniture

Fauna were recorded using both the culvert floor and fauna furniture to traverse underpasses (Table 7). Exceptions occurred at Sites 4, 9, and 10 where no fauna were recorded using the furniture. Use of the culvert floor was substantially greater than use of furniture across all sites (Figure 3). Excluding Sites 1 and 5, which did not contain fauna furniture, a total of 345 complete crossings were recorded on the culvert floor and 20 were recorded on the furniture.

No species was detected using the furniture only. As expected, several terrestrial species were recorded using the floor only. Short-eared brushtail possum was recorded using the furniture only at Site 7 and floor and furniture at Site 8 (Table 7). Short-eared brushtail possum, *Trichosurus* spp., water dragon, cat, and black rat were recorded using both the floor and furniture. Medium frog was recorded crossing the camera monitoring zone at Site 1 on five occasions. Due to the proportion of the crossing monitored at Site 1 this is

not considered as evidence of complete crossings. Koalas were recorded on 19 occasions using the floor only (Plate 3).

Plate 4: Koala recorded at Site 12, moving east on 22 October (left) and west of 23 October (right).

Table 8: Number of complete crossings made by each species/group at each of 12 underpasses monitored on the WC2NH upgrade. NB – Sites 1 and 5 did not contain fauna furniture. [I] = introduced species, Fl = Floor, Fu = furniture.

Species/group	Site and number of complete crossings																					
	1	2		3		4		5	6		7		8		9		10		11		12	
	Fl	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fu
Short-beaked echidna	1	13																				
Peramelidae spp.													1									
Koala						10					2				1				2		2	
Short-eared brushtail possum				1								8	14	4								
Common brushtail possum				1																		
Trichosurus spp.	1			2									3	2					1			
Swamp wallaby	2	6							1		2		5		1							
Red-necked wallaby		1		2		1					2											
Eastern grey kangaroo				1							3											
Macropodidae spp.	1	2							2		1											
House mouse [I]						1			1													
Black rat [I]		2	3					3	1	1					1		2					
Rodentia spp.									1													
Cat [I]		2		68		8			10		4		8		6		3		11		11	1
Red fox [I]		3		13		7			5				7		2		2					
European Hare [I]				1																		
Lace monitor		1				21			3		1		26		5		3		4		4	
Eastern water dragon				3															6	1	3	
Pacific black duck								2														
Pheasant coucal				2																		
Intermediate egret																						
Medium frog spp.	5																					

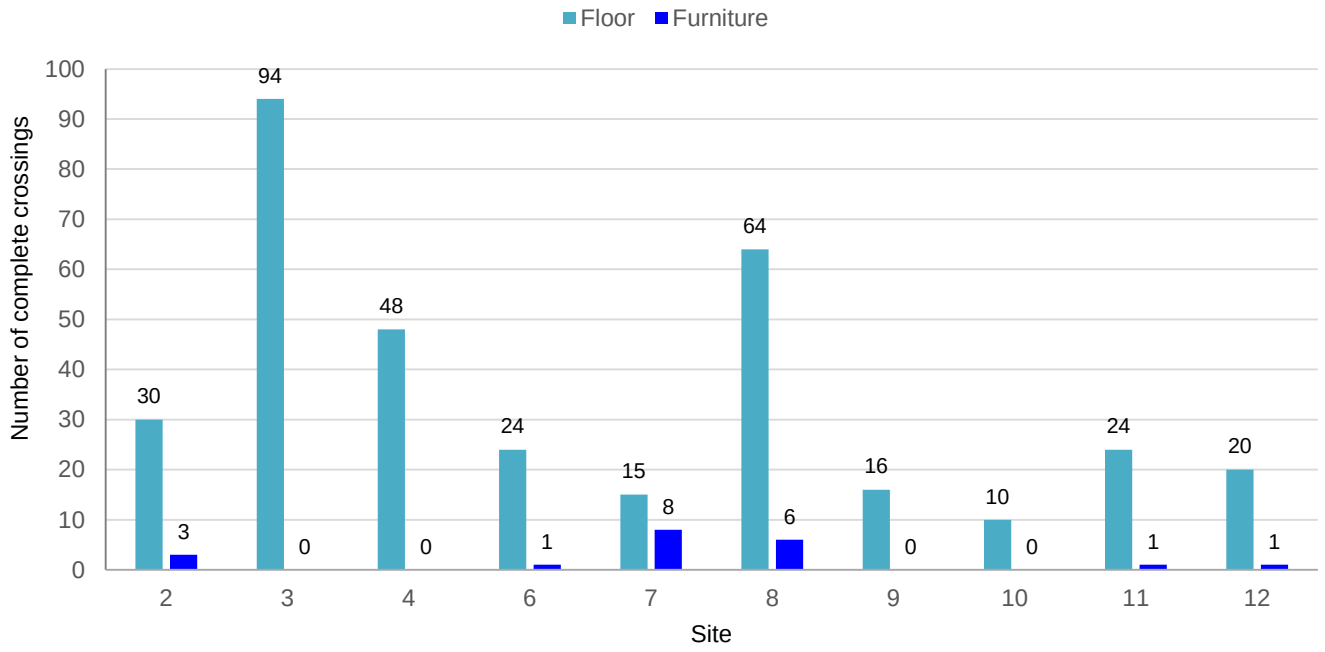


Figure 3: Complete crossings by all species on underpass floor and fauna furniture.

3.2 Adjacent habitat

Forty species were recorded in habitat adjoining underpasses (Table 8). A further six species were identified to the level of Genera only. Most of these are likely to belong to one of the identified species. For example *Petaurus* spp. was most likely a sugar glider. Some records during active search and spotlighting were assigned to three families, Macropodidae (wallaby/kangaroo), Peramelidae (bandicoots), and Chelidae (freshwater turtles). Three threatened species were recorded in adjacent habitat. Yellow-bellied glider (*Petaurus australis*) was recorded on the west side of the alignment at Site 8, giant barred frog (*Mixophyes iteratus*) was recorded on the west side of the alignment at Site 1, and little eagle (*Hieraaetus morphnoides*) was recorded soaring above the alignment at Sites 11 and 12.

The majority of species/groups (38 in total) were detected by diurnal and nocturnal active searches (Table 8). No fauna were captured in pipe traps and only one species (short-eared brushtail possum) was captured in an arboreal Elliott trap. Six species, four reptiles and two frogs, were captured in pitfall traps and four species were captured in ground Elliott traps. A total of 54 individuals were captured in all trap types, 12 individuals in cage traps, 15 in ground Elliott traps, 26 in pitfall traps and one in an arboreal Elliott trap (Appendix B). The introduced black rat was the most commonly captured species (14 individuals), followed by garden skink (*Lampropholis delicata*; 9 individuals); *Calyptotis ruficauda* (7 individuals), fawn-footed Melomys (*Melomys cervinipes*; 5 individuals; Plate 4), grass skink (*L. guichenoti*; 4 individuals), and brown antechinus (*Antechinus stuartii*; 3 individuals; Plate 4).

Table 9: Species of vertebrate recorded during surveys of habitat adjoining each side of all underpasses. [V] = vulnerable species; [E] = Endangered species; [I] = Introduced species.

Species	Active Search	Spotlight	Ground Elliott trap	Arboreal Elliott trap	Pitfall trap	Pipe trap	Cage trap	Hair funnel
Mammals								
Swamp wallaby		*						
Macropodidae spp.	*	*						
Northern brown bandicoot							*	*
Peramelidae spp.	*							
Short-beaked echidna	*							
Fawn-footed melomys			*					
Melomys spp.			*					
Short-eared brushtail possum		*		*			*	
Trichosurus spp.								*
Common ringtail possum								*
Bush rat			*				*	*
Rattus spp.								*
Brown antechinus			*					
Sugar glider		*						
Yellow-bellied glider [V]		*						
Petaurus spp.		*						
Black rat [I]			*				*	*
Red fox [I]	*							
Reptiles								
Egernia mcpheii	*							
Lampropholis delicata	*				*			
Lampropholis guitchinoti					*			
Lampropholis spp.	*							
Calyptotis ruficauda	*				*			
Eastern water-skink	*							
Red-bellied black snake	*							
Yellow-faced whipsnake	*							
Black-bellied swamp snake	*							
Blackish blind snake					*			
Coastal carpet python	*							
Burton's legless lizard	*							
Eastern water dragon	*	*						
Lace monitor	*							
Chelidae spp. (Freshwater turtle)	*							
Birds								
Tawny frogmouth		*						
Owlet-nightjar		*						
Little eagle [V]	*							
Frogs								
Litoria fallax	*	*						
Litoria tyleri		*						
Litoria chloris		*						
Litoria tyleri (tadpoles)	*							
Litoria peronii (tadpoles)	*							
Uperolia fusca		*						
Adelotus brevis	*	*						
Crinia signifera		*						
Mixophyes fasciolatus		*						
Mixophyes iteratus [E]		*						
Limnodynastes peronii		*			*			
Pseudophryne coriacea		*			*			
Uperolia spp.		*						
Total N[o.] Species/groups	22	20	5	1	6	0	4	6

Plate 5: *Melomys* spp. (left) and brown antechinus (right) captured in adjacent habitat during spring 2018 monitoring.

3.3 Species recorded in underpasses and adjacent habitat

A total of 46 species, including five introduced species, five Genera, four Families and nine fauna groups were identified by the various survey methods during spring 2018 monitoring of underpasses and adjacent habitat were identified by the various survey methods. Several of the Genera, Families and Groups would be include species that were also recorded. For example, *Trichosurus* spp. would be either short-eared or common brushtail possum, *Rattus* spp. would most likely be bush rat or black rat, small and medium reptiles could be one of the several species of skink and lizard recorded, and small mammal and Dasyuridae spp. would most likely be one of the *Rattus* species or brown antechinus.

The use of various sample methods each with different degrees of accuracy in identifying fauna to species level has contributed to the large number of Families and groups recorded. Methods such as sand pads only allow identification to the group level for some fauna and contribute substantially to the inclusion of broad groups such as small or medium reptile. The inclusion of broad groups makes it difficult to be definitive in determining how many species from adjacent habitat have used underpasses. In addition, infra-red cameras often miss small reptiles and frogs meaning these groups are under represented in underpass monitoring results. It is highly likely that several of the fauna groups recorded in underpasses (particularly during sand pad surveys) include species that were recorded in adjacent habitats.

Eight species, one genera (*Trichosurus* spp.), and three Families (Macropodidae spp., Peramelidae spp., & Rodentia spp) were recorded in both adjacent habitat and underpasses. Excluding gliders, 23% of species/groups recorded in adjacent habitat were recorded in underpasses. For the reasons noted above this represents a substantial underestimate of the actual proportion of species present that are likely to be using underpasses. Notwithstanding, some species were recorded using the underpasses but not detected in adjacent habitat. These species include red-necked wallaby (*Macropus rufogriseus*), eastern grey kangaroo (*M. giganteus*), common brushtail possum (*T. vulpecula*), and possibly, long-nosed potoroo.

Table 10: Species and fauna groups recorded using underpasses by all methods and those recorded in adjacent habitat. Shading denotes a species or group not confirmed in both areas that is likely to be represented in another species/group that was recorded in both areas, for example northern brown bandicoot is likely represented by Peramelidae spp.

Species	Recorded in underpass	Recorded in adjacent habitat
Mammals		
Short-beaked echidna	*	*
Brown antechinus		*
Northern brown bandicoot		*
Peramelidae spp.	*	*
Koala[V]	*	*[t]
Short-eared brushtail possum	*	*
Common brushtail possum	*	
Trichosurus spp.	*	*
Common ringtail possum		*
Sugar glider		*
Yellow-bellied glider		*
Petaurus spp		*
Swamp wallaby	*	*
Red-necked wallaby	*	
Eastern grey kangaroo	*	
Macropodidae spp.	*	*
Miniopterus spp.	*	
Fawn-footed melomys		*
Melomys spp.		*
Bush rat		*
Rodentia spp.	*	*
Long-nosed potoroo[V]	*	
Small mammal spp.	*	
Dasyuridae spp.	*	
Reptiles		
Chelidae spp.		*
Calyptotis ruficauda		*
Egernia mcpheii		*
Eastern water skink		*
Lampropholis delicata		*
Lampropholis guichenoti		*
Lampropholis spp.		*
Scincidae spp.		*
Burton's legless lizard		*
Lace monitor	*	*
Eastern water dragon	*	*
Red-bellied black snake		*
Yellow-faced whipsnake		*
Black-bellied swamp snake		*
Blackish blind snake		*
Coastal carpet python		*
Medium reptile spp.	*	
Small reptile spp.	*	
Birds		
Pacific black duck	*	
Pheasant coucal	*	
Intermediate egret	*	
Water bird spp.	*	
Medium bird spp.	*	
Small bird spp.	*	

Species	Recorded in underpass	Recorded in adjacent habitat
Frogs		
Litoria fallax		*
Litoria tyleri		*
Litoria chloris		*
Uperolia fusca		*
Adelotus brevis		*
Crinia signifera		*
Mixophyes fasciolatus		*
Mixophyes iteratus[V]		*
Limnodynastes peronii		*
Pseudophryne coriacea		*
Uperolia spp.		*
Medium frog spp.	*	
Frog spp.	*	
Introduced		
Cat	*	
Red fox	*	*
Black rat	*	*
European Hare	*	
House mouse	*	

4. Key findings

1. Survey methods used to monitor fauna use of underpasses were suitable for obtaining an indication of the frequency of fauna movement and the range of species using underpasses and the range of species occurring in adjacent habitat.
2. Inclusion of motion-activated cameras in adjacent habitat monitoring would compliment existing methods.
3. Motion activated cameras, sand pads, and scat and track searches, used in underpasses, are deficient in detecting use by small reptiles and frogs. Whilst sand pads and scat and track surveys confirmed the presence of both groups it is exceedingly difficult to determine which species were using the underpasses.
4. The duration of camera monitoring was compromised by a high incidence of false triggers at some sites, and the theft of one camera. False triggers are attributed to ongoing construction work at some sites, regular movement through underpasses by ecologists completing other activities, and detection of traffic on the adjacent carriageway. Detection of traffic was an issue for furniture cameras at the vegetated median underpasses.
5. In total, 18 species (including 5 introduced species), one genera, four families and eight fauna groups were identified using underpasses. There is likely overlap in species between fauna groups, families and species and the totals presented should not be interpreted as individual species. Mammals, reptiles, frogs and birds were all recorded using underpasses.
6. Fauna were recorded using both the culvert floor and fauna furniture. Use of the floor was substantially higher than furniture, although data need to be analysed using crossings/unit of time as opposed to raw counts to determine the scale of difference between the two surfaces.
7. A total of 405 fauna detections were recorded by underpass cameras, of which 94% were classed as complete crossings.

8. Identification of species is difficult from tracks in sand pads and there is some doubt regarding small the Dasyuridae spp. as no dasyurids were recorded on cameras.
9. Koalas were recorded using five underpasses on 17 occasions, with the highest use recorded at Site 4. Evidence suggests that koalas have been using underpasses to move east and west across the alignment.
10. Two tracks in sand pads at Site 7 were identified as possible long-nosed potoroo. Further evidence of potoroos is required before their presence is confirmed.
11. Monitoring the large bridge underpass at Site 1 (Upper Warrell Creek) for giant barred frog is difficult due to the large area available for movement. In spring 2018 camera sampling was focused on the small areas of landscape planting around the creek bank.
12. Five introduced species were recorded using underpasses. Cats were the most frequently recorded species (10 sites, 134 crossings) followed by foxes (7 sites, 39 crossings). The higher incidence of cats than foxes may be associated with the contiguous nature of forest adjoining most sites. The occurrence of both species peaked at Site 3, which is situated in a more fragmented agricultural landscape with nearby residents. Black rats were recorded at five sites on 19 occasions.
13. Forty species and six genera were identified in habitat adjoining underpasses, of which, 18% were confirmed using underpasses. This figure does not include the fauna groups identified during sand pad monitoring (i.e. small and medium reptiles, small frog etc) and the actual proportion is likely to be higher.

5. Recommendations

1. Fauna furniture cameras at the vegetated median underpasses should be oriented outwards i.e. towards the forest as opposed to the standard east orientation.
2. Video duration should be reduced from 10s to 5s with no delay between activation. Based on the spring monitoring a 5s video sequence will be sufficient to identify fauna and confirm movement direction.
3. The adjacent habitat trapping and underpass sand pad survey should be completed immediately prior to commencement of underpass camera monitoring.
4. Inclusion of infrared cameras as part of adjacent habitat monitoring should be considered.
5. Management to control feral predator use of underpasses should be evaluated following the winter 2019 sample period.
6. Using time-lapse photography in underpasses should be considered to confirm use by small reptiles, frogs and small mammals.

6. References

Menkhorst, P. & Knight, F. (2004). *A field guide to the mammals of Australia*. Oxford University press, Melbourne.

Pizzey, G. & Knight, F. (2007). *The field guide to the birds of Australia*. Harper Collins, Sydney.

RMS (2018). *Warrell Creek to Nambucca Heads Operational Ecological and Water Quality Monitoring Brief*. NSW Government.

Sandpiper Ecological (2017a). Pacific Highway Upgrade – Sapphire to Woolgoolga: operational phase fauna monitoring year 2 – Greys Dam Frog Pipes. Report prepared for Roads and Maritime Services.

Sandpiper Ecological (2017b). Pacific Highway Upgrade – Glenugie: operational phase fauna crossing monitoring program (years 1-3). Report prepared for NSW Roads and Maritime Services.

Sandpiper Ecological (2018a). Pacific Highway Upgrade – Sapphire to Woolgoolga: operational phase fauna monitoring year 3 – Greys Dam Frog Pipes. Report prepared for Roads and Maritime Services.

Sandpiper Ecological (2018b). Sapphire to Woolgoolga pacific Highway Upgrade: operational phase fauna crossing monitoring program years 1-3. Report prepared for NSW Roads and Maritime Services.

Sandpiper Ecological (2019). Nambucca Heads to Urunga Pacific Highway Upgrade: operational phase monitoring year one. Report prepared for NSW Roads and Maritime Services.

Soanes. K., Vesk, P. A. and van der Ree, R. (2015). Monitoring the use of road-crossing structures by arboreal marsupials: insights gained from motion-triggered cameras and passive integrated transponder (PIT) tags. *Wildlife Research:* 10.107.

Wilson, S. & Swan, G. (2010). A complete guide to reptiles of Australia. New Holland, Sydney.

Van Dyck, S., Gynther, I. & Baker, A. (2013). *Field companion to the mammals of Australia*. New Holland, Sydney.

Appendix A – Species list

Table A1: Common and scientific names for all species recorded during spring 2018 monitoring event at WC2NH. ^ = Threatened species.

Common Name	Scientific Name
Koala^	*Phascolarctos cinereus*
Swamp wallaby	*Wallabia bicolor*
Red-necked wallaby	*Macropus rufogriseus*
Wallaby spp.	
Eastern grey kangaroo	*Macropus giganteus*
	Macropod spp.
Short-beaked echidna	*Tachyglossus aculeatus*
Short-eared brushtail possum	*Trichosurus caninus*
Common brushtail possum	*Trichosurus vulpecula*
Brushtail possum spp.	*Trichosurus spp.*
Common ringtail possum	*Pseudocheirus peregrinus*
Northern brown bandicoot	*Isoodon macrourus*
Bandicoot spp.	
Fawn-footed melomys	*Melomys cervinipes*
	Melomys spp.
Bush rat	*Rattus fuscipes*
Rodent spp.	*Muridae spp.*
Brown antechinus	*Antechinus stuartii*
Long-nosed potoroo^	*Potorous tridactylus*
Small mammal spp.	
	Dasyuridae spp.
McPhee's skink	*Egernia mcpheii*
Rainbow skink	*Lampropholis delicata*
Common garden skink	*Lampropholis guichenoti*
Red-tailed calyptotis	*Calyptotis ruficauda*
Eastern water-skink	*Eulamprus quoyii*
Red-bellied black snake	*Pseudechis porphyriacus*
Yellow-faced whipsnake	*Demansia psammophis*
Black-bellied swamp snake	*Hemiaspis signata*
Blackish blind snake	*Anilios nigrescens*
Coastal carpet python	*Morelia spilota*
Burton's legless lizard	*Lialis burtonis*
Lace monitor	*Varanus varius*
Eastern water dragon	*Intellagama lesueurii*
Medium reptile spp.	
Small reptile spp.	
Pacific black duck	*Anas superciliosa*
Pheasant coucal	*Centropus phasianinus*
Intermediate egret	*Ardea intermedia*

Common Name	Scientific Name
Tawny frogmouth	*Podargus strigoides*
Owlet-nightjar	*Aegotheles*
Little eagle^	*Hieraaetus morphnoides*
Water bird spp.	
Medium bird spp.	
Small bird spp.	
Eastern dwarf tree frog	*Litoria fallax*
Tyler's tree frog	*Litoria tyleri*
Red-eyed tree frog	*Litoria chloris*
Dusky toadlet	*Uperolia fusca*
Tusked frog	*Adelotus brevis*
Common eastern froglet	*Crinia signifera*
Great barred frog	*Mixophyes fasciolatus*
Giant barred frog^	*Mixophyes iteratus*
Striped marsh frog	*Limnodynastes peronii*
Red-backed toadlet	*Pseudophryne coriacea*
Cat	*Felis catus*
Red fox	*Vulpes vulpes*
Black rat	*Rattus rattus*
European hare	*Lepus europaeus*
House mouse	*Mus musculus*

Appendix B – Field Data

Table B1: Weather during and immediately prior to the spring / summer 2018 giant barred frog survey.

Date	MAXIMUM Wind Speed km/h	AVERAGE Wind Direction DESCRIPTION	AVERAGE Relative Humidity %	MAXIMUM Air Temperature DegC	MINIMUM Air Temperature DegC	TOTAL Rain Gauge mm
20/10/18	32.4	ESE	82.9	25.4	14.5	0.2
21/10/18	36	ESE	85.6	25.9	17.6	8.4
22/10/18	13.4	SW	90.1	24.9	17	0.2
23/10/18	18.5	SSW	87.9	25.8	14.9	0.2
24/10/18	25.3	S	85.7	26.1	16.1	0
25/10/18	16.9	SSW	80.7	27.5	17.4	0
26/10/18	13.6	S	82.2	24.2	15.1	0
27/10/18	20.5	SSW	80.5	28.2	16.6	0
28/10/18	19.9	SSE	81.6	25.4	14.4	0
29/10/18	16.4	SW	79.9	22.2	15.6	0
30/10/18	12.8	SSW	77.7	22.2	15.3	0
31/10/18	28.5	SSE	83.2	24.7	13.7	0
1/11/18	18.5	S	80.5	30.5	14.1	0
2/11/18	23	SSE	80.1	27.5	12.4	0
3/11/18	33.4	ESE	72.5	29.7	18.8	0
4/11/18	22.8	SSE	73.4	33.6	19.6	0
5/11/18	14.4	S	82.6	30	17.3	0
6/11/18	16.6	SSE	88.2	28.6	19.1	0
7/11/18	20.9	ESE	84.9	30.4	22.9	0.2
8/11/18	24	SSE	89.8	30.2	14.9	21
9/11/18	20.4	SW	76.8	23	10.7	0
10/11/18	17.4	S	74.2	22.9	13.5	0
11/11/18	32.1	S	79.3	25.4	12.8	0
12/11/18	20.5	SW	81	25.7	12.8	0
13/11/18	18.5	SSW	79.8	25	12.5	0
14/11/18	25	SE	81.5	25.1	13.3	0
15/11/18	25.9	SSE	82.8	27.1	18.5	0
16/11/18	21.2	SSE	83	28.4	19.1	0
17/11/18	15.4	SSW	83.6	26.1	18.1	0
18/11/18	24	SSW	87.8	26.3	16.6	14.2
19/11/18	16	SW	93	23	15.7	15
20/11/18	17.4	SSW	78.3	23.7	14.6	0.2
21/11/18	30.2	ESE	77.9	27	17.6	0
22/11/18	16	SSE	89.9	30.3	19.5	6
23/11/18	33.1	SW	58.9	31.7	9.4	0
24/11/18	31.1	WSW	44.6	28.1	10.3	0
25/11/18	20.5	SW	68	28.8	10.9	0
26/11/18	21.9	SSW	66.2	30.4	13.9	0
27/11/18	18.7	SSW	73	26.2	14.3	0
28/11/18	28.5	SE	83.3	27.1	17.8	0
29/11/18	33.5	SSW	69.2	28.7	18.3	9.6
30/11/18	17	SW	69.4	28.6	13.4	0
1/12/18	20.2	S	80.6	27.1	14.1	0

2/12/18	20.2	SSW	77.8	31.8	12.5	0
3/12/18	24.1	SSE	70.8	33.9	17.8	0
4/12/18	19.9	SSE	78.1	27.9	14.4	0
5/12/18	19.5	S	76.3	28.8	18.3	9.6
6/12/18	17.7	SSW	82	25.9	17	1.2
7/12/18	22.4	S	74.9	25.8	15.4	0.2
8/12/18	24	SSE	75.6	25.8	14.9	0
9/12/18	33.7	ESE	78.1	26.9	13.5	0
10/12/18	30.1	SE	80.9	27.4	14.7	0
11/12/18	26.2	SE	84.4	29.3	17.7	0
12/12/18	13.7	SSW	92.1	28.2	19.2	6.8
13/12/18	13	SE	89.9	26.2	18.1	0.8
14/12/18	29.3	ENE	88.4	28.5	19.8	14.8
15/12/18	38.2	NE	86.3	29	22.2	0
16/12/18	50	NE	88	28.8	22.2	0
17/12/18	27.1	ESE	97.2	25	17.5	101.6
18/12/18	40.5	ESE	89.8	27.7	18.1	0
19/12/18	28.2	ESE	72.8	28.7	21	0
20/12/18	23.1	SE	79.2	29.6	20.1	12.8

Table B2: Underpass camera survey effort.

Location	Cam Location	Easting	Northing	Date installed	Date checked	Pics	Last pic date	Days Active	Date removed	Pics	Days Active	Total Days Active	Comment
12	Furniture	497115	6610068	17/10/18	22/11/18	383	1/11/18	16	17/12/18	38	29	45	
	Ground	497115	6610068	16/10/18	22/11/18	326	22/11/18	38	17/12/18	73	29	67	
11	Furniture	497168	6610040	17/10/18	22/11/18	286	22/11/18	37	17/12/18	300	27	64	All false triggers, need to reconfigure/change settings.
	Ground	497168	6610040	17/10/18	22/11/18	397	22/11/18	37	17/12/18	47	29	66	
10	Furniture	496622	6609409	17/10/18	22/11/18	317	22/11/18	37	17/12/18	Stolen		37	Stolen
	Ground	496622	6609409	17/10/18	22/11/18	543	5/11/18	20	17/12/18	75	23	43	Destroyed 14/12/18 - cam retrieved
9	Furniture	496622	6609409	17/10/18	22/11/18	169	22/11/18	37	17/12/18	37	23	60	Destroyed 14/12/18 cam retrieved
	Ground	496622	6609409	17/10/18	22/11/18	412	22/11/18	37	17/12/18	47	23	60	Destroyed 14/12/18 cam retrieved
8	Furniture	496506	6609219	17/10/18	22/11/18	110	22/11/18	37	17/12/18	19	26	63	
	Ground	496506	6609219	17/10/18	22/11/18	202	22/11/18	37	17/12/18	85	26	63	
7	Furniture	496438	6608780	17/10/18	22/11/18	154	30/10/18	14	17/12/18	14	26	40	
	Ground	496438	6608780	17/10/18	22/11/18	158	22/11/18	37	17/12/18	30	26	63	
6	Furniture	496188	6608319	17/10/18	21/11/18	10	21/11/18	36	17/12/18	13	27	63	
	Ground	496188	6608319	17/10/18	21/11/18	138	21/11/18	36	17/12/18	50	27	63	
5	North	496171	6608286	22/10/18	21/11/18	184	21/11/18	31	17/12/18	64	27	58	
	South	496168	6608282	22/10/18	21/11/18	128	21/11/18	31	17/12/18	75	27	58	
4	Furniture	495702	6607693	17/10/18	22/11/18	60	22/11/18	37	17/12/18	18	26	63	
	Ground	495702	6607693	17/10/18	22/11/18	175	22/11/18	37	17/12/18	106	26	63	
3	Furniture	495082	6606515	17/10/18	21/11/18	186	2/11/18	17	17/12/18	317	12	29	Mostly W. swallows and false triggers
	Ground	495082	6606515	17/10/18	21/11/18	258	21/11/18	36	17/12/18	60	12	48	
2	Furniture	494477	6605329	18/10/18	21/11/18	718	21/11/18	35	17/12/18	676	31	66	All false triggers, need to reconfigure
	Ground	494477	6605329	18/10/18	21/11/18	185	5/11/18	19	17/12/18	66	6	25	
1	North	489300	6594286	30/10/18	22/11/18	13799	22/11/18	24	17/12/18	15000	39	63	
	South	489262	6594252	24/10/18	22/11/18	17400	22/11/18	30	17/12/18	15000	39	69	

Table B3: All species detected in fauna underpasses by infrared camera. ^ = Threatened species, D = Definite, Pr = Probable, Po = Possible.

Site	Side	Date	Time	Species	Accuracy	Movement	Pic/vid No.	Complete or incomplete	Comments
12	**Furniture**	13/12/18	2213	Cat	D	E	36	Complete	
	Ground	17/10/2018	0105	Cat	D	W	38-40	Complete	
		17/10/2018	2332	Cat	D	W	50	Complete	
		22/10/2018	0147	Koala^	D	E	54	Complete	
		23/10/2018	0337	Koala^	D	W	77	Complete	
		28/10/2018	0020	Cat	D	W	145	Complete	
		31/10/2018	2237	Cat	D	E	199	Complete	
		5/11/2018	0840	Lace monitor	D	East	14	Complete	
		5/11/2018	1124	Water dragon	D	West	15	Complete	
		5/11/2018	2305	Cat	D	East	16	Complete	
		8/11/2018	1359	Water dragon	D	East	46	Complete	
		9/11/2018	2305	Cat	D	East	53	Complete	
		13/11/2018	1138	Water dragon	D	East	82	Complete	
		17/11/2018	1431	Lace monitor	D	East	102	Complete	
		19/11/2018	2307	Cat	D	West	103	Complete	
		20/11/2018	1855	Cat	D	West	104	Complete	
		1/12/2018	2005	SEBtP	D	NDM	33-42	Incomplete	Back and forth then climbs railing (prob)
		2/12/2018	1944	Cat	D	E	43	Complete	
		3/12/2018	1110	Lace Monitor	D	E	44	Complete	
		7/12/2018	1954	Cat	D	E	51	Complete	
		11/12/2018	1056	Lace Monitor	D	W	52, 53	Complete	
		13/12/2018	1955	Cat	D	W	54	Complete	
11	**Furniture**	3/11/2018	1400	Water dragon	D	East	172	Complete	
	Ground	22/10/2018	146	Koala^	D	East	26-34,36-42	Complete	
		23/10/2018	332	Koala^	D	West	49	Complete	
		28/10/2018	0015	Cat	D	W	214	Complete	
		31/10/2018	2243	Cat	D	E	259	Complete	
		3/11/2018	1042	Water dragon	Pr	East	215	Complete	
		5/11/2018	0121	Cat	D	West	219	Complete	
		5/11/2018	0832	Lace Monitor	D	East	225	Complete	
		5/11/2018	1459	Water dragon	D	West	226	Complete	
		5/11/2018	1518	Water dragon	D	East	227	Complete	
		8/11/2018	0804	Intermediate Egret	D	EXM	248-259	Incomplete	
		9/11/2018	2305	Cat	D	East	264	Complete	
		17/11/2018	1421	Lace Monitor	D	East	302	Complete	
		17/11/2018	2153	Cat	D	West	303	Complete	
		18/11/2018	2051	Cat	D	West	304	Complete	
		19/11/2018	2312	Cat	D	W-E	305-306	Incomplete	
		20/11/2018	1904	Cat	D	West	307	Complete	
		21/11/2018	0851	Water dragon	D	West	308	Complete	
		27/11/2018	2337	BtPoss spp.	D	E	227	Complete	

Site	Side	Date	Time	Species	Accuracy	Movement	Pic/vid No.	Complete or incomplete	Comments
		2/12/2018	0232	Cat	D	W	229	Complete	
		2/12/2018	1949	Cat	D	E	230	Complete	
		3/12/2018	1109	Lace Monitor	D	E	231	Complete	
		7/12/2018	1951	Cat	D	E	236	Complete	
		10/12/2018	1417	EW Dragon	D	W	237	Complete	
		11/12/2018	1103	Lace Monitor	D	W	238, 239	Complete	
		13/12/2018	1008	EW Dragon	D	E	240	Complete	
		17/12/2018	0054	Cat	D	W	243	Complete	
10	**Furniture**	27/11/2018	1945	Microbat spp.	D	NDM	8	Incomplete	Roosting in FF joins. Not recorded hereafter.
	Ground	19/10/2018	0259	Cat	D	E	11	Complete	
			0150	Fox	D	W	12	Complete	
		28/11/2018	0858	Lace Monitor	D	E	9	Complete	
		28/11/2018	2132	Black Rat	D	E	10	Complete	
		2/12/2018	2004	Black Rat	D	W	11, 12, 13	Complete	
		2/12/2018	2119	Cat	D	W	14	Complete	
		3/12/2018	1153	Lace Monitor	D	W	15	Complete	
		3/12/2018	1926	Black Rat	D	EthenW	16, 17	Incomplete	
		4/12/2018	0241	Cat	D	W	18	Complete	
		7/12/2018	0006	Fox	D	E	30	Complete	
		13/12/2018	1311	Lace Monitor	D	E	34	Complete	
				Human x 2 tagging					
9	**Furniture**	5/11/2018	0034	Small mammal	Pr	NDM	111	Incomplete	Only eyeshine visible
				Cam stolen					
	Ground	19/10/2018	0303	Cat	D	east	39	Complete	
		21/10/2018	0030	Cat	D	east	40	Complete	
		21/10/2018	0152	Fox	D	W	41-42	Complete	
		7/11/2018	0247	Cat	D	W	309	Complete	
		20/11/2018	1248	Lace monitor	D	W	403	Complete	
		21/11/2018	0259	Koala^	D	W	404	Complete	
		22/11/2018	0258	Cat	D	W	409	Complete	
		26/11/2018	0356	Swamp Wallaby	D	W	236, 237	Complete	
		28/11/2018	2142	Black Rat	D	E	238	Complete	
		2/12/2018	0923	Lace Monitor	D	E	239	Complete	
		2/12/2018	2118	Cat	D	W	241	Complete	
		3/12/2018	1152	Lace Monitor	D	W	243	Complete	
		4/12/2018	0242	Cat	D	W	244	Complete	
		7/12/2018	0009	Fox	D	E	250	Complete	
		13/12/2018	1318	Lace Monitor	D	E	252	Complete	
		14/12/2018	1404	Lace Monitor	D	E	253	Complete	
				Human x 2					

Site	Side	Date	Time	Species	Accuracy	Movement	Pic/vid No.	Complete or incomplete	Comments
				tagging					
8	**Furniture**	31/10/2018	2250	SEBtP	D	E	34	Complete	
		7/10/2018	0233	SEBtP	D	E	65	Complete	
		10/11/2018	2339	SEBtP	D	E	72	Complete	
		12/11/2018	2138	SEBtP	D	E	88	Complete	
		29/11/2018	0026	BtPoss spp.	D	E	7	Complete	
		2/12/2018	0222	BtPoss spp.	D	E	9	Complete	
		9/12/2018	2109	Microbat spp.	D	NDM	13	Incomplete	Roosting in FF joins?
	Ground	17/10/2018	2303	Fox	D	E	12	Complete	
		19/10/2018	2135	SEBtP	D	E	13	Complete	
		21/10/2018	0140	Fox	D	E	14	Complete	
		22/10/2018	1418	Lace monitor	D	W	17	Complete	
		26/10/2018	1058	Lace monitor	D	W	22	Complete	
		27/10/2018	1119	Lace monitor	D	E	23	Complete	
		29/10/2018	2137	Cat	D	E	27	Complete	
		30/10/2018	2328	Bandicoot spp	Pr	E	50	Complete	
		31/10/2018	2004	Echidna	D	E	63-65	Incomplete	
		1/11/2018	1922	Cat	D	E	83	Complete	
		2/11/2018	1826	Cat	D	E	94	Complete	
		6/11/2018	2343	Cat	D	W	131	Complete	
		7/11/2018	0238	Cat	D	E	132	Complete	
		10/11/2018	0012	Swamp wallaby	Pr	E	149	Complete	
		10/11/2018	0944	Lace Monitor	D	W	150	Complete	
		11/11/2018	0847	Swamp wallaby	D	W	151-152	Complete	
		11/11/2018	1645	Swamp wallaby	Pr	E	153	Complete	
		12/11/2018	0921	Lace Monitor	D	W	155	Complete	
		17/11/2018	0007	Fox	D	E	187-189	Complete	
		18/11/2018	2328	Fox	D	E	190	Complete	
		20/11/2018	0824	Lace Monitor	D	W	192	Complete	
		20/11/2018	2036	SEBtP x 2	D	W	193	Complete	Mother with back young
		20/11/2018	2107	SEBtP x 2	D	E-W	194-195	Incomplete	
		20/11/2018	2137	SEBtP x 2	D	E	196	Complete	
		23/11/2018	2202	SEBtPx2	Pr	W	14	Complete	
		23/11/2018	2339	SEBtPx2	D	E	15	Complete	
		24/11/2018	2112	BtPoss spp.	Pr	W	20	Complete	
		26/11/2018	1216	Lace Monitor	D	W	21	Complete	
		26/11/2018	1602	Lace Monitor	D	E	22	Complete	
		28/11/2018	2142	SEBtPx2	D	E	24	Complete	
		29/11/2018	0751	Lace Monitor	D	W	26	Complete	
		30/11/2018	0829	Lace Monitor	D	W	27	Complete	
		30/11/2018	2136	Cat	D	W	28	Complete	

Site	Side	Date	Time	Species	Accuracy	Movement	Pic/vid No.	Complete or incomplete	Comments
		1/12/2018	0226	Fox	D	E	29	Complete	
		2/12/2018	1031	Lace Monitor	D	E	31	Complete	
		2/12/2018	1455	Lace Monitor	D	E	32	Complete	
		2/12/2018	2129	BtPoss spp.x2	D	W	33	Complete	
		2/12/2018	2314	Cat	D	E	34	Complete	
		2/12/2018	2339	SEBtPx2	D	E	35	Complete	
		4/12/2018	1326	Lace Monitor	D	W	36	Complete	
		6/12/2018	0021	Fox	D	W	37	Complete	
		7/12/2018	1131	Lace Monitor	D	W	39	Complete	
		7/12/2018	1345	Lace Monitor	D	E	40	Complete	
		8/12/2018	2352	Cat	D	W	41	Complete	
		9/12/2018	1129	Lace Monitor	D	W	42	Complete	
		9/12/2018	1438	Lace Monitor	D	W	43	Complete	
		9/12/2018	1949	Swamp Wallaby	Pr	E	44	Complete	
		9/12/2018	1954	Swamp Wallaby	D	NDM	46/47	Incomplete	
		9/12/2018	1958	SEBtP	D	W	49	Complete	
		9/12/2018	2023	Swamp Wallaby	Pr	E	50	Complete	
		10/12/2018	1017	Lace Monitor	D	W	52	Complete	
		10/12/2018	1411	Lace Monitor	D	E	53	Complete	
		13/12/2018	0853	Lace Monitor	D	W	54	Complete	
		13/12/2018	1359	Lace Monitor	D	E	55	Complete	
		14/12/2018	1347	Lace Monitor	D	W	56	Complete	
		15/12/2018	0033	Fox	D	E	57	Complete	
		15/12/2018	1046	Lace Monitor	D	W	58	Complete	
		15/12/2018	1128	Lace Monitor	D	W	59	Complete	
		15/12/2018	1312	Lace Monitor	D	W	60	Complete	
		15/12/2018	1616	Lace Monitor	D	E	61	Complete	
7	**Furniture**	20/10/2018	0142	SEBtP	D	E	14	Complete	
		25/10/2018	2114	SEBtP x 2	D	W	15	Complete	
		5/12/2018	1955	SEBtP x 2	D	E	10	Complete	
		5/12/2018	2116	SEBtP x 2	D	W	11	Complete	
		6/12/2018	1937	SEBtP	Pr	E	12	Complete	Urinates on FF
	Ground	26/10/2018	1723	EG Kangaroo x 3	Pr	E	30-32	Complete	
		26/10/2018	2242	Red-necked wallaby	Pr	W	34-35	Complete	
		3/11/2018	0103	Swamp Wallaby	D	W	77	Complete	
		3/11/2018	1821	Cat	D	W	81	Complete	
		7/11/2018	0539	Macropod spp	D	E	95	Complete	
		8/11/2018	0011	Red-necked wallaby	Pr	W	98-99	Complete	
		11/11/2018	0351	Cat	D	E	107	Complete	
		11/11/2018	1846	Cat	D	W	109	Complete	

Site	Side	Date	Time	Species	Accuracy	Movement	Pic/vid No.	Complete or incomplete	Comments
		20/11/2018	0013	Koala^	D	E	152	Complete	
		23/11/2018	1440	Lace Monitor	D	E	14	Complete	
		1/12/2018	1848	Swamp Wallaby	Pr	E	15	Complete	
		5/12/2018	2127	Cat	D	W	16	Complete	
		8/12/2018	2255	Koala^	D	W	19	Complete	
6	**Furniture**	3/12/2018	0013	Black Rat	Pr	W	6	Complete	
		18/10/2018	2321	Cat	D	W	16	Complete	
		20/10/2018	1935	Cat	D	W	17	Complete	
		21/10/2018	0144	Fox	D	W	18	Complete	
		21/10/2018	0312	Cat	D	W	19	Complete	
		1/11/2018	0257	Cat	D	E	51	Complete	
		2/11/2018	0130	Fox	D	W	58	Complete	
		2/11/2018	1919	Cat	D	W	61	Complete	
		3/11/2018	0434	Cat	D	E	62	Complete	
		7/11/2018	1311	Lace Monitor	D	E	86	Complete	
		8/11/2018	0057	Rodent spp	Pr	E	87	Complete	
		11/11/2018	0029	Fox	D	W	91	Complete	
		20/11/2018	0215	House mouse	Pr	E	136	Complete	
		24/11/2018	2033	Cat	D	E	15	Complete	
	Ground	25/11/2018	2341	Wallaby spp.	D	W	16	Complete	
		26/11/2018	0902	Lace Monitor	D	W	19	Complete	
		27/11/2018	2055	Small mammal spp.	D	W	20	Complete	
		30/11/2018	0434	Wallaby spp.	D	E	28	Complete	
		3/12/2018	0237	Fox	D	W	31	Complete	
		5/12/2018	1925	Cat	D	W	32	Complete	
		5/12/2018	2017	Cat	D	E	33	Complete	
		8/12/2018	2020	Fox	D	E	34	Complete	
		9/12/2018	0032	Cat	D	E	35	Complete	
		9/12/2018	2008	Swamp Wallaby	Pr	W	36	Complete	
		10/12/2018	2311	Wallaby spp.	D	E	37	Complete	
		14/12/2018	1142	Lace Monitor	D	E	38	Complete	
5		30/10/2018	1527	Microbat spp.	D	EXM	46-49	Incomplete	
		1/11/2018	0331	Microbat spp	D	NDM	62	Incomplete	
	North	7/11/2018	0109	Black rat	Pr	West	134	Complete	
		8/11/2018	0358	Microbat spp	D	EXM	142	Incomplete	
		10/11/2018	0005	Black rat	D	West	150-153	Complete	
		14/12/2018	2320	Black Rat	Pr	E	49	Complete	
		26/10/2018	0140	Microbat spp	D	EXM	42,51-53	Incomplete	
		27/10/2018	2251	Microbat spp	D	EXM	58-60	Incomplete	
		1/11/2018	0409	Microbat spp	D	EXM	76	Incomplete	
	South	3/11/2018	0407	Microbat spp	D	EXM	80,82-83	Incomplete	
		6/11/2018	1843	Microbat spp	D	EXM	88	Incomplete	
		9/11/2018	0355	Microbat spp	D	East	104	Complete	
		11/11/2018	0354	Microbat spp	D	EXM	105	Incomplete	

Site	Side	Date	Time	Species	Accuracy	Movement	Pic/vid No.	Complete or incomplete	Comments
		14/11/2018	0401	Microbat spp	D	EXM	112	Incomplete	
		19/11/2018	1904	Microbat spp	D	EXM	117,120	Incomplete	
		2/12/2018	0413	Microbat spp.	D	W	29	Complete	
		7/12/2018	1656	PB Duck x 2	D	E	34, 35	Complete	
4	**Furniture**			Nil					
	Ground	17/10/2018	2006	Cat	D	W	55	Complete	
		20/10/2018	0108	Koala^	D	E	56	Complete	
		22/10/2018	1250	Cat	D	E	57-58	Complete	
		26/10/2018	1042	Lace monitor	D	E	68	Complete	
		30/10/2018	1020	Lace monitor	D	W	71	Complete	
		30/10/2018	1140	Lace monitor	D	E	72	Complete	
		30/10/2018	2030	Koala^	D	E	93	Complete	
		31/10/2018	1044	Lace monitor	D	E	98	Complete	
		31/10/2018	2131	House mouse	D	E	99	Complete	
		2/11/2018	0054	Fox	D	E	108	Complete	
		2/11/2018	0220	Cat	D	E	109	Complete	
		2/11/2018	0411	Cat	D	W	110	Complete	
		2/11/2018	0837	Lace monitor	D	W	51	Complete	
		2/11/2018	1201	Lace monitor	D	W	52	Complete	
		3/11/2018	1341	Lace monitor	D	E	55	Complete	
		4/11/2018	0132	Koala^	D	W	56	Complete	
		6/11/2018	1036	Lace monitor	D	W	70	Complete	
		7/11/2018	2015	Koala^	D	E	80	Complete	
		10/11/2018	1302	Lace monitor	D	W	81	Complete	
		10/11/2018	1840	Cat	D	W	82	Complete	
		10/11/2018	2254	Koala^	D	W	83	Complete	
		10/11/2018	2358	Fox	D	E	84	Complete	
		11/11/2018	1348	Lace monitor	D	E	85	Complete	
		12/11/2018	2305	Koala^	D	E	86	Complete	
		13/11/2018	0059	Koala^	D	W	87	Complete	
		15/11/2018	0937	Lace monitor	D	E	102	Complete	
		16/11/2018	2257	Fox	D	E	121	Complete	
		17/11/2018	0155	Cat	D	W	122	Complete	
		19/11/2018	2252	Koala^	D	E	136	Complete	
		20/11/2018	1228	Lace monitor	D	W	139	Complete	
		20/11/2018	2038	Cat	D	W	144	Complete	
		23/11/2018	1126	Lace monitor	D	E	69, 70	Complete	
		24/11/2018	1222	Lace Monitor	D	E	72	Complete	
		29/11/2018	0858	Lace monitor	D	E	77	Complete	
		29/11/2018	1734	RN Wallaby	Pr	W	80	Complete	
		1/12/2018	0432	Koala^	D	W	81	Complete	
		2/12/2018	0858	Lace Monitor	D	E	82	Complete	
		3/12/2018	0155	Fox	D	E	83	Complete	
		5/12/2018	1314	Lace Monitor	D	W	84	Complete	
		5/12/2018	2314	Fox	D	E	85	Complete	
		7/12/2018	0310	Cat	D	W	86	Complete	
		8/12/2018	0944	Lace monitor	D	E	87	Complete	

Site	Side	Date	Time	Species	Accuracy	Movement	Pic/vid No.	Complete or incomplete	Comments
		8/12/2018	1045	Lace monitor	D	E	88	Complete	
		8/12/2018	2051	Fox	D	E	91-92	Complete	
		9/12/2018	1201	Lace Monitor	D	W	93	Complete	
		14/12/2018	2313	Koala^	D	E	96	Complete	
		15/12/2018	0249	Fox	D	W	97	Complete	
		15/12/2018	1245	Lace monitor	D	W	98	Complete	
3		18/10/2018	0830	Welcome swallow x 2	D	NDM	7-81	Incomplete	Not recorded hereafter.
	Furniture	30/10/2019	1009	Water dragon	D	E-W	82-97	Incomplete	
		23/11/2018	0101	Microbat spp.	D	W	38, 39, 40	Complete	Not recorded hereafter.
		18/10/2018	0002	Cat	D	East	5	Complete	
		19/10/2018	0841	Fox	D	East	7	Complete	
		20/10/2018	0831	Welcome swallow x 2	D	NDM	8	Incomplete	Not recorded hereafter
		20/10/2018	1522	Water dragon	D	East	12	Complete	
		20/10/2018	1606	Water dragon	D	West	13	Complete	
		22/10/2018	0109	Cat	D	West	15	Complete	
		22/10/2018	0549	Fox	D	East	16	Complete	
		23/10/2018	0945	Cat	D	West	17	Complete	
		24/10/2018	0319	Cat	D	West	18-19	Complete	
		24/10/2018	0452	Cat	D	East	20	Complete	
		24/10/2018	0517	Cat	D	East	22-31	Complete	
		24/10/2018	2339	Cat	D	West	32	Complete	
		25/10/2018	0104	Cat	D	East	33-34	Complete	
		25/10/2018	0342	Brushtail Possum spp	D	East	35	Complete	
	Ground	26/10/2018	0255	Cat	D	West	36-37	Complete	
		26/10/2018	0518	Cat	D	East	38	Complete	
		27/10/2018	0908	Water dragon	D	East	39	Complete	
		27/10/2018	1942	Cat	D	West	42	Complete	
		27/10/2018	2207	Fox	D	West	43	Complete	
		27/10/2018	2209	Cat	D	West	44	Complete	
		27/10/2018	2331	Cat	D	East	45-69	Complete	
		28/10/2018	2004	Cat	D	West	71	Complete	
		29/10/2018	0307	Cat	D	East	72-73	Complete	
		29/10/2018	1854	Cat	D	West	74	Complete	
		29/10/2018	2009	Cat w prey	D	East	75	Complete	
		30/10/2018	1345	Pheasant coucal	D	West	76	Complete	
		30/10/2018	2006	Cat	D	West	105	Complete	
		30/10/2018	2031	Cat	D	East	106	Complete	
		30/10/2018	2200	Cat	D	West	107	Complete	
		31/10/2018	0220	Cat	D	East	108	Complete	
		31/10/2018	0450	Cat	D	East	109	Complete	

Site	Side	Date	Time	Species	Accuracy	Movement	Pic/vid No.	Complete or incomplete	Comments
		31/10/2018	1817	Cat	D	West	117	Complete	
		31/10/2018	2013	Cat	D	East	118	Complete	
		1/11/2018	0107	Cat	D	West	119	Complete	
		1/11/2018	0249	Cat	D	East	120	Complete	
		1/11/2018	2330	Cat	D	West	131	Complete	
		2/11/2018	0232	Cat	D	East	132	Complete	
		2/11/2018	2017	Cat	D	West	142	Complete	
		2/11/2018	2346	Cat	D	East	143	Complete	
		3/11/2018	0037	Cat	D	West	144	Complete	
		3/11/2018	0401	Cat	D	East	145	Complete	
		3/11/2018	2124	Cat	D	West	152	Complete	
		4/11/2018	0607	Fox	D	East	154	Complete	
		4/11/2018	1859	Cat	D	W-E	157-158	Incomplete	
		5/11/2018	0319	Cat	D	East	159	Complete	
		6/11/2018	0106	Cat	D	West	167	Complete	
		6/11/2018	0334	Cat	D	East	168	Complete	
		7/11/2018	0312	Cat	D	East	178	Complete	
		7/11/2018	1938	Cat	D	West	182	Complete	
		7/11/2018	2218	Cat	D	East	183	Complete	
		7/11/2018	2227	Fox	D	West	184	Complete	
		8/11/2018	2207	Cat	D	West	185	Complete	
		9/11/2018	0224	Brushtail Possum spp	D	East	186	Complete	
		9/11/2018	0253	Cat	D	East	187	Complete	
		9/11/2018	0352	Swamp Wallaby	D	East	188	Complete	
		9/11/2018	1951	Cat	D	West	191	Complete	
		9/11/2018	2114	Fox	D	West	192	Complete	
		10/11/2018	0030	Cat	D	East	193-194	Complete	
		11/11/2018	0117	Cat	D	West	196	Complete	
		11/11/2018	0304	Cat	D	East	197	Complete	
		11/11/2018	0346	Swamp Wallaby	D	East	198-199	Complete	
		11/11/2018	2132	Swamp Wallaby	D	W-E	200	Incomplete	
		11/11/2018	2209	Cat	D	East	201	Complete	
		12/11/2018	0050	Cat	D	West	203	Complete	
		12/11/2018	0207	Fox w prey	D	East	204	Complete	
		12/11/2018	0350	Cat	D	East	205	Complete	
		13/11/2018	0154	Cat	D	East	206	Complete	
		15/11/2018	0319	Cat	D	West	215	Complete	
		15/11/2018	0538	Cat	D	East	216	Complete	
		17/11/2018	0109	Fox	D	West	236	Complete	
		18/11/2018	0239	Cat	D	East	239	Complete	
		19/11/2018	0312	Common Brushtail possum	D	East	249	Complete	

Site	Side	Date	Time	Species	Accuracy	Movement	Pic/vid No.	Complete or incomplete	Comments
		19/11/2018	2124	Cat	D	East	250	Complete	
		20/11/2018	0424	Cat	D	West	251	Complete	
		20/11/2018	0526	Cat	D	East	252	Complete	
		21/11/2018	0059	Cat	D	West	255	Complete	
		21/11/2018	0358	Cat	D	East	256	Complete	
		21/11/2018	2100	Fox	D	W	25	Complete	
		21/11/2018	2107	Cat	D	E	26	Complete	
		21/11/2018	0221	Fox	D	E	27	Complete	
		21/11/2018	0236	Fox	D	W	28	Complete	
		23/11/2018	0225	Cat	D	W	32	Complete	
		23/11/2018	0406	Cat	D	E	33	Complete	
		24/11/2018	0311	Cat	D	E	35	Complete	
		24/11/2018	0440	EG Kangaroo	Pr	E	36	Complete	
		25/11/2018	0229	Fox	D	E	38	Complete	
		25/11/2018	2048	Cat	D	W	39	Complete	
		25/11/2018	2306	Cat	D	E	40	Complete	
		26/11/2018	0242	Hare	Po	E	41	Complete	
		26/11/2018	0314	Cat	D	E	42	Complete	
		27/11/2018	0110	Fox	Pr	W	43	Complete	
		27/11/2018	0323	Cat	D	E	44	Complete	
		27/11/2018	2316	SEBtP	D	W	45	Complete	
		28/11/2018	2129	Cat	D	W	46	Complete	
		28/11/2018	2319	Cat	D	E	47	Complete	
		29/11/2018	0501	EG Kangaroo	Pr	E	48	Complete	
		29/11/2018	2009	Cat	D	W	51	Complete	
2	**Furniture**	27/10/2018	2057	Black rat	D	W-E	41-46	Incomplete	
		28/10/2018	2049	Black rat	D	W-E	49-52	Incomplete	
		31/10/2018	2003	Black rat	D	W-E	91-94	Incomplete	
		2/11/2018	2124	Black rat	D	W	203	Complete	
		2/11/2018	2144	Black rat	D	E	205-208	Complete	
		7/11/2018	0045	Black rat	D	W-E	341-348	Incomplete	
		8/11/2018	0040	Black rat	Pr	W	381	Complete	
		17/11/2018	0213	Black rat	D	W-E	637-644	Incomplete	
	Ground	19/11/2018	0321	Echidna	D	East	11	Complete	
		20/11/2018	0502	Cat	D	East	12	Complete	
		20/11/2018	1925	Echidna	D	West	13	Complete	
		20/11/2018	2144	Echidna	D	West	14	Complete	
		21/11/2018	2340	Fox	D	East	15	Complete	
		23/10/2018	0122	Echidna	D	East	16-17	Complete	
		23/10/2018	2022	Echidna	D	East	18	Complete	
		24/10/2018	0329	Echidna	D	East	19	Complete	
		26/10/2018	1923	Swamp Wallaby	Pr	West	24	Complete	
		27/10/2018	0209	Swamp Wallaby	D	East	25	Complete	
		27/10/2018	2014	Swamp Wallaby	D	EXM	26-36	Incomplete	

Site	Side	Date	Time	Species	Accuracy	Movement	Pic/vid No.	Complete or incomplete	Comments
		28/10/2018	2338	Swamp Wallaby	D	East	38	Complete	
		29/10/2018	0045	Fox	D	East	39	Complete	
		29/10/2018	0243	Swamp Wallaby	D	East	40	Complete	
		29/10/2018	0410	Swamp Wallaby	D	East	41	Complete	
		30/10/2018	1834	Swamp Wallaby	D	West	42	Complete	
		31/10/2018	2353	Echidna	D	East	72	Complete	
		1/11/2018	0102	Echidna	D	East	73	Complete	
		2/11/2018	0218	Echidna	D	West	113	Complete	
		3/11/2018	2249	Echidna	D	East	153	Complete	
		23/11/2018	1223	Lace monitor	D	E	29	Complete	
		23/11/2018	1854	RN Wallaby	Pr	E	35	Complete	
		23/11/2018	2146	Black rat	Pr	E	36	Complete	
		24/11/2018	1934	Black rat	Pr	E	48	Complete	
		24/11/2018	2313	Fox	D	E	49	Complete	
		24/11/2018	2346	Cat	D	W	50	Complete	
		26/11/2018	0049	Echidna	D	E	59, 60	Complete	
		26/11/2018	0121	Wallaby spp.	D	E	61	Complete	
		26/11/2018	0237	Echidna	D	E	62	Complete	
		13/12/2018	2311	Med frog	D	NDM	2853	Incomplete	
		25/11/2018	2045	Echidna	D	W	1906	Complete	
		10/12/2018	0017	Macropod spp.	D	W	519	Complete	
1		31/10/2018	1205	BtPoss spp	D	W	306	Complete	
		2/11/2018	2127	Swamp Wallaby	Pr	NDM	1948	Incomplete	
		3/11/2018	0222	Swamp Wallaby	D	W	2243,2246	Complete	
		3/11/2018	2329	Swamp Wallaby	Pr	E	2670	Complete	
		6/11/2018	0147	Medium frog spp	D	E	4008-4017	Complete	
	North	6/11/2018	1112	Medium frog spp	D	E	4453-4461	Complete	
		7/11/2018	1920	Medium frog spp	D	W	4821-4825	Complete	
		21/11/2018	2246	Medium frog spp	D	NDM	91-96	Complete	
		22/11/2018	0112	Medium frog spp	D	E	237-240	Complete	
		13/12/2018	2311	Medium frog spp	D	NDM	2853	Incomplete	
		25/11/2018	2045	Echidna	D	W	1906	Complete	
	South	10/12/2018	0017	Macropod spp.	D	W	519	Complete	

Table B4: Results from diurnal active searches. OBS = Observed, prob = probable.

Site	Date	Side	Day/Night (survey no.)	Obs	Start Time	Finish Time	Wind	Rain	Visibility	Air Temp	RH	Species (no. of individuals / behaviour)	Signs (scats/tracks)
11 & 12	26/10/2018	W	D1	NP	938	1010	RL	Nil	Good	22.5	76	Lampropholis spp.	OBS
												Wallaby spp.	Scats
	26/10/2018	E	D1	NP	1015	1045	RL	Nil	Good	22.5	76	Lace Monitor	OBS
												Yellow-faced whip snake	OBS
												Bandicoot spp.	Diggings
												Macropod spp.	Scat
												Lampropholis spp.	OBS
												Adelotis brevis	HC
												Little Eagle soaring above	
	14/11/2018	W	D2	DR	940	1010	Nil	Nil	Good	25	77	Lampropholis delicata x2	OBS
	14/11/2018	E	D2	DR	1015	1050	Nil	Nil	Good	25	77	Egernia mcpheei	OBS
												Lampropholis delicata	OBS
												Lampropholis spp.	OBS
	22/11/2018											Swamp Snake	Incidental obs
9 & 10	26/10/2018	W	D1	NP	1110	1140	Msb	Nil	Good	23	73	Nil	
	26/10/2018	E	D1	NP	1145	1215	Msb	Nil	Good	23	73	Wallaby spp.	Tracks
												Bandicoot spp.	Diggings
												Echidna	Diggings
	14/11/2018	E	D2	DR	1100	1135	Nil	Nil	Good	25	75	Lampropholis spp.	OBS
	14/11/2018	W	D2	DR	1137	1210	Nil	Nil	Good	25	75	Lampropholis spp.	OBS
												Litoria fallax	Heard
8	1/11/2018	E	D1	NM/OT	1217	1232	Msb	Nil	Good	23.9	75	Lampropholis spp.	OBS
												Wallaby spp.	Scat
	1/11/2018	W	D1	NM/OT	1233	1248	Msb	Nil	Good	23.9	75	Bandicoot spp.	Diggings
												Wallaby spp.	Scat
	14/11/2018	W	D2	DR	1300	1330	Nil	Nil	Good	28	75	Lampropholis delicata	OBS
												Lampropholis spp.	OBS
	14/11/2018	E	D2	DR	1335	1410	Nil	Nil	Good	30	72	Nil	
7	1/11/2018	W	D1	NM/OT	1259	1314	MsB	Nil	Good	25.4	73	Wallaby spp.	Scat

Site	Date	Side	Day/Night (survey no.)	Obs	Start Time	Finish Time	Wind	Rain	Visibility	Air Temp	RH	Species (no. of individuals / behaviour)	Signs (scats/tracks)
	1/11/2018	E	D1	NM/OT	1315	1330	Msb	Nil	Good	24.7	69	Wallaby spp.	Scat
												Bandicoot spp.	Diggings
	16/11/2018	W	D2	LA	1400	1430	Nil	Light shower	Good	26	70	Wallaby spp.	Scat
												Small Scincidae spp.	OBS
	16/11/2018	E	D2	NP	1400	1430	Nil	Light shower	Good	26	70	Nil	
5 &	6/11/2018	W	D1	NP	1047	1120	Nil	Nil	Good	26.9	75	Lampropholis delicata	OBS
6	6/11/2018	E	D1	NP	1120	1150	Nil	Nil	Good	26.9	75	Carpet Python	OBS
												Lampropholis delicata	OBS
												Swamp Wallaby	Scat
												Tadpoles (prob Lit. tyleri, Lit peronii)	OBS
												Freshwater Turtle spp.	OBS
	16/11/18	W	D2	NP/LA	1145	1200	Nil	Nil	Good	22.6	74	Swamp snake	OBS
												Wallaby spp.	Tracks
												Lampropholis spp.	OBS
												Bandicoot spp.	Diggings
	16/11/18	E	D2	NP/LA	1200	1215	Nil	Nil	Good	22.6	74	Wallaby spp.	Scat, tracks
												Large snake spp.	Skin
												Lampropholis spp.	Obs
												Lampropholis delicata	OBS
												Fox	Tracks
												Tadpoles (prob Lit. tyleri, Lit. peronii)	OBS
4	11/06/2018	W	D1	NP	1200	1230	Nil	Nil	Good	26	76	Lampropholis delicata	OBS
												Swamp Wallaby	OBS
	11/06/2018	E	D1	NP	1230	1300	Nil	Nil	Good	26	76	Lampropholis spp.	OBS
												Swamp Wallaby	Scat
	16/11/2018	W	D2	LA	1320	1350	Nil	Nil	Good	23.7	75	Swamp Wallaby (prob)	Heard

Site	Date	Side	Day/Night (survey no.)	Obs	Start Time	Finish Time	Wind	Rain	Visibility	Air Temp	RH	Species (no. of individuals / behaviour)	Signs (scats/tracks)
												Lampropholis spp.	OBS
	6/11/2018	E	D2	NP	1320	1350	Nil	Nil	Good	23.7	75	Lampropholis spp.	OBS
												Burton's Legless Lizard (prob)	OBS
												Bandicoot spp.	Diggings
3	9/11/2018	E	D1	NP	1130	1200	Nil	Nil	Good	22	55	Lampropholis spp.	OBS
												Wallaby spp.	Scat
												Bandicoot spp.	Diggings
	14/11/2018	W	D1	NP	920	950	Nil	Nil	Good	24	53	Bandicoot spp.	Diggings
												Lampropholis spp.	OBS
												EW Dragon	Scat
	16/11/2018	W	D2	NP/LA	1200	1245	Nil	Nil	Good	24.3	74	Calyptotis ruficauda (prob)	OBS
												EW Dragon	Scat
	16/11/2018	E	D2	NP/LA	1245	1300	Nil	Nil	Good	24.3	74	Bandicoot spp.	Diggings
2	9/11/2018	E	D1	NP	1020	1050	Nil	Nil	Good	21.3	53	Lampropholis spp.	OBS
												Wallaby spp.	Scats
												Echidna	Diggings
												Bandicoot spp.	Diggings
	11/09/2018	W	D1	NP	1050	1120	Nil	Nil	Good	21.3	53	Wallaby spp.	Scats
												Lampropholis spp.	OBS
	14/11/2018	W	D2	NP	1330	1400	MLB	Nil	Good	26	62	Bandicoot spp.	Diggings
												Wallaby spp.	Scat
												Lampropholis spp.	Obs
	14/11/2018	E	D2	NP	1400	1430	MLB	Nil	Good	26	62	Echidna	Tracks and diggings
												Bandicoot	Diggings
												Lampropholis spp.	OBS
1	8/11/2018	E	D1	NP	1230	1300	Msb	Nil	Good	20.2	60	Wallaby spp.	Scat
	8/11/2018	W	D1	NP	1300	1330	Msb	Nil	Good	20.2	60	Eastern Water Dragon	OBS
												Wallaby spp.	Scat
	14/11/2018	E	D2	NP	1100	1130	RL	Nil	Good	25.6	54	EW Dragon	OBS

Site	Date	Side	Day/Night (survey no.)	Obs	Start Time	Finish Time	Wind	Rain	Visibility	Air Temp	RH	Species (no. of individuals / behaviour)	Signs (scats/tracks)
												Wallaby spp.	Scats
												Water Skink	OBS
	14/11/2018	W	D2	NP	1130	1200	RL	Nil	Good	25.6	54	Red-bellied Black Snake	OBS
												EW Dragon	OBS
												Wallaby spp.	Scat
												Total 18 species and 6 groups detected.	

Table B5: Results from nocturnal active searches. Upe = Uperolia spp., P. coriacea = Pseudophryne coriacea, ONj = Owlet-nightjar, A. = Adelotus, M. = Mixophyes, Lim. = Limnodynastes, Lit = Litoria, YBG = Yellow-bellied glider.

Location	Side	Date	Obs. No.	Observers	Start	Finish	Species	Wind	Rain	Visibility	Air Temp	RH	Comment
11&12	E	08/11/2018	1	DR	2215	2245	P. coriacea, A. brevis, Upe. spp., Wallaby spp.	Nil	Nil	Good	15.6	65	
	W	08/11/2018	1	NP	2215	2245	Nil	Nil	Nil	Good	15.6	65	
	E	21/11/18	2	NP/NM	2230	2255	P. coriacea, A. brevis	Nil	Nil	Moderate	23	90	
	W	21/11/2018	2	DR, LA	2255	2315	Nil	Nil	Nil	Moderate	23	90	
9&10	E	08/11/2018	1	DR	2140	2210	ONj, P. coriacea	Nil	Nil	Good	16	64	
	W	08/11/2018	1	NP	2140	2210	A. brevis, P. coriacea	Nil	Nil	Good	16	64	
	E	21/11/2018	2	DR, LA	2235	2250	M. fasciolatus, A. brevis	Nil	Nil	Moderate	23	90	
	W	21/11/2018	2	DR, LA	2215	2230	P. coriacea	Nil	Nil	Moderate	23	90	
8	E	08/11/2018	1	DR	2107	2137	P. coriacea, A. brevis	RL	Nil	Good	16.1	65	
	W	08/11/2018	1	NP	2107	2137	A. brevis, Lit. fallax	RL	Nil	Good	16.1	65	
	E	21/11/2018	2	DR, LA	2145	2205	Sugar glider, Lim. peroni, A. brevis	Nil	light	Moderate	23	88	
	W	21/11/2018	2	DR, LA	2120	2140	Sugar glider, Lit. fallax, A. brevis; **YBG** (496489; 6609135)	Nil	light	Moderate	23	88	YBG heard calling from east side of H'way, clear call heard by both obs.
7	E	08/11/2018	1	DR	2030	2100	P. coriacea	Nil	Nil	Good	16.1	67	
	W	08/11/2018	1	NP	2030	2100	P. coriacea, A. brevis	Nil	Nil	Good	16.1	67	
	E	21/11/2018	2	DR, LA	2050	2110	A. brevis	Nil	light	Moderate	23	88	
	W	21/11/2018	2	DR, LA	2025	2040	Petaurus spp. (prob breviceps), A. brevis, P. coriacea	Nil	light	Moderate	23	88	
5&6	E	08/11/2018	1	DR	1950	2025	TF, Lit. peronii, Lit. fallax	Msb	Nil	Good	18.4	63	
	W	08/11/2018	1	NP	1950	2025	P. coriacea, Lit. tyleri, Long-finned eel	Msb	Nil	Good	18.4	63	Eel heading west in fish passage
	E	19/11/18	2	DR, LA	2320	2335	L. fallax, L. peroni, L. tyleri	Nil	Nil	Good	17.5	81	
	W	19/11/18	2	DR, LA	2300	2315	Ps. coriacea	Nil	Nil	Good	17.5	81	

4	E	16/11/2018	1	NP	1945	2015	Nil	Nil	Showers	Poor	20.6	83	
	W	16/11/18	1	NP	2015	2045	Nil	Msb	Rain	Poor	20	88	
	E	19/11/18	2	DR, LA	2125	2145	Ps. coriacea, Lim. peroni	Nil	Nil	Good	16.5	81	
	W	19/11/18	2	DR, LA	2105	2120	Ps. coriacea	Nil	Nil	Good	16.5	81	
3 (E only)	E	21/11/18	1	NP/NM	1955	2022	Ps. coriacea, Upe. fusca, C. signifera	Nil	Moderate	Moderate	22.4	90	
	E	22/11/18	2	NP/NM	1955	2015	SEBtP, Wallaby spp., Ps. coriacea	RL	Nil	Moderate	25.6	27	Dust storm
2	E	19/11/18	1	DR, LA	2230	2245	Ps. coriacea	Nil	Nil	Good	16.8	64	
	W	19/11/18	1	DR, LA	2205	2220	Nil	Nil	Nil	Good	16.8	64	
	E	21/11/18	2	NP/NM	2047	2104	A. brevis, C. signifera	Nil	Light	Moderate	21	97	
	W	21/11/18	2	NP/NM	2030	2045	Wallaby spp.	Nil	Light	Moderate	21	97	
1	E	19/11/18	1	DR, LA	2000	2015	Microbat spp.	Nil	Nil	Good	18	69.7	
	W	19/11/18	1	DR, LA	2020	2040	L. fallax, L. chloris, A. Brewis, **M. iteratus** (M, at trib), SEBtP x 2, swamp wallaby	Nil	Nil	Good	18	69.7	
	E	21/11/18	2	NP/NM	2200	2220	EW Dragon	Nil	Nil	Good	20	90	
	W	21/11/18	2	NP/NM	2130	2200	**M. iteratus x 2** (F1: 489368, 6594460, M: 5m SW of previous location), A. brevis, L. fallax, EW Dragon	Nil	Nil	Good	20	90	
							Totals: 15 species and 4 groups detected						

Table B6: Adjacent habitat trapping data.

Site	Date	Trap type	Species	Sex	Weight	Comments
1 east	19/11/2018	Small cage	Black rat	F	NR	
1 east	19/11/2018	Large cage	Black rat	F	NR	
1 east	21/11/2018	Small elliott	Black rat	M	130	
1 west	19/11/2018	Small cage	Black rat	F	130g	Euthanised
1 west	21/11/2018	Small elliott	Black rat	F	130	Euthanised
1 west	21/11/2018	Large elliott	SEBtP	M	NR	
2 east	19/11/2018	Small elliott	Melomys spp.	M	87g	
2 east	19/11/2018	Small elliott	Melomys spp.	F	82g	Lactating
2 east	20/11/2018	Small elliott	Fawn-footed melomys	M	92g	
2 east	20/11/2018	Pitfall	Lampropholis delicata	Uk	NA	
2 east	21/11/2018	Small elliot	Black rat	F	150	
2 east	21/11/2018	Small elliott	Bush rat	M	120	
2 west	20/11/2018	Large cage	Black rat	M	NR	
2 west	20/11/2018	Pitfall	Lampropholis guichenoti	Uk	NA	
2 west	21/11/2018	Small elliott	Black rat	UK	NA	
3 east	15/11/2018	Pitfall	Lampropholis delicata x 2	UK	NA	
3 east	18/11/2018	Pitfall	Calyptotis ruficauda	Uk	NA	
3 east	18/11/2018	Pitfall	Lampropholis delicata	F		
3 west	16/11/2018	Pitfall	Calyptotis ruficauda	UK	NA	
3 west	16/11/2018	Pitfall	Calyptotis ruficauda	UK	NA	
3 west	17/11/2018	Pitfall	Lampropholis delicata	UK	NA	RN Wallaby in veg patch .
3 west	18/11/2018	Pitfall	Calyptotis ruficauda	UK	NA	
3 west	18/11/2018	Pitfall	Lampropholis guichenoti	UK	NA	
3 west	20/11/2018	Pit fall	Lampropholis guichenoti	UK	NA	
4 east	17/11/2018	Pitfall	Pseudophryne coriacea	UK	NA	
4 west	15/11/2018	Pitfall	Blackish blind snake	UK	NA	
4 west	18/11/2018	Small elliott	Black rat	M	183g	Euthanised
5&6 east	14/11/2018	Pitfall	Lampropholis delicata x 2	UK	NA	All animals in same trap.
5&6 west	14/11/2018	Pitfall	Lampropholis delicata	UK	NA	
5&6 west	15/11/2018	Small cage	Bush rat	M	120g	
5&6 west	15/11/2018	Small elliot	Bush rat	M	155g	
5&6 west	16/11/2018	Large cage	Northern brown bandicoot	UK	NA	
5&6east	15/11/2018	Pitfall	Calyptotis ruficauda	UK	NA	
7 east	16/11/2018	Pitfall	Lampropholis guitchinoti	UK	NA	
7 west	14/11/2018	Pitfall	Lampropholis delicata	UK	NA	
7 west	14/11/2018	Small cage	SEBtP	UK	NA	Released immediately
7 west	15/11/2018	Pitfall	Calyptotis ruficauda	UK	NA	
8 west	13/11/2018	Small elliot	Fawn-footed melomys	F	80g	Lactating teats
8 west	13/11/2018	Small elliot	Brown antechinus	F	30g	Evidence of recent pouch young
8 west	15/11/2018	Small elliott	Brown antechinus	F	37g	Evidence of recent pouch young
8west	14/11/2018	Small elliott	Fawn-footed melomys	Male	87g	
8west	14/11/2018	Pitfall	Red-backed toadlet	UK	NA	
9&10 east	14/11/2018	Pitfall	Lampropholis delicata	UK	NA	
9&10 east	15/11/2018	Large cage	SEBtP	UK	NA	
9&10 west	13/11/2018	Large cage	Black rat	F	NA	Euthanised
9&10 west	14/11/2018	Small cage	Black rat	M	NA	Euthanised

Site	Date	Trap type	Species	Sex	Weight	Comments
9&10 west	15/11/2018	Small cage	Black rat	UK	NA	Escaped
9&10 west	15/11/2018	Small elliot	Brown antechinus	UK	24g	
11&12 east	13/11/18	Pitfall	Calyptotis ruficauda	UK	NA	
11&12 west	14/11/2018	Pitfall	Striped marsh frog	Uk	NA	
11&12 west	14/11/2018	Small cage	Black rat	Male	100g	Euthanised
11&12 west	14/11/2018	Pitfall	Lampropholis delicata	UK	NA	

Table B7: Results from hair funnel sampling in adjacent habitat. BtPoss = Brushtail possum species, CRtP = Common ringtail possum.

Site	Side	Spring 2018		
		Install Date	Collect date	Fauna
1	E-1	12-16/11/18	30/11/2018	BtPoss spp.
	E-2	12-16/11/18	30/11/2018	
	W-1	12-16/11/18	30/11/2018	BtPoss spp.
	W-2	12-16/11/18	30/11/2018	Rattus spp.
2	E-1	12-16/11/18	30/11/2018	
	E-2	12-16/11/18	30/11/2018	Bush rat
	W-1	12-16/11/18	30/11/2018	Black rat
	W-2	12-16/11/18	30/11/2018	
3	E-1	12-16/11/18	30/11/2018	
	E-2	12-16/11/18	30/11/2018	
	W-1	12-16/11/18	30/11/2018	Northern brown bandicoot
	W-2	12-16/11/18	30/11/2018	
4	E-1	12-16/11/18	30/11/2018	
	E-2	12-16/11/18	30/11/2018	
	W-1	12-16/11/18	30/11/2018	
	W-2	12-16/11/18	30/11/2018	
5 & 6	E-1	12-16/11/18	30/11/2018	
	E-2	12-16/11/18	30/11/2018	
	W-1	12-16/11/18	30/11/2018	Rattus spp.
	W-2	12-16/11/18	30/11/2018	
7	E-1	12-16/11/18	30/11/2018	BtPoss spp.
	E-2	12-16/11/18	30/11/2018	Bush rat
	W-1	12-16/11/18	30/11/2018	

Site	Side	Spring 2018		
		Install Date	Collect date	Fauna
	W-2	12-16/11/18	30/11/2018	
8	E-1	12-16/11/18	30/11/2018	CRtP
	E-2	12-16/11/18	30/11/2018	BtPoss spp.
	W-1	12-16/11/18	30/11/2018	BtPoss spp.
	W-2	12-16/11/18	30/11/2018	
9 & 10	E-1	12-16/11/18	30/11/2018	BtPoss spp.
	E-2	12-16/11/18	30/11/2018	
	W-1	12-16/11/18	30/11/2018	
	W-2	12-16/11/18	30/11/2018	
11 & 12	E-1	12-16/11/18	30/11/2018	Carnivora spp.
	E-2	12-16/11/18	30/11/2018	
	W-1	12-16/11/18	30/11/2018	
	W-2	12-16/11/18	30/11/2018	

Table B8: Sandpad data.

Location	Easting	Northing	Sand pad	Date	Action	Species (direction & no passes)	Pad condition
12 median west	497115	6610068	East	30/10/2018	Install	NA	
			West	30/10/2018		NA	
			East	31/10/2018	Insp1	nil	Good
			West	31/11/2018		Nil	Good
			East	1/11/2018	Insp2	Cat (definite, 1e)	Fair
			West	1/11/2018		Cat (definite, 1e)	Fair
			East	2/11/2018	Insp3	Nil	Fair
			West	2/11/2018		Nil	Fair
			East	3/11/2018	Insp4	Nil	Fair
			West	3/11/2018		Nil	Fair
			East	4/11/2018	Insp5	Small reptile (definite, 1e,1w), medium reptile (definite, 3 e, 1w)	Fair
			West	4/11/2018		Medium reptile (definite, 2e, 1w meandering)	Fair
			East	5/11/2018	Insp6	Small reptile (definite, 2w, 1e, 1 meandering) cat (definite 1w meandering)	Fair
			West	5/11/2018		Small reptile (definite, 1w, 1e) cat (definite 1w)	Fair
			East	6/11/2018	Insp7	Lace monitor (definite 1e), medium size reptile (definite 1e, 1w) small reptile (definite, 1e 1w)	Fair

Location	Easting	Northing	Sand pad	Date	Action	Species (direction & no passes)	Pad condition
			West	6/11/2018		Lace monitor (definite 1e), medium size reptile (definite 1e, 1w) small reptile (definite, 1e 1w)	Fair
			East	7/11/2018	Insp8	Small reptile (definite 2e2w)	Poor
			West	7/11/2018		Small reptile (definite 2e2w)	Poor
11 median east	497168	6610040	East	30/10/2018	Install	NA	
			West	30/10/2018		NA	
			East	31/10/2018	Insp1	Nil	Good
			West	31/10/2018		Nil	Good
			East	1/11/2018	Insp2	Cat (definite, 1e)	Good
			West	1/11/2018		Cat (definite, 1e)	Fair
			East	2/11/2018	Insp3	Nil	Fair
			West	2/11/2018		Nil	Fair
			East	3/11/2018	Insp4	Nil	Fair
			West	3/11/2018		Nil	Fair
			East	4/11/2018	Insp5	Nil	Good
			West	4/11/2018		Nil	Fair
			East	5/11/2018	Insp6	Nil	Fair
			West	5/11/2018		Nil	Fair
			East	6/11/2018	Insp7	Lace monitor (definite 1e), medium reptile (definite 1e) cat (probable 1e)	Fair
			West	6/11/2018		Lace monitor (definite 1e), medium reptile (definite 1e) cat (probable 1e)	Fair
			East	7/11/2018	Insp8	Nil	Poor
			West	7/11/2018		Nil	Poor
10 median west	496622	6609409	East	30/10/2018	Install	NA	
			West	30/10/2018		NA	
			East	31/10/2018	Insp1	Small mammal (possible:1 track e/w)	Good
			West	31/10/2018		Nil	Good
			East	1/11/2018	Insp2	Nil	Fair
			West	1/11/2018		Nil	Fair
			East	2/11/2018	Insp3	Nil	Fair
			West	2/11/2018		Nil	Fair
			East	3/11/2018	Insp4	Nil	Fair
			West	3/11/2018		Nil	Fair
			East	4/11/2018	Insp5	Nil	Fair
			West	4/11/2018		Nil	Fair
			East	5/11/2018	Insp6	Nil	Fair
			West	5/11/2018		Nil	Fair
			East	6/11/2018	Insp7	Nil	Fair
			West	6/11/2018		Nil	Good
			East	7/11/2018	Insp8	Cat (definite 1w)	Poor
			West	7/11/2018		Cat (definite 1w)	Poor
9 median east	496622	6609409	East	30/10/2018	Install	NA	
			West	30/10/2018		NA	
			East	31/10-18	Insp1	Nil	Fair
			West	31/10/2018		Nil	Good

Location	Easting	Northing	Sand pad	Date	Action	Species (direction & no passes)	Pad condition
			East	1/11/2018	Insp2	Nil	Fair
			West	1/11/2018		Nil	Fair
			East	2/11/2018	Insp3	Nil	Fair
			West	2/11/2018		Nil	Fair
			East	3/11/2018	Insp4	Nil	Fair
			West	3/11/2018		Nil	Good
			East	4/11/2018	Insp5	Nil	Fair
			West	4/11/2018		Nil	Fair
			East	5/11/2018	Insp6	Nil	Fair
			West	5/11/2018		Nil	Fair
			East	6/11/2018	Insp7	Rat sp. (probable, 1e)	Fair
			West	6/11/2018		Rat sp. (probable, 1e)	Fair
			East	7/11/2018	Insp8	Cat (definite 1w)	Poor
			West	7/11/2018		Cat (definite 1w) small Dasyurid (probable 1e)	Poor
8 full length	496506	6609219	East	30/10/2018	Install	NA	
			West	30/10/2018		NA	
			East	31/10/2018	Insp1	Lace monitor (definite:1track e/w), Bandicoot sp. (definite 1track e/w), **LN Potoroo** (possible, 1track w/e)	Good
			West	31/10/2018		Lace monitor (definite:1track e/w), Bandicoot sp. (definite 1 track e/w), Bandicoot sp. (definite 1 track w/e).	Good
			East	1/11/2018	Insp2	Lace monitor (definite, 1 w), echidna (probable, 1 w)	Good
			West	1/11/2018		Lace monitor (definite, 1w), echidna (probable, 1 w)	Fair
			East	2/11/2018	Insp3	Cat (definite 1e)	Fair
			West	2/11/2018		Cat (definite, 1e)	Fair
			East	3/11/2018	Insp4	Definite lace monitor (1e) fox (probable, 1 e), definite medium sized reptile (1 e)	Fair
			West	3/11/2018		Definite lace monitor (1e) fox (probable, 1 e), definite medium sized reptile (1 e), Dasyurid(possible, 1e)	Fair
			East	4/11/2018	Insp5	Lace monitor (definite, 1w), Frog(definite, 1e)	Fair
			West	4/11/2018		Lace monitor (definite, 1w), Frog(definite, 1e)	Fair
			East	5/11/2018	Insp6	Dasyurid (possible 1w) small rodent (probable 1e)	Fair
			West	5/11/2018		Dasyurid (possible 2w 1e), probable small rodent (1e)	Fair
			East	6/11/2018	Insp7	Lace monitor (definite 1e)	Fair
			West	6/11/2018		Lace monitor (definite 1e) dasyurid (probable 1w)	Fair
			East	7/11/2018	Insp8	Cat (definite 1e1w), brushtail possum (definite 1e)	Fair
			West	7/11/2018		Cat (definite 1e1w), brush tail possum (definite 1e)	Fair
7 full length	496438	6608780	East	30/10/2018	Install	NA	
			West	30/10/2018		NA	
			East	31/10/2018	Insp1	Nil	Good
			West	31/10/2018		Nil	Good
			East	1/11/2018	Insp2	Nil	Good
			West	1/11/2018		Nil	Good
			East	2/11/2018	Insp3	Nil	Good
			West	2/11/2018		Nil	Good
			East	3/11/2018	Insp4	Definite swamp wallaby (1e)	Good

Location	Easting	Northing	Sand pad	Date	Action	Species (direction & no passes)	Pad condition
			West	3/11/2018		Definite swamp wallaby(1e,1w)	Good
			East	4/11/2018	Insp5	Cat (definite 1w)	Good
			West	4/11/2018		Cat (definite 1w)	Good
			East	5/11/2018	Insp6	Nil	Good
			West	5/11/2018		Definite swamp wallaby(1e,1w)	Good
			East	6/11/2018	Insp7	Nil	Good
			West	6/11/2018		Nil	Good
			East	7/11/2018	Insp8	Lace monitor (definite, 1w)	Good
			West	7/11/2018		Lace monitor (definite, 1w)	Good
6 full length	496188	6608319	East	30/10/2018	Install	NA	
			West	30/10/2018		NA	
			East	31/10/2018	Insp1	Nil	Good
			West	31/10/2018		Nil	Good
			East	1/11/2018	Insp2	Cat (definite, 1 e)	Good
			West	1/11/2018		Cat (definite, 1e)	Good
			East	2/11/2018	Insp3	Fox (probable 1 w)	Good
			West	2/11/2018		Fox (probable 1w)	Fair
			East	3/11/2018	Insp4	Probable cat (1e)	Fair
			West	3/11/2018		Probable cat (1e,1w)	Fair
			East	4/11/2018	Insp5	Possible small mammal(1e)	Fair
			West	4/11/2018		Nil	Fair
			East	5/11/2018	Insp6	Nil	Fair
			West	5/11/2018		Nil	Fair
			East	6/11/2018	Insp7	Dasyurid (possible 1e)	Fair
			West	6/11/2018		Nil	Fair
			East	7/11/2018	Insp8	Nil	Fair
			West	7/11/2018		Dasyurid (possible 1e)	Fair
5			West	30/10/2018	Install	NA	
			West	30/10/2018		NA	
			West	31/10/2018	Insp1	Nil	Good
			West	31/10/2018		Nil	Good
			West	1/11/2018	Insp2	Nil	Fair
			West (water)	1/11/2018		Cat (definite, 2e,2w)	Fair
			East	2/11/2018	Insp3	Nil	Fair
			West	2/11/2018		Nil	Fair
			West (water)	2/11/2018		Nil	Fair
			East	3/11/2018	Insp4	Nil	Fair
			West	3/11/2018		Nil	Fair
			West	3/11/2018		Nil	Fair
			East	4/11/2018	Insp5	Small reptile (probable, 1e)	Fair
			West	4/11/2018		Rat sp, (definite, 1e,1w, 1ew)	Fair
			West	4/11/2018		Small reptile (probable, 1e)	Fair

Location	Easting	Northing	Sand pad	Date	Action	Species (direction & no passes)	Pad condition
			East	5/11/2018	Insp6	Nil	Fair
			West	5/11/2018		Rat sp, (definite, 1e,1w)	Fair
			West	5/11/2018		Definite bandicoot (1e1w)	Fair
			East	6/11/2018	Insp7	Dasyurid (possible 1w)	Fair
			West	6/11/2018		Nil	Fair
			West	6/11/2018		Nil	Fair
			East	7/11/2018	Insp8	Rat sp (definite 1e1w)	Fair
			West	7/11/2018		Rat sp (definite 1e1w)	Fair
			West	7/11/2018		Rat sp (definite 1e1w)	Fair
4	495702	6607693	East	30/10/2018	Install	NA	
			West	30/10/2018		NA	
			East	31/10/2018	Insp1	**Koala** (definite: 1 e)	Good
			West	31/10/2018		**Koala** (definite: 1 e)	Good
			East	1/11/2018	Insp2	Lace monitor(definite: 1e)	Good
			West	1/11/2018		Lace monitor (definite , 1e)	Good
			East	2/11/2018	Insp3	Cat (definite, 1e 1w) Fox(definite 1e)	Good
			West	2/11/2018		Cat (definite 1 e 1w) Fox (definite 1 e)	Good
			East	3/11/2018	Insp4	Lace monitor (2w)	Good
			West	3/11/2018		Lace monitor (2w)	Good
			East	4/11/2018	Insp5	**Koala** (definite 1w) medium reptile (definite 1e) lace monitor (definite 1e)	Good
			West	4/11/2018		**Koala** (definite 1w) medium reptile (definite 1e) lace monitor (definite 1e)	Good
			East	5/11/2018	Insp6	Nil	Good
			West	5/11/2018		Nil	Good
			East	6/11/2018	Insp7	Nil	Good
			West	6/11/2018		Nil	Good
			East	7/11/2018	Insp8	Lace monitor (definite, 1w)	Good
			West	7/11/2018		Lace monitor (definite, 1w)	Good
3	495082	6606515	East	30/10/2018	Install	NA	
			West	30/10/2018		NA	
			East	31/10/2018	Insp1	Cat (definite, 3e, 2w)	Good
			West	31/10/2018		Cat (definite, 1e,1 canid (probable 1 e)	Good
			East	1/11/2018	Insp2	Cat (definite, 1e, 1 w)	Fair
			West	1/11/2018		Cat (definite, 2e, 1 w)	Fair
			East	2/11/2018	Insp3	Cat (probable 1w), Fox (definite 1e)	Fair
			West	2/11/2018		Cat probable (1 w), Fox (probable e)	Fair
			East	3/11/2018	Insp4	Cat (definite, 1 e 1w) fox(probable 1w)	Fair
			West	3/11/2018		Cat (definite, 1 e) fox (probable 1e1w)	Fair
			East	4/11/2018	Insp5	Fox(definite, 1e,1w) Brushtail possum (definite, 1w)	Poor
			West	4/11/2018		Fox(definite, 1e,1w) Brushtail possum (definite, 1w)	Poor
			East	5/11/2018	Insp6	Fox(definite 2e,1w)	Poor
			West	5/11/2018		Fox(definite 2e,1w)	Poor
			East	6/11/2018	Insp7	Fox(definite 1e,1w)	Poor
			West	6/11/2018		Fox(definite 1e, 1w)	Poor
			East	7/11/2018	Insp8	Fox (probable 1e) bandicoot (definite 1w)	Poor

Location	Easting	Northing	Sand pad	Date	Action	Species (direction & no passes)	Pad condition
			West	7/11/2018		Fox (probable 1e) bandicoot (definite 1w)	Poor
2	494477	6605329	East	30/10/2018	Install	NA	
			West	30/10/2018		NA	
			East	31/10/2018	Insp1	Nil	Good
			West	31/10/2018		Nil	Good
			East	1/11/2018	Insp2	Echidna(definite, 1 w/meander)	Good
			West	1/11/2018		Echidna(definite, 1e, 1w/meander)	Good
			East	2/11/2018	Insp3	echidna (definite, 1 w) dasyurid (possible 1w)	Good
			West	2/11/2018		echidna (definite, 1 w) dasyurid (possible 1w)	Good
			East	3/11/2018	Insp4	Nil	Fair
			West	3/11/2018		Nil	Good
			East	4/11/2018	Insp5	Echidna (definite 1w)	Good
			West	4/11/2018		Echidna (definite 1w)	Good
			East	5/11/2018	Insp6	Definite bandicoot (1e1w)	Fair
			West	5/11/2018		Definite bandicoot (1e1w)	Fair
			East	6/11/2018	Insp7	Fox (definite, 1w) echidna (probable 1e) dasyurid (possible 1e)	Fair
			West	6/11/2018		Fox (definite, 1w) echidna (probable 1e)	Fair
			East	7/11/2018	Insp8	Echidna (definite 1w), dasyurid (possible 2e 1w) rat sp(definite 1e)	Fair
			West	7/11/2018		Echidna (definite 1w), dasyurid (possible 1e 1w) rat sp(definite 1e)	Fair
1	489375	6594290	North	14/11/2018	Install		
			South	14/11/2018			
			North	15/11/2018	Insp 1	Nil	Dry
			South	15/11/2018		Medium bird (prob 1e)	Dry
			North	16/11/2018	Insp 2	Nil	Dry, water added
			South	16/11/2018		Nil	Dry, water added
			North	17/11/2018	Insp 3	Wallaby sp. (1/e)	Dry, water added
			South	17/11/2018		Nil	Dry, water added
			North	18/11/2018	Insp 4	Small bird (1/e)	
			South	18/11/2018		Small bird (1/w); small lizard (1/w)	
			North	19/11/2018	Insp 5	Nil	
			South	19/11/2018		Nil	
			North	20/11/2018	Insp 6	Nil	
			South	20/11/2018		Nil	
			North	21/11/2018	Insp 7	Nil	
			South	21/11/2018		Med reptile (def 1/?), small reptile (prob 1/?)	
			North	22/11/2018	Insp 8	Water bird (def 1/w)	
			South	22/11/2018		Waterbird (def 1/meander)	

Table B9: Scat and Track search data.

Site	Cell	Date	Check no.	Scats/tracks	Comments
1	Bridge	26/10/2018	1	Wallaby sp. tracks, fox scats, large amphibian scat.	Scat in front of cam on south side
		8/11/2018	2	Wallaby sp. tracks, Bandicoot scats, rodent scats, Wallaby sp. scats. Dead EW Dragon stuck in fauna fence.	
2	1	17/10/2018	1	Nil	
		31/10/2018	2	Nil	
3	1	17/10/2018	1	Rat scat ground (pic), Bird scat on rail and ground	
		31/10/2018	2	Miniopterus sp. x2, Large frog scat.	
4	1	17/10/2018	1	Nil	
		31/10/2018	2	Nil	
5	2	17/10/2018	1	Nil	
		31/10/2018	2	E. Water Dragon (full crossing), microbat scat, rodent tracks.	
6	1	17/10/2018	1	Nil	
		31/10/2018	2	Nil	
7	1	17/10/2018	1	Brushtail possum scat	On FF
		31/10/2018	2	Wallaby sp. scat, Brushtail possum scat.	CBtP prob on FF (location of scat)
8	1	17/10/2018	1	Nil	
		31/10/2018	2	Nil	
9 & 10	East	17/10/2018	1	Nil	
	West	17/10/2018	1	Nil	
	East	31/10/2018	2	Cat tracks, fox tracks	
	West	17/10/2018	2	Cat tracks, Rattus sp.	
11 & 12	West	16/10/2018	1	Nil	
	East	16/10/2018	1	Nil	
	West	31/10/2018	2	Nil	
	East	31/10/2018	2	Nil	

Appendix E Giant Barred Frog

Warrell Creek to Nambucca Heads

Interim Giant barred Frog Monitoring Report – spring year one operational phase

Roads and Maritime Services | December 2018

THIS PAGE LEFT INTENTIONALLY BLANK

Document Review

Date	Version	Status	Sent to	Represent	Delivered Format	Dispatched By
13/12/18	A	Draft	S. Hardiman	RMS	MSW	D. Rohweder

Document Distribution

Date	Version	Status	Sent to	Represent	Delivered Format	Dispatched By
19/12/2018	B	Final	S. Hardiman	RMS	MSW & PDF	D. Rohweder

Project team:

Dr D. Rohweder (project management, survey report writing)
Mr N. Priest (project management, field survey)

Report prepared for:

Roads and Maritime Services NSW

© Sandpiper Ecological Surveys 2018
ABN: 82 084 096 828

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

Cover Photo: NA.

Disclaimer:
This report has been prepared in accordance with the scope of services described in the contract or agreement between Sandpiper Ecological Surveys (ABN 82 084 096 828) and Pacific Complete. The report relies upon data, surveys and measurement obtained at the times and locations specified herein. The report has been prepared solely for Pacific Complete and Sandpiper Ecological Surveys accepts no responsibility for its use by other parties. Sandpiper Ecological Surveys accepts no responsibility or liability for changes in context, meaning, conclusions or omissions caused by cutting, pasting or editing the report.

Table of contents

1. Introduction 3
1.1 Background 3
1.2 Study area 4
2. Methodology 5
2.1 Timing and weather conditions 5
2.2 Frog survey 5
2.3 Tadpole survey 8
2.4 Habitat assessment 8
2.5 Water quality 8
3. Results and discussion 9
3.1 Frog survey 9
3.2 Tadpole survey 9
3.3 Habitat 10
3.3.1 Upper Warrell creek 10
3.3.2 Butchers Creek 10
3.4 Water quality 11
4. References 12
Appendix A – Weather conditions 13
Appendix B – Habitat data 14

List of tables

Table 1: Giant barred frogs captured during the spring 2018 survey at Upper Warrell creek... 9

Table 2: Results of water sample analysis for Upper Warrell creek and Butchers Creek. ID = insufficient data to derive a reliable trigger value (ANZECC 2000)..... 11

List of figures

Figure 1: Location of giant barred frog sample sites in relation to the WC2NH alignment. 4

Figure 2: Survey zones within the Upper Warrell creek sample site and location of spring 2018 giant barred frog records. 6

Figure 3: Survey zones within the Butchers Creek giant barred frog sample site. 7

List of plates

Plate 1: Female giant barred frog recorded at Upper Warrell Creek during the spring 2018 survey. 10

1. Introduction

In 2015, Roads and Maritime Services (RMS) NSW, in conjunction with Acciona Ferrovial Joint Venture (AFJV), commenced the upgrade of the Pacific Highway between Warrell Creek and Nambucca Heads (WC2NH). The WC2NH project was opened to traffic in two stages: stage 2a - 13.5km section from Lower Warrell Creek Bridge to Nambucca Heads opened on 18 December 2017; and stage 2b 6.25km section from the southern end of the project to the Lower Warrell Creek bridge opened in late June 2018.

Approvals for the WC2NH upgrade required monitoring of several species and mitigation measures during the operational phase. Species and mitigation measures targeted include koala, yellow-bellied glider, giant barred frog, green-thighed frog ponds, underpasses, vegetated median, roadkill, exclusion fence, and threatened flora. Sandpiper Ecological Surveys (SES) has been contracted by RMS to deliver the WC2NH operational ecological and water quality monitoring program.

The following report details the methods and results of spring year 1 operational phase giant barred frog population monitoring. The objective of giant barred frog monitoring is "To demonstrate through the life of the Project that mitigation has maintained or improved population sizes and habitat of the Giant Barred Frog. The use of preconstruction, during construction and post construction monitoring to measure frog distribution, abundance and habitat quality with defined thresholds will be used to measure the overall performance of the mitigation" (Lewis 2014a).

The following report presents and methods and results of the spring 2018 giant barred frog survey more detailed analysis of the giant barred frog population and habitat within the study area will be provided in the annual giant barred frog monitoring report, which is due in May 2019.

1.1 Background

The giant barred frog is listed as 'Endangered' under both the NSW *Biodiversity Conservation Act 2016* (BC Act) and Federal *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The impact of the upgrade on giant barred frog (*Mixophyes iteratus*) was assessed in the Project Environmental Assessment (Sinclair Knight Merz [SKM] 2010). Following identification of potential giant barred frog habitat during the Project environmental assessment Lewis Ecological conducted targeted surveys (in November 2011 and January/February 2013) (Lewis 2014a). A population of giant barred frog was subsequently confirmed at Upper Warrell Creek and a management strategy prepared (see Lewis 2014a). LSEP

Measures proposed to manage impacts on giant barred frogs included: population monitoring, pre-clearing surveys, temporary frog fencing during construction, clearing supervision, dewatering procedures (tadpoles surveys) and permanent frog exclusion fence. Population monitoring was recommended to occur within a 1km transect in spring, summer and autumn of Year 1 and 3 of the construction phase using the methods applied during pre-construction baseline surveys.

Pre-construction baseline surveys for giant barred frog were conducted between 20 September 2013 and 2 April 2014. The baseline surveys recorded 47 individuals within the 20 survey zones, including 22 adults (11 females & 11 males), 8 sub-adults, and 8 juveniles. Based on these results the population of giant barred frog at the Upper Warrell creek site was calculated as 45 adults (with a 1:1 sex ratio), 19 sub-adults, and 16 juveniles (Lewis Ecological 2014b). Geolink (2018) recalculated population size for baseline, year 1 and year 3 samples and obtained population estimates of 41 (2013/14), 7 (2015/16), and 8 (2017/18) respectively. The results suggest a substantial decline in population between 2013/14 and 2015/16.

During early construction work *Mixophyes* spp. tadpoles were recorded at Butchers Creek (Geolink 2015).

There was some conjecture about the identification of tadpoles and targeted surveys for adult frogs and further consultation with frog specialists was undertaken in an attempt to confirm the identification. The final consensus was that the tadpoles were great barred frog (*Mixophyes fasciolatus*) and the giant barred frog was unlikely to occur at Butchers Creek (see Geolink 2015; Lewis 2015). Nonetheless, a precautionary approach was adopted and the Butchers Creek site was included in population monitoring (Geolink 2016). No giant barred frogs were recorded at Butchers Creek during the construction phase (Geolink 2018).

1.2 Study area

The WC2NH project covers a total length of 19.75km and extends from Warrell Creek in the south to Nambucca Heads in the north (Figure 1). The alignment bypasses the town of Macksville and the northern section traverses Nambucca State Forest.

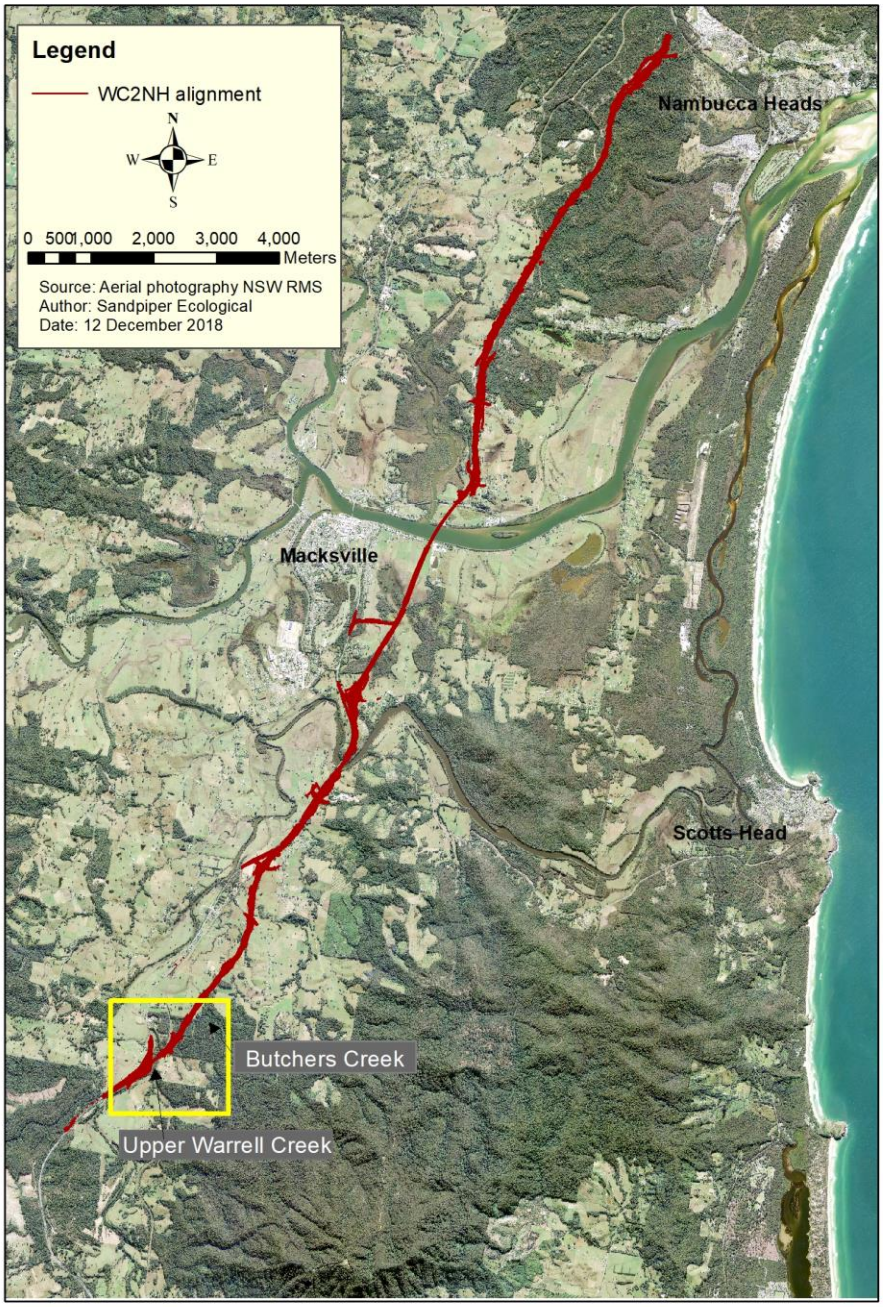


Figure 1: Location of giant barred frog sample sites in relation to the WC2NH alignment.

2. Methodology

2.1 Timing and weather conditions

The spring 2018 giant barred frog survey was conducted on 16 and 17 October 2018. The rainfall trigger of 10mm in a 24hr period measured at the WC2NH south compound project weather station was achieved. Rainfall continued after the initial trigger was achieved and a total of 142mm was recorded immediately prior to, and during, the survey. Rainfall resulted in elevated water levels at both sites and heavy rain during the later stage of the Upper Warrell Creek survey is likely to have reduced frog activity. The elevated water level at Upper Warrell Creek affected access to the creek bank. Relative humidity, air temperature, dew point and wind speed were all suitable for giant barred frog surveys (Table A1, Appendix A).

2.2 Frog survey

Frog surveys followed the method specified in the Brief and baseline population survey (Lewis 2014b). The method involved:

1. Two ecologists conducted a nocturnal meandering foot-based traverse of each 50m survey zone on each side of the watercourse i.e. 40 zones at Upper Warrell Creek (20/side; Figure 2); and 16 zones at Butchers Creek (8/side; Figure 3).
2. Each ecologist was equipped with a 200lumen spotlight and slowly traversed the riparian zone searching for frogs listening for calls. Giant barred frog calls were broadcast through a 5 watt megaphone for five minutes within each zone. Both ecologists listened for call responses during and immediately after call broadcast.
3. All captured giant barred frogs were scanned with a Trovan Nanotransponder to determine if that frog had been previously pit-tagged. If the captured individual had not been pit-tagged a tag was inserted beneath the skin on the right side and the insertion hole sealed with vetbond. The insertion point was swabbed with disinfectant prior to the tag being inserted.
4. Data collected on each captured frog included:
    a. Survey zone (20x50m).
    b. Distancefromthestreamedgemeasuredtothenearest0.1m.
    c. Position within the microhabitat (i.e. under litter, above litter, exposed, on rock/ log).
    d. Sex (male, female, unknown).
    e. Age class (adult=>60mm; sub-adult=40-60mm; juvenile=<40mm).
    f. Snout-vent length (mm).
    g. Weight (grams).
    h. Breeding condition:
        i. males assessed on the colouration of their nuptial pads (i.e. no colour, light, moderate, dark) in accordance with the classification developed by Lewis (2014);
        ii. females assessed based on whether they are gravid (i.e. egg bearing, with the typically adult weighing > 100 grams) or not gravid.
        iii. Frogs with a snout vent length of <60 mm were classified as immature.

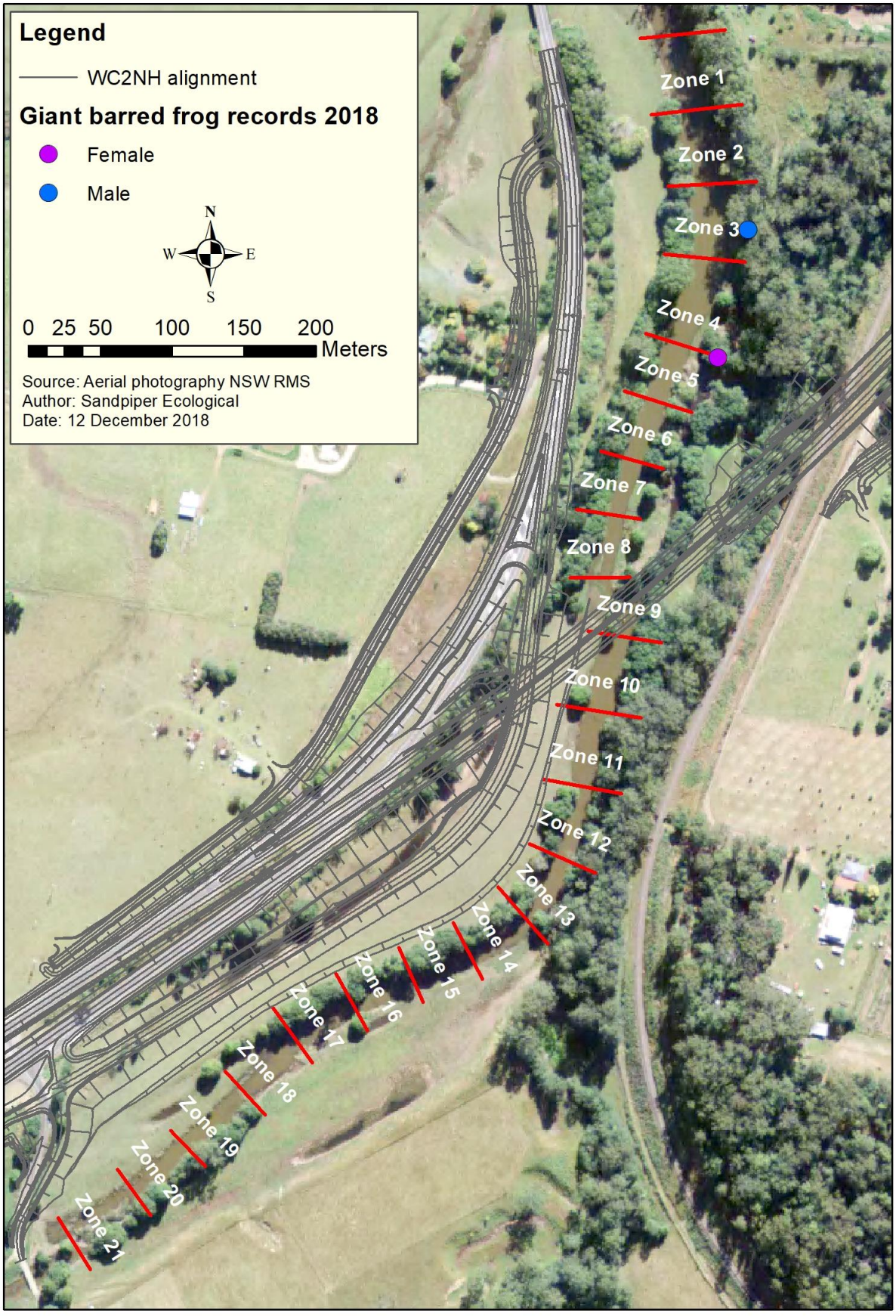


Figure 2: Survey zones within the Upper Warrell creek sample site and location of spring 2018 giant barred frog records.

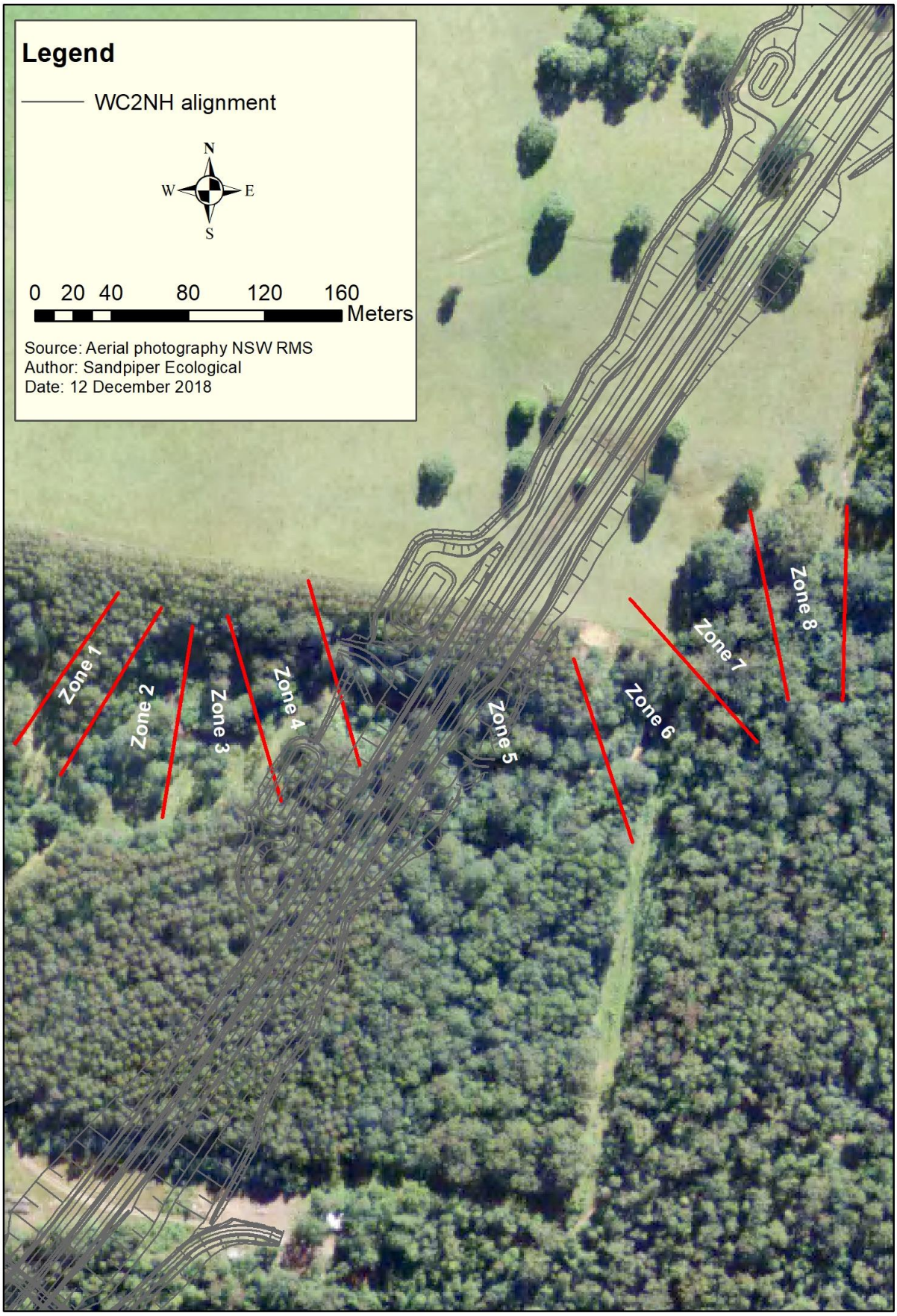


Figure 3: Survey zones within the Butchers Creek giant barred frog sample site.

2.3 Tadpole survey

Tadpole surveys were undertaken using the following procedure:

1. Dip-netting was undertaken by two ecologists within each survey zone. Dip-netting targeted areas of undercut bank and detritus.
2. One bait trap (~300 mm x 200 mm), baited with bread, was installed within each zone for a minimum of three hours. This equated to 20 bait traps in Upper Warrell Creek and eight bait traps in Butchers Creek.
3. The following information was collected for each tadpole:
    a. Survey zone (20x50m).
    b. Sex (male, female, unknown).
    c. Weight (grams).

2.4 Habitat assessment

Key habitat components in each survey zone are required to be sampled annually (i.e. once/year). Habitat assessment was abandoned during the spring survey due to the elevated water level at both Butchers Creek and Upper Warrell Creek.

The following habitat data were recorded in each zone at each site:

1. Land use: Description of existing land uses e.g. grazing, dairy, horticulture, conservation, private native forestry.
2. Broad vegetation type within the immediate riparian zone (primary stream bank): Riparian Rainforest, Dry Sclerophyll, Wet Sclerophyll, Sedgeland, Grassland or Cleared Land.
3. In stream physical characteristics including: stream width and depth(metres), presence of pools and/or riffles, bed composition (sand, clay, rock, organic or other to be specified), and type of emergent vegetation, if present.
4. Stream bank characteristics including bank profile expressed as steep, benched or a gradual incline from the water's edge.
5. Foliage projective cover of overstorey, midstorey and ground layer vegetation on the stream bank.
6. Groundcover expressed as a percentage of vegetation, leaf litter, soil, and exposed rock.
7. Litter depth - Deep (>10 mm); Moderate (20-100 mm); Shallow (>0-20 mm); or Absent (0 mm).

2.5 Water quality

Water samples and field measurements were taken at approximate locations E 489301 N 6594447 at Upper Warrell Creek and E 489642 N 6594927 at Butchers Creek. Single one-litre samples were collected at each site and placed immediately into an esky. Samples were analysed by the Environmental Analysis Laboratory (EAL), a NATA accredited laboratory, at Southern Cross University. Water quality parameters measured included:

1. Heavy Metals including arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc.
2. Nutrients including Nitrogen (as N), Suspended Solids and Total Phosphorus.
3. Turbidity and dissolved oxygen.
4. Hydrocarbons from the following groups:
    a. Naphthalene group including TRH>C10-C16, TRH>C10-C16 less Naphthalene (F2),

TRH>C16-C34, TRH>34-C40, TRH C6-C10 and TRH C6-C10 LESS BTEX (F1).

b. BTEX group including Benzene, Ethylbenzene, m&p-Xylenes, o-Xylene, Toluene and Xylenes – total.

Field physicochemical measurements including Conductivity, pH, and Temperature, were measured using a Horiba Laqua PC110 portable water quality meter.

3. Results and discussion

3.1 Frog survey

A total of 14 person hours were spent conducting nocturnal frog surveys, 11 hours at Upper Warrell Creek and 5 hours at Butchers Creek. No giant barred frogs were recorded at Butchers Creek. Two adult giant barred frogs, one male and one female, were recorded at Upper Warrell Creek (Table 1). The male frog was a recapture that was originally captured and micro-chipped on 7 February 2018. The captured female was the largest recorded over the monitoring period with a weight of 173 grams and snout-vent length of 101.5mm (Plate 1). The female was considered gravid based on weight, size and shape.

Both captures occurred on the north bank downstream of the alignment, with the male captures in zone six and the female in zone eight. Both individuals were initially observed on top of the leaf litter. The male was recorded near a small flooded tributary close to its original point of capture. The female was recorded on the main creek bank.

Table 1: Giant barred frogs captured during the spring 2018 survey at Upper Warrell creek.

Upper Warrell Creek	Frog 1	Frog 2
Capture date	17/10/18	17/10/18
Zone	4/5	3
Creek side	N	N
GPS location	489351, 6594448	489372, 6594537
Distance from stream edge (nearest 0.1m)	3.4	4.05
Position in micro-habitat*	On leaf litter	On leaf litter
Sex**	Female	Male
Age***	Adult	Adult
S/V length	101.5mm	77.1mm
Weight	173g	67g
Breeding condition[#]	Gravid	Moderate
Microchip ID (new or re-capture)	New: 991001000620130	Recapture: 00078ABB9B

*Microhabitat: under leaf litter, under veg, on leaf litter, exposed, on a log/rock etc.
**Sex: Frogs >78mm were deemed female unless heard calling.
***Age: >60mm = adult, 40-60mm = sub, <40mm = Juv.
[#]Breeding: Males: colour of nuptial pads; light/moderate/dark/no colour. Females: Gravid, typically weighing >100g. Immature: SV length <60mm.

3.2 Tadpole survey

No tadpoles were recorded during the spring 2018 survey.

Plate 1: Female giant barred frog recorded at Upper Warrell Creek during the spring 2018 survey.

3.3 Habitat

3.3.1 Upper Warrell creek

High water level at Upper Warrell Creek affected the habitat assessment at that site as the immediate bank and bank vegetation was inundated. Habitat at Upper Warrell Creek ranges from grassland to moderate quality riparian and wet sclerophyll forest with a dense litter layer (Appendix B). Parts of the Upper Warrell Creek study area contained fragmented riparian forest that is grazed. The width of riparian vegetation varied throughout the site but in virtually all zones was restricted to the bank. Leaf litter cover ranged from high (>75%) in areas with an intact riparian zone to low (<40%) in cleared and grazed areas. One notable aspect of concern was growth of pigeon grass (*Setaria sphacelata*) and broad-leaved paspalum (*Paspalum mandiocanum*) on the north bank in zones 4 and 5. Whilst giant barred frogs have been recorded in broad-leaved paspalum, pigeon grass may create a barrier to movement when it occurs in dense clumps.

3.3.2 Butchers Creek

Habitat at Butchers Creek varied substantially across the transect. West of the alignment habitat was dominated by a narrow degraded riparian zone was predominantly cleared immediately prior to the survey commencing. East of the alignment habitat was characterised by wet sclerophyll forest that extended well beyond the riparian zone. The substrate consisted of rock and gravel with a steep bank and gravel bars. Leaf litter cover varied from 25 to 80% and ground vegetation cover from 10 to 60%. Habitat at Butchers

Creek did not contain the moist micro-climate that is typical of many giant barred frog habitats. The site lacked continuous overhanging riparian vegetation and thick dense leaf litter required to create moist ground conditions.

3.4 Water quality

Most water quality parameters were within the ANZECC trigger values for freshwater ecosystems in south eastern Australia (Table 2). Exceptions were Total phosphorus and Total nitrogen, and dissolved oxygen at Warrell Creek. Phosphorus and nitrogen levels exceeded the ANZECC threshold and dissolved oxygen was below the ANZECC threshold. Nitrogen and phosphorus values exceeded thresholds during the 2017/18 sample period. Elevated nutrients recorded in spring 2018 are attributed to recent run-off from adjoining farmland after a period of dry weather and the result is not of concern.

Table 2: Results of water sample analysis for Upper Warrell creek and Butchers Creek. ID = insufficient data to derive a reliable trigger value (ANZECC 2000).

Parameter	Warrell Creek	Butchers Creek	ANZECC/ARMCANZ Trigger value for freshwater (95% species level of protection)
Temperature (^{0}C)	19.6	18.5	
pH	6.7	6.9	6.5-8.0
Conductivity (us/cm)	256	110	125-2200
Dissolved oxygen (mg/L O_2)	8.4	9.0	9-10.5
Total Suspended Solids (mg/L)	9	1	
Turbidity (NTU)	18	17	6-50
Total Phosphorus (mg/L P)	0.04	0.02	0.025
Total Nitrogen (mg/L N)	0.49	0.19	0.35
BTEX			
Benzene (µg/L or ppb)	<0.5	<0.5	950
Toluene (µg/L or ppb)	<0.5	<0.5	ID
Ethylbenzene (µg/L or ppb)	<0.5	<0.5	ID
m+p-Xylene (µg/L or ppb)	<1	<1	200
o-Xylene (µg/L or ppb)	<0.5	<0.5	350
Naphthalene (µg/L or ppb)	<0.5	<0.5	16
Total Recoverable Hydrocarbons (TRH)			
C6-C9 Fraction (µg/L or ppb)	<40	<40	ID
C10-C14 Fraction (µg/L or ppb)	<50	<50	ID
C15-C28 Fraction (µg/L or ppb)	<200	<200	ID
C29-C36 Fraction (µg/L or ppb)	<200	<200	ID
C10-C16 Fraction (µg/L or ppb)	<60	<60	ID
C10-C16 less Naphthalene Fraction (µg/L or ppb)	<60	<60	ID
C16-C34 Fraction (µg/L or ppb)	<500	<500	ID
C34-C40 Fraction (µg/L or ppb)	<500	<500	ID

4. References

ANZECC/ARMCANZ (2000). *Australian and New Zealand Guidelines for Fresh and Marine Water Quality – Vol 1.* Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.

Geolink (2018). *Annual report – WC2NH giant barred frog population monitoring 2017/2018 – year 3*. Report prepared for Pacifico.

Geolink (2015). *WC2NH Butchers Creek – Mixophyes unexpected find summary*. Letter report prepared for Pacifico.

Geolink (2016). *Annual report – WC2NH giant barred frog population monitoring*. Report prepared for Pacifico.

Lewis, B. D. (2014a). *Warrell Creek to Urunga: giant barred frog management strategy*. Report prepared for the Roads and Maritime Services by Lewis Ecological Surveys.

Lewis, B. D. (2014b). *Warrell Creek to Nambucca Heads: giant barred frog pre-construction baseline monitoring*. Report prepared for the Roads and Maritime Services by Lewis Ecological Surveys.

Lewis, B. D. (2015). *Giant barred frog (Mixophyes iteratus): design review at Butchers Creek following discovery of tadpoles.* Letter report prepared for Pacifico by Lewis Ecological Surveys.

SKM (2010). *Environmental Assessment Volume 2 - Working paper 1 Flora and Fauna.* January 2010 for Roads and Traffic Authority.

Appendix A – Weather conditions

Table A1: Weather during and immediately prior to the spring 2018 giant barred frog survey.

Site	Date	Start/ Finish	Time	Rainfall (present)	Rainfall (prev 24hr)	Rainfall (prev 7 days)	Rainfall (prev 30 days)	RH	Temp	Dew point	Wind (0=no wind, 1= rustles leaves, 2 = branches moving, 3 - canopy moving)
Butchers Creek	16/10/18	Start	2010	Nil	30	142.2	181.4	94.5	19.5	18.5	0
		Finish	2210	Moderate				100	18.9	19.4	0
Warrell Creek	17/10/18	Start	1949	Nil				100	20.7	21.3	2
		Finish	0049	Moderate				100	20.2	21.8	2

Appendix B – Habitat data

Table B1: Habitat data collected in 21 zones at Upper Warrell Creek

Zone	Landuse (E&W)	Broad veg community (E&W)	In-stream physical characteristics (logs, boulders etc)	Stream width	Stream depth	Presence of pools or riffles	Bed composition	Emergent veg
1	Agriculture	Wet sclerophyll	Silt & sand; occ logs	40m	>1m	P	Uk	Absent
2	Agriculture	Wet sclerophyll	Silt & sand; occ logs	40m	>1m	P	Uk	Absent
3	Agriculture	Riparian/ wet sclerophyll	Silt & sand; occ logs	40m	>1m	P	Uk	Absent
4	Agriculture	Riparian/ wet sclerophyll	Silt & sand; occ logs	40m	>1m	P	Uk	Absent
5	Agriculture	Riparian	Silt & sand; occ logs	40m	>1m	P	Uk	Absent
6	Road reserve/ conservation	Riparian	Lateral vegetated bar; occ logs o/h vegt	35m	>1m	P	Uk	Absent
7	Road reserve	Riparian	Occ logs; overhanging veg;	40m	>1m	P	Uk	Absent
8	Road reserve	Riparian/ cleared	Boulders; occ logs	25-40m	>1m	P/R	Uk	Absent
9	Road reserve	Cleared land	Boulders; occ logs	25-40m	>1m	P/R	Uk	Absent
10	Agriculture / road reserve	Riparian / cleared	Occ logs	45m	>1m	P	Uk	Absent
11	Utility corridor	Wet sclerophyll/ grassland	Occ logs & fallen trees; prob silty substrate	25m	>1m	P	Uk	Present
12	Utility corridor	Wet sclerophyll/ grassland	Freq logs & fallen trees; prob silty substrate	25m	>1m	P	Uk	Present
13	Utility corridor	Riparian	Occ logs & fallen trees; prob silty substrate	20m	>1m	P	Uk	Present
14	Utility corridor	Riparian	Logs, fallen trees, mat rush on bank, bank slumping,	20m	>1m	P	Uk	Absent
15	Agriculture / road reserve	Riparian / grassland	Rare logs; persicaria & grasses & mat rush on bank;	25-30m	>1m	P	Uk	Absent
16	Agriculture / road reserve	Riparian / grassland	Rare logs; persicaria & grasses & mat rush on bank;	25-30m	>1m	P	Uk	Absent
17	Agriculture / road reserve	Riparian / grassland	Rare logs; persicaria & grasses & mat rush on bank;	25-30m	>1m	P	Uk	Absent
18	Agriculture / road reserve	Riparian / grassland	Occ logs; persicaria & grasses on bank; back channel	30m	>1m	P	Uk	Absent
19	Agriculture / road reserve	Riparian / grassland	Occ logs; persicaria & grasses on bank; back channel	20m	>1m	P	Uk	Absent
20	Agriculture / road reserve	Riparian / grassland	Occ logs; persicaria & grasses on bank; back channel	20m	>1m	P	Uk	Absent
21	Agriculture / road reserve	Riparian / grassland	Occ logs; occ mat rush clumps; back channel	20m	>1m	P	Uk	Absent

Table B2: Habitat data collected in 21 zones at Upper Warrell Creek.

Zone	Stream bank characteristics	Bank profile	Bank vegetation cover	Groundcover composition	Depth of leaf litter	Tadpoles (trap) weight, sex, location.	Tadpoles (dip net) weight, sex, location.
1	High bank on nth; clumping vegt ; undercuts; cleared south bank	Steep	40.0%	30% vegt; 50% litter; 20% bare	30mm	Nil	Nil
2	High bank on nth; clumping vegt ; undercuts	Steep	60.0%	25% vegt; 50% litter; 25% bare	30mm	Nil	Nil
3	High bank on nth; clumping vegt ; undercuts	Steep both banks	60.0%	25% vegt; 70% litter; 5% bare	20mm	Nil	Nil
4	Grassy patches with leaf litter	Sloping - moderate	60.0%	60% litter; 20% vegt; 20% bare	30mm	Nil	Nil
5	Grassy patch; established riparian vegt	Benched on nth; steep on Sth	75%	30% veg; 55% litter; 15% bare	30mm	Nil	Nil
6	Clumps of lomandra, logs, grasses and litter, lantana	Steep; gentle on central bar		60% veg; 35% litter; 5% logs	30mm	Nil	Nil
7	Clumps of lomandra, logs, grasses and litter	Steep; central island = gentle slope	75%%	50% veg; 40% litter; 10% logs	40mm	Nil	Nil
8	Rock, grasses,	Gentle to mod slope	10.0%	50% veg; 50% rock	10mm	Nil	Nil
9	Rock & grasses	Gentle slope	10.0%	50% veg; 50% rock	Nil	Nil	Nil
10	Undercuts; clumping vegt	Steep & short on Sth; sloping (mod) & tall on nth	50.0%	30% veg; 50% litter; 20% bare	10mm	Nil	Nil
11	Undercuts; clumping vegt; artificial rock	Steep east, benched west	50.0%	55% vegt; 30% litter; 15% bare	10mm	Nil	Nil
12	Silty, undercuts, mat rush; some erosion of inside bank	Vertical on west, steep slope on east	40.0%	60% vegt; 30% litter; 10% bare	20mm	Nil	Nil
13	Silty, undercuts, mat rush, woody debris	Verticals & steep slope	75%	40% vegt; 50% litter; 10% bare	40mm	Nil	Nil
14	Silty, undercuts, mat rush, o/h vegt	Vertical on west, steep slope on east	90.0%	30% vegt; 50% litter; 20% bare	50mm	Nil	Nil
15	Silty, o/h vegt, narrow rip zone, one bank cleared; cleared bank benched	Steep; cleared bank benched	35%	60% vegt; 25% litter; 15% bare	20mm	Nil	Nil
16	Silty, o/h vegt, narrow rip zone, one bank cleared; cleared bank benched	Steep; cleared bank benched	30.0%	60% vegt; 25% litter; 15% bare	20mm	Nil	Nil
17	Silty, o/h vegt, narrow rip zone, one bank cleared; cleared bank benched	Steep; cleared bank benched	40.0%	60% vegt; 20% litter; 20% bare	20mm	Nil	Nil
18	Silty, o/h vegt, narrow rip zone, one bank cleared	Steep; cleared bank benched	40.0%	60% vegt; 20% litter; 20% bare	20mm	Nil	Nil
19	Silty, o/h vegt, narrow rip zone, one bank cleared	Steep; cleared bank benched	35%	50% vegt; 20% litter; 30% bare	<10mm	Nil	Nil
20	Silty, o/h vegt, narrow rip zone, one bank cleared	Steep; cleared bank benched	35%	50% vegt; 20% litter; 30% bare	<10mm	Nil	Nil
21	Silty, sparse vegt	Steep; cleared bank benched	25%	55% vegt; 20% litter; 25% bare	<10mm	Nil	Nil

Table B3: Habitat data collected in 8 zones at Butchers Creek.

Site	Zone	Landuse (E&W)	Broad veg community (E&W)	In-stream physical characteristics (logs, boulders etc)	Stream width	Stream depth	Presence of pools or riffles	Bed composition	Emergent veg
Butchers Creek	1	Agriculture / cleared (imm prior to survey	Wet sclerophyll / cleared	Rock/ gravel / silt	1-4m	1M	P/R	Rock & sand	Absent
Butchers Creek	2	Agriculture / cleared (imm prior to survey	Wet sclerophyll / cleared	Rock/ gravel / silt	2-7m	0.8M	P/R	Rock & sand	Absent
Butchers Creek	3	Agriculture	Wet sclerophyll / cleared	Rock/ gravel / silt	2-7m	>1.5m	P/R	Rock / gravel	Absent
Butchers Creek	4	Road reserve / conservation	Grassland & wet sclerophyll	Rock/ gravel; occ logs	1-6m	0.6M	P/R	Rock	Absent (mat rush due to higher water level)
Butchers Creek	5	Conservation/ forestry	Wet sclerophyll	Rock/gravel bed; occ logs	1-4.5m	0.4M	P/R	Rock/coarse gravel	Absent
Butchers Creek	6	Conservation/ forestry	Wet sclerophyll (flooded gum)	Rock/ coarse gravel bed; rare log	1-7m	0.4M	P/R	Rock/ coarse gravel	Absent
Butchers Creek	7	Conservation/ forestry	Wet sclerophyll (flooded gum)	Rock/ coarse gravel bed; rare log	1.5-5m	0.75M	P/R	Rock/ coarse gravel	Absent
Butchers Creek	8	Agriculture/ forestry	Wet sclerophyll	Rock / coarse gravel	1.5-6m	>1m	P/R	Rock/ coarse gravel	Absent

Table B4: Habitat data collected at 8 zones at Butchers Creek.

Zone	Stream bank characteristics	Bank profile	Bank vegetation cover	Groundcover composition	Depth of leaf litter	Tadpoles (trap) weight, sex, location.	Tadpoles (dip net) weight, sex, location.
1	Benched with steep sections	NR	20.0%	10% veg; 80% litter; 10% soil	10mm	Nil	Nil
2	Benched with gentle slope in places	NR	40.0%	25% veg; 25% rock; 25% litter; 25% soil	10mm patchy	Nil	Nil
3	Steep	NR	60.0%	20% veg; 60% litter; 15% bare; 5% rock	20mm	Nil	Nil
4	Steep	NR	45%	60% veg; 40% litter	20mm patchy	Nil	Nil
5	Benched with gravel bars	NR	50.0%	40% veg; 10% rock; 15% sand; 35% litter	10mm	Nil	Nil
6	Benched with gravel bars	NR	40.0%	10% veg; 20% rock; 70% litter	10mm	Nil	Nil
7	Benched with gravel bars	NR	70.0%	15% veg; 20% rock; 25% leaf; 40% bare	10mm	Nil	Nil
8	Benched with gravel bars	NR	45%	20% veg; 20% rock; 45% litter; 15% soil		Nil	Nil

rms.nsw.gov.au

13 22 13

Customer feedback
Roads and Maritime
Locked Bag 928,
North Sydney NSW 2059

December 2018

Appendix F Microbat habitat

ABN 79 896 839 729
ACN 101 084 557

Return address:
PO Box 119
LENNOX HEAD
NSW 2478

LENNOX HEAD
T 02 6687 7666
F 02 6687 7782

COFFS HARBOUR
T 02 6651 7666
F 02 6651 7733

www.geolink.net.au

13 November 2018
Ref No.: 2378-1470

Pacifico
124 Albert Drive
DONNELLYVILLE NSW 2447

Attention: Mr Jason Haslett

WC2NH Microbat Habitat Flyway Monitoring Report - October 2018

Introduction

GeoLINK has been engaged by Pacifico to undertake microbat flyway monitoring for the Warrell Creek to Nambucca Heads (WC2NH) Pacific Highway upgrade. In accordance with monitoring requirement *G2 Habitat Monitoring:*

Habitat monitoring would focus on inspections of the riparian zone to assess whether flyways have been constricted as part of construction works. Therefore, on either side of the construction corridor, a photo point would be installed and a visual assessment be undertaken to gauge whether the flyway has been maintained or is in need of corrective actions (i.e. vegetation management). Monitoring of water quality would also be undertaken.

This report presents the findings of the microbat flyway monitoring for the last four months of year 4 of the construction stage of the project (July to October 2018) and is the final monitoring event for the project. These results are compared with all construction phase monitoring results. Monitoring of microbat flyways has been undertaken monthly during years 1, 3 and 4 of construction as outlined in the *WC2NH Ecological Monitoring Program* (Lewis, 2014).

Methodology

In order to monitor potential microbat flyways, the following riparian zones have been nominated as monitoring sites:

- Crouches Creek;
- Rosewood Creek;
- Butchers Creek;
- Un-named tributary near Cockburns Lane (Cockburns Creek); and
- Upper Warrell Creek (UWC).

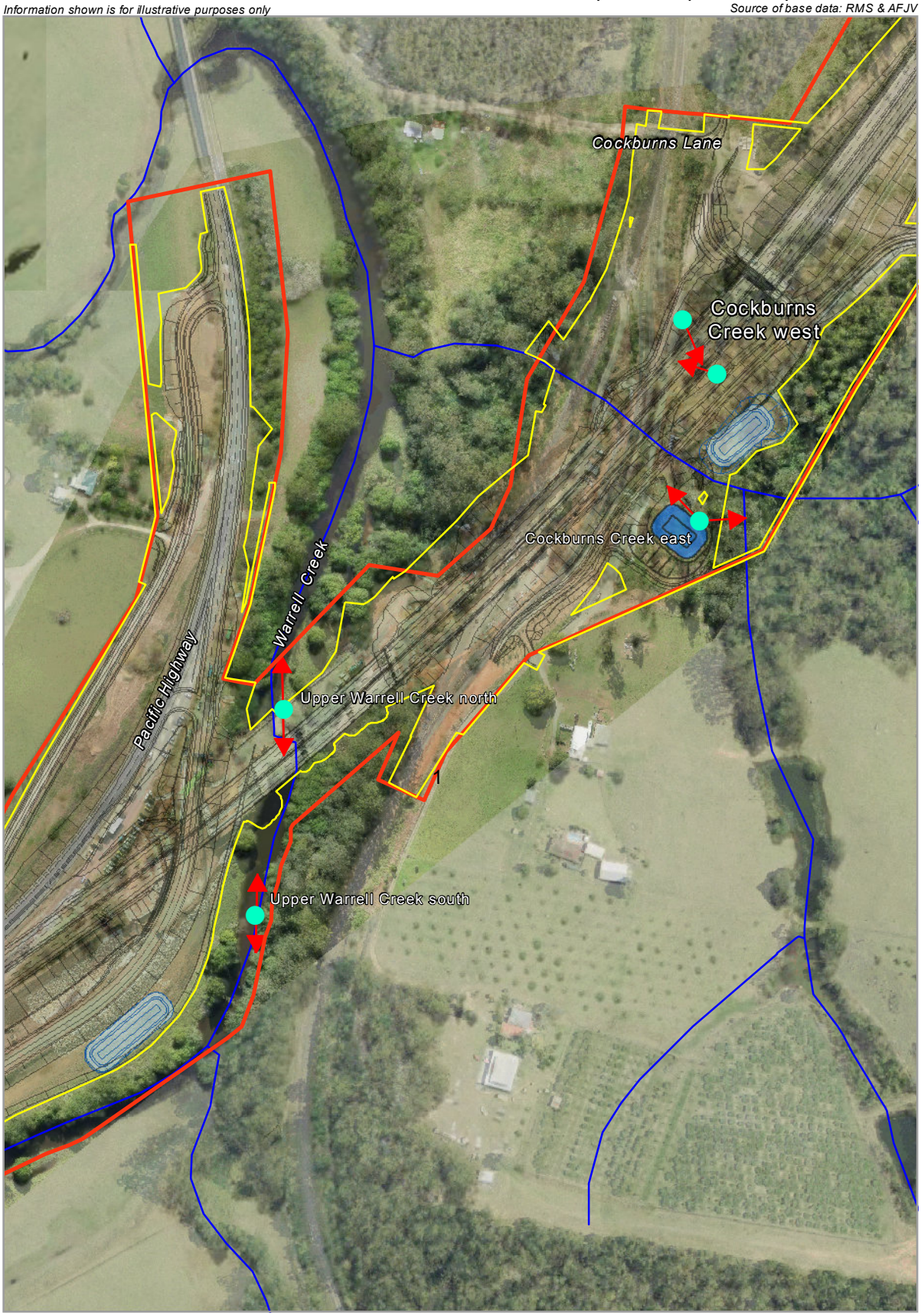
Two photo points, one on either side of the nominated creek, have been established. Photographs were taken looking towards the highway construction zone and towards the intact riparian zone adjacent (refer to **Illustrations 1.1** to **1.4** for photo point locations). Global Positioning System (GPS) coordinates for the photo point locations are provided in **Table 1**. Due to relocation of the railway alignment, the Cockburns Creek western photo point has been repositioned with updated coordinates provided in **Table 1**. The condition of the flyway habitat was recorded, noting changes to the quality of the flyway or any visible obstructions.

Urban and Regional Planning | Environmental Engineering | Civil Design | Environmental Impact Assessment | Ecological Surveys and Monitoring | Landscape Architecture | Urban Design | Coastline and Waterways Management

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 06/11/2018

Information shown is for illustrative purposes only

Source of base data: RMS & AFJV



LEGEND

- Site Boundary
- Clearing Limit
- Watercourse
- Microbat Habitat Flyway Photo Points
- Photopoint direction

0 80

Microbat Flyway Photo Locations

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 06/11/2018
Source of base data: RMS & AFJV

Information shown is for illustrative purposes only

LEGEND

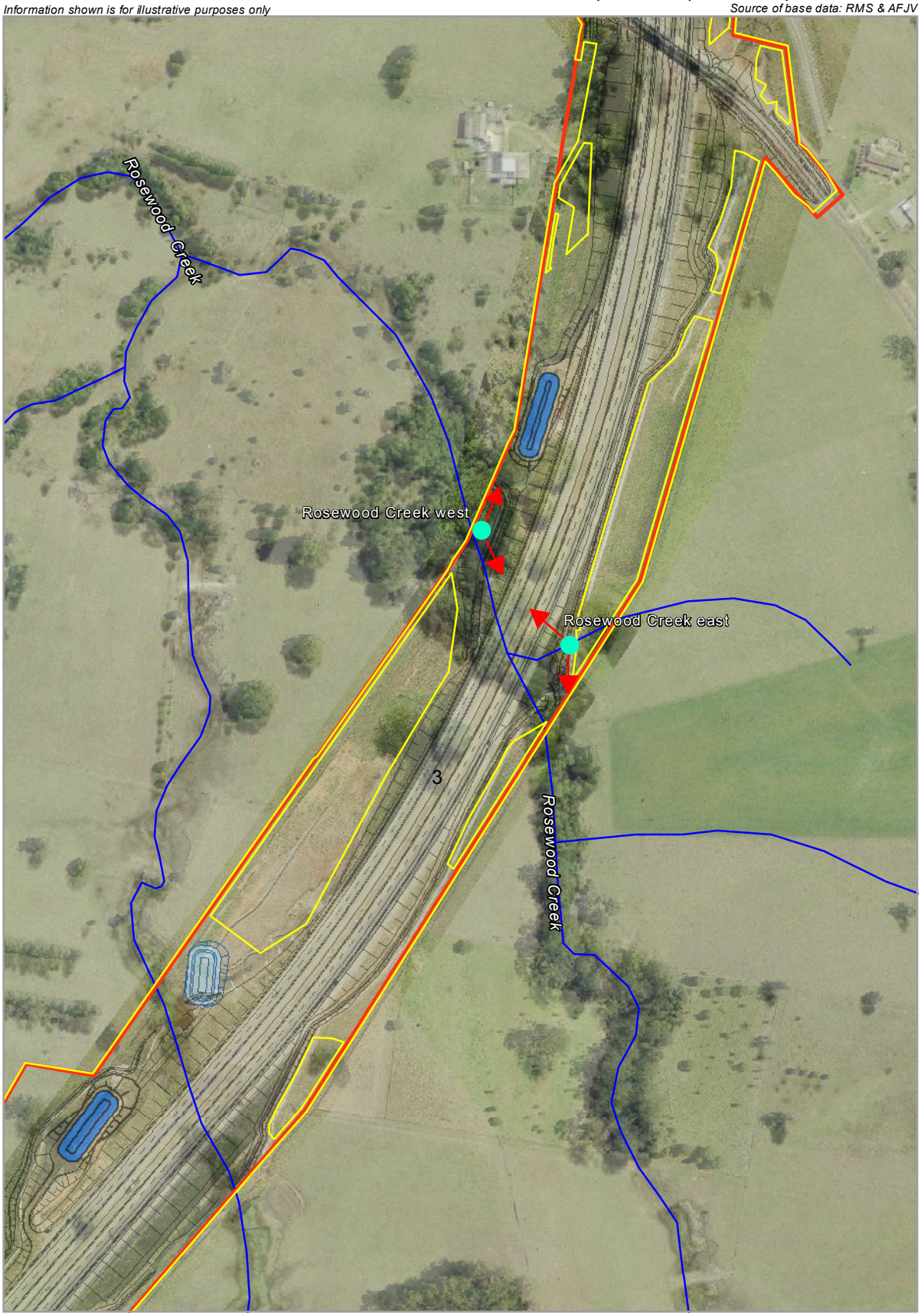
- Site Boundary
- Clearing Limit
- Watercourse
- Microbat Habitat Flyway Photo Points
- Photopoint direction

0 80

Microbat Flyway Photo Locations

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 06/11/2018
Source of base data: RMS & AFJV

Information shown is for illustrative purposes only



LEGEND

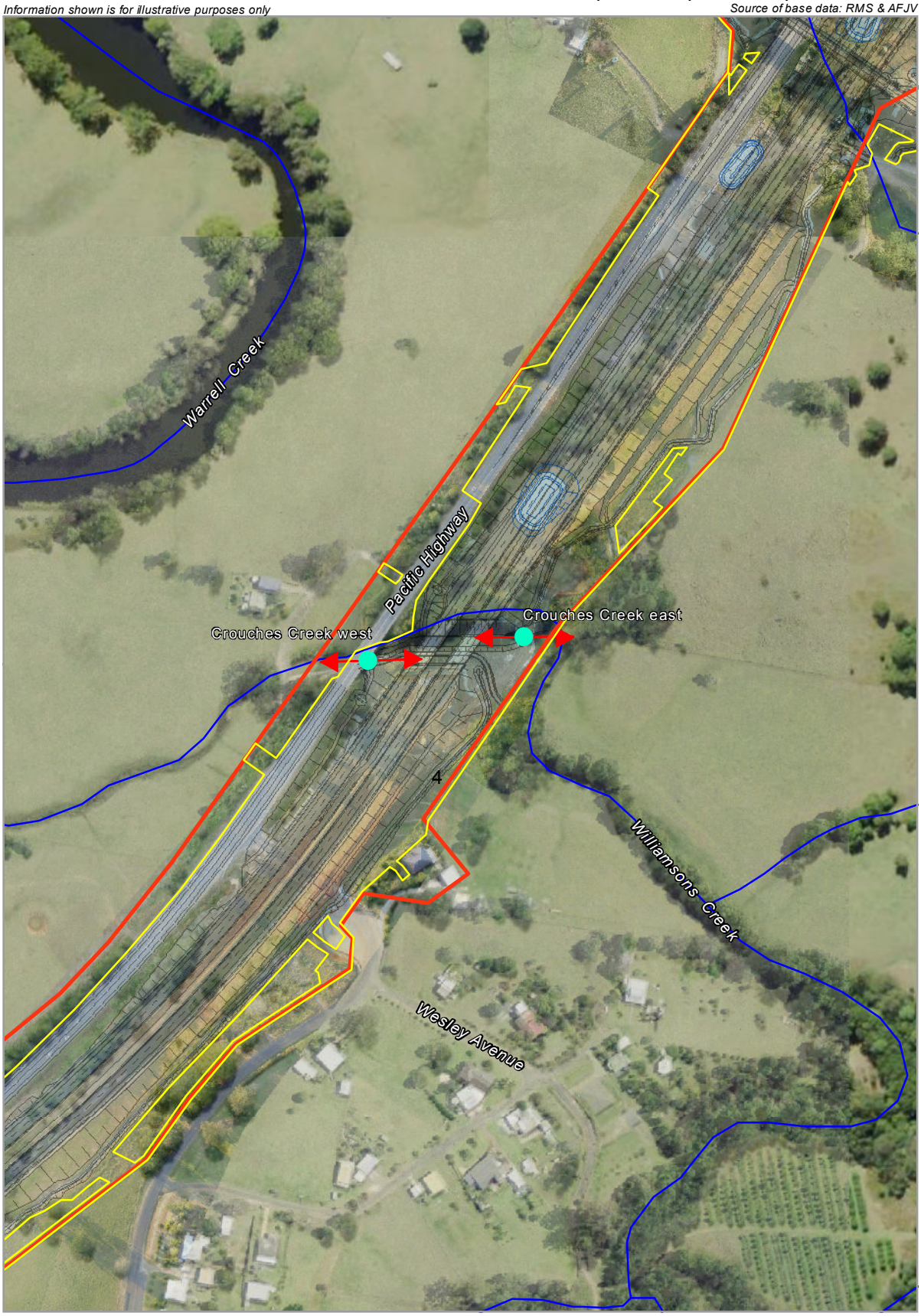
- Site Boundary
- Clearing Limit
- Watercourse
- Microbat Habitat Flyway Photo Points
- Photopoint direction

0 80

Microbat Flyway Photo Locations

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 06/11/2018
Source of base data: RMS & AFJV

Information shown is for illustrative purposes only



LEGEND

- Site Boundary
- Clearing Limit
- Watercourse
- Microbat Habitat Flyway Photo Points
- Photopoint direction

0 80

Microbat Flyway Photo Locations

Dates on which monthly flyway monitoring occurred during the reporting period are as follows:

- 25 July 2018
- 31 August 2018
- 19 September 2018
- 23 October 2018.

Table 1 Flyway Photo Point Monitoring GPS Coordinates (GDA 94)

Photo Point Location	*Easting*	*Northing*
Crouches Creek east	491686	6598052
Crouches Creek west	491579	6598035
Rosewood Creek east	490758	6596127
Rosewood Creek west	490696	6596206
Butchers Creek east	489855	6594879
Butchers Creek west	489766	6594934
Cockburns Creek east	489569	6594435
Cockburns Creek west looking southeast	489557	6594574
Cockburns Creek west looking east	489580	6594536
Upper Warrell Creek south	489262	6594163
Upper Warrell Creek north	489282	6594305

Results

A total of five riparian sites were monitored, with four photographs taken at each site. A comparison of photos between the first and last monitoring sessions listed below are provided in **Appendix A**.

- Year 1 of construction – April 2015 and January 2016
- The first six months of year 3 – February 2017 and July 2017
- The last six months of year 3 – August 2017 and January 2018
- The first six months of year 4 – February 2018 and June 2018
- The last four months of year 4 – July 2018 to October 2018.

Records of all photos taken are available upon request. An assessment of impacts/ changes for each flyway site is provided in the **Table 2**.

Table 2 Flyway Photo Point Monitoring Results

Site	*Impacts/ Changes*	*Weed Control Required*
Crouches Creek	Substantial changes have occurred within the site associated with the Crouches Creek Bridge construction. However, the bridge does not constrict potential flyways and no weed infestations or vegetation overgrowth has been recorded. Crouches Creek remains unobstructed as a potential flyway. No significant change to flyway opportunities has occurred since the June 2018 monitoring report was issued.	No
Rosewood Creek	Construction in this area has substantially altered the riparian zone reducing the quality of the flyway. Whilst the terrain has changed in this area, aerial passage of microbats is possible over the alignment. Under passage options are also possible through the culvert. Batters hydroseeded with native seed mix have struck, moderate growth of native species is now present.	No
Butchers Creek	Despite substantial changes within the construction site associated with the Butchers Creek culvert, the potential flyway associated with Butchers Creek remains unobstructed. Dense Small-leaved Privet and Lantana grow along the riparian zone to the west (outside) of the project boundary at this location.	No
Cockburns Creek	Substantial changes associated with earthworks have reduced the quality of the flyway due to the removal of vegetation and placement of fill. However, the area remains unobstructed and capable of providing aerial passage above the highway alignment for microbats. Where the basin to the east has been hydroseeded at the beginning of the year, Acacia saplings have grown and are beginning to obstruct the lower levels of the flyway in an east to westerly direction (refer to **Plates 1.125 to 1.130**).	No
Upper Warrell Creek (UWC)	Despite the construction of the temporary creek crossing (removed in June 2018) over the creek involving minor clearing of the riparian zone and the construction of the UWC Bridge, the potential flyway remains largely unobstructed and capable of supporting microbat aerial passage under the bridge. No significant change to flyway opportunities have occurred since the June 2018 monitoring report was issued.	No

Discussion

The last four months of construction phase microbat flyway monitoring (July to October 2018) has recorded little to no change when compared to the previous five months monitoring event (February to June 2018). However, the general findings of the monitoring to date indicate substantial changes associated with flyways as a result of highway construction. Due to the required clearing and construction of the highway, the quality of flyways has been reduced; particularly for the Cockburn and Rosewood Creek riparian zones where the previously continuous vegetation has been intercepted by the highway alignment and substantial placement of fill embankments. Although there is limited to no under passage flyway options to adjacent vegetation at Cockburn Creek, flyway passage above the highway alignment is still viable at this location.

Crouches Creek, Rosewood Creek, Butchers Creek and Upper Warrell Creek all provide flyway opportunities beneath the highway to adjacent vegetation by way of fauna underpass structures (two culverts and two bridges). Above highway flyway opportunities are also possible at these locations however due to the road height in relation to the adjacent vegetation (particularly Rosewood and Cockburns Creek), there is potential increased risk that microbats will fly over the road in the path of passing vehicles.

Rosewood Creek and Butchers Creek box culverts have both recorded occupancy by roosting microbats within the segment joint gaps during and since their construction (GeoLINK, 2016 and 2017).

Retained areas of vegetation outside the alignment remain unobstructed or as they naturally existed prior to construction and are generally free of fallen trees or weed infestations which may obstruct flyways. The exception is the western side of Butchers Creek, where dense infestations of Lantana and Small-leaved Privet occur outside of the project footprint (which existed prior to construction).

Water quality monitoring for the subject sites (flyways) has been undertaken routinely by Pacifico and is available on request. The water quality of the associated waterways has been managed in accordance with the *Soil and Water Quality Management Plan*.

No remediation measures are currently required for microbat flyways. Operational phase flyway monitoring will continue and identify if maturing landscaped vegetation obstructs the flyways.

Conclusion

Recent monitoring has recorded no significant change to microbat flyway habitat when compared with the previous five-month monitoring event. Microbat flyway monitoring to date has indicated that the flyways are largely unobstructed by vegetation overgrowth or weeds and therefore no management actions such as weed control or vegetation management within microbat flyway habitat are required.

While riparian vegetation is intercepted by construction of the highway, flyway opportunities are provided via under passage (via bridges or culverts) or viable aerial passage above the highway, hence satisfying the objectives of the *Microchiropteran Bat Management Strategy* (Lewis, 2014).

It is understood that the October 2018 monitoring report will be the last construction phase monitoring report, due to the switch from construction to operational phase monitoring. Both Stage 2A and Stage 2B have been operational and open to traffic since June 2018.

Please feel free to contact me should you require any additional information.

Yours sincerely
GeoLINK

Jessica O'Leary
Ecologist

References

Lewis, B (2014). *Warrell Creek to Urunga Microchiropteran Bat Management Strategy*. Unpublished report to *Roads and Maritime Service, NSW.*

Lewis, B (2014). *Warrell Creek to Urunga Pacific Highway Upgrade Ecological Monitoring Program. Stage 2 Warrell creek to Nambucca Heads*. Unpublished report to *Roads and Maritime Service, NSW*.

GeoLINK (2017). *Warrell Creek to Nambucca Heads Microbat Overwintering Structures Monitoring July 2017(Ref: 2378-1367)* Unpublished report for *Acciona and Ferrovial Joint Venture.*

RMS (2014). *Soil and Water Management Sub Plan - Warrell Creek to Nambucca Heads Pacific Highway Upgrade*. Unpublished report for *Road and Maritime Services*.

Appendix A

Microbat Flyway Photos

Crouches Creek – east looking west

Plate 1.1 April 2015

Plate 1.2 January 2016

Plate 1.3 February 2017

Plate 1.4 July 2017

Plate 1.5 August 2017

Plate 1.6 January 2018

Plate 1.7 February 2018

Plate 1.8 June 2018

Plate 1.9 July 2018

Plate 1.10 October 2018

Crouches Creek – east looking southeast

Plate 1.11 April 2015

Plate 1.12 January 2016

Plate 1.13 February 2016

Plate 1.14 July 2017

Plate 1.15 August 2017

Plate 1.16 January 2018

Plate 1.17 February 2018

Plate 1.18 June 2018

Plate 1.19 July 2018

Plate 1.20 October 2018

Crouches Creek – west looking east

Plate 1.21 April 2015

Plate 1.22 January 2016

Plate 1.23 February 2017

Plate 1.24 July 2017

Plate 1.25 August 2017

Plate 1.26 January 2018

Plate 1.27 February 2018

Plate 1.28 June 2018

Plate 1.29 July 2018

Plate 1.30 October 2018

Crouches Creek – west looking west

Plate 1.31 April 2015

Plate 1.32 January 2016

Plate 1.33 February 2017

Plate 1.34 July 2017

Plate 1.35 August 2017

Plate 1.36 January 2018

Plate 1.37 February 2018

Plate 1.38 June 2018

Plate 1.39 July 2018

Plate 1.40 October 2018

Rosewood Creek – east looking west

Plate 1.41 April 2015

Plate 1.42 January 2016

Plate 1.43 February 2017

Plate 1.44 July 2017

Plate 1.45 August 2017

Plate 1.46 January 2018

Plate 1.47 February 2018

Plate 1.48 June 2018

Plate 1.49 July 2018

Plate 1.50 October 2018

Rosewood Creek – east looking south-east

Plate 1.51 April 2015

Plate 1.52 January 2016

Plate 1.53 February 2017

Plate 1.54 July 2017

Plate 1.55 August 2017

Plate 1.56 January 2018

Plate 1.57 February 2018

Plate 1.58 June 2018

Plate 1.59 July 2018

Plate 1.60 October 2018

Rosewood Creek – west looking south-east

Plate 1.61 April 2015

Plate 1.62 January 2016

Plate 1.63 February 2017

Plate 1.64 July 2017

Plate 1.65 August 2017

Plate 1.66 January 2018

Plate 1.67 February 2018

Plate 1.68 June 2018

Plate 1.69 July 2018

Plate 1.70 October 2018

Rosewood Creek – west looking north-west

Plate 1.71 April 2015

Plate 1.72 January 2016

Plate 1.73 February 2017

Plate 1.74 July 2017

Plate 1.75 August 2017

Plate 1.76 January 2018

Plate 1.77 February 2018

Plate 1.78 June 2018

Plate 1.79 July 2018

Plate 1.80 October 2018

Butchers Creek – east looking east

Plate 1.81 April 2015

Plate 1.82 January 2016

Plate 1.83 February 2017

Plate 1.84 July 2017

Plate 1.85 August 2017

Plate 1.86 January 2018

Plate 1.87 February 2018

Plate 1.88 June 2018

Plate 1.89 July 2018

Plate 1.90 October 2018

Butchers Creek – east looking west

Plate 1.91 April 2015

Plate 1.92 January 2016

Plate 1.93 February 2017

Plate 1.94 July 2017

Plate 1.95 August 2017

Plate 1.96 January 2018

Plate 1.97 February 2018

Plate 1.98 June 2018

Plate 1.99 July 2018

Plate 1.100 October 2018

Butchers Creek – west looking south

Plate 1.101 April 2015

Plate 1.102 January 2016

Plate 1.103 February 2017

Plate 1.104 July 2017

Plate 1.105 August 2017

Plate 1.106 January 2018

Plate 1.107 February 2018

Plate 1.108 June 2018

Plate 1.109 July 2018

Plate 1.110 October 2018

Butchers Creek – west looking east

Plate 1.111 April 2015

Plate 1.112 January 2016

Plate 1.113 February 2017

Plate 1.114 July 2017

Plate 1.115 August 2017

Plate 1.116 January 2018

Plate 1.117 February 2018

Plate 1.118 June 2018

Plate 1.119 July 2018

Plate 1.120 October 2018

Cockburns Creek – east looking west

Plate 1.121 April 2015

Plate 1.122 January 2016

Plate 1.123 February 2017

Plate 1.124 July 2017

Plate 1.125 August 2017

Plate 1.126 January 2018

Plate 1.127 February 2018

Plate 1.128 June 2018

Plate 1.129 July 2018

Plate 1.130 October 2018

Cockburns Creek – east looking east

Plate 1.131 April 2015

Plate 1.132 January 2016

Plate 1.133 February 2017

Plate 1.134 July 2017

Plate 1.135 August 2017

Plate 1.136 January 2018

Plate 1.137 February 2018

Plate 1.138 June 2018

Plate 1.139 July 2018

Plate 1.140 October 2018

Cockburns Creek – west looking west

Plate 1.141 April 2015

Plate 1.142 January 2016

Plate 1.143 February 2017

Plate 1.144 July 2017

Plate 1.145 August 2017

Plate 1.146 January 2018

Plate 1.147 February 2018

Plate 1.148 June 2018

Plate 1.149 July 2018

Plate 1.150 October 2018

Cockburns Creek – west looking east

Plate 1.151 April 2015

Plate 1.152 January 2016

Plate 1.153 February 2017

Plate 1.154 July 2017

Plate 1.155 August 2017

Plate 1.156 January 2018

Plate 1.157 February 2018

Plate 1.158 June 2018

Plate 1.159 July 2018

Plate 1.160 October 2018

Upper Warrell Creek – south looking north

Plate 1.161 April 2015

Plate 1.162 January 2016

Plate 1.163 February 2017

Plate 1.164 July 2017

Plate 1.165 August 2017

Plate 1.166 January 2018

Plate 1.167 February 2018

Plate 1.168 June 2018

Plate 1.169 July 2018

Plate 1.170 October 2018

Upper Warrell Creek – south looking south

Plate 1.171 April 2015

Plate 1.172 January 2016

Plate 1.173 February 2017

Plate 1.174 July 2017

Plate 1.175 August 2017

Plate 1.176 January 2018

Plate 1.177 February 2018

Plate 1.178 June 2018

Plate 1.179 July 2018

Plate 1.180 October 2018

Upper Warrell Creek – north looking north

Plate 1.181 April 2015

Plate 1.182 January 2016

Plate 1.183 February 2017

Plate 1.184 July 2017

Plate 1.185 August 2017

Plate 1.186 January 2018

Plate 1.187 February 2018

Plate 1.188 June 2018

Plate 1.189 July 2018

Plate 1.190 October 2018

Upper Warrell Creek – north looking south

Plate 1.191 April 2015

Plate 1.192 January 2016

Plate 1.193 February 2017

Plate 1.194 July 2017

Plate 1.195 August 2017

Plate 1.196 January 2018

Plate 1.197 February 2018

Plate 1.198 June 2018

Plate 1.199 July 2018

Plate 1.200 October 2018

ABN 79 896 839 729
ACN 101 084 557

Return address:
PO Box 119
LENNOX HEAD
NSW 2478

LENNOX HEAD
T 02 6687 7666
F 02 6687 7782

COFFS HARBOUR
T 02 6651 7666
F 02 6651 7733

www.geolink.net.au

4 July 2018
Ref No.: 2378-1445

Pacifico
124 Albert Drive
DONNELLYVILLE NSW 2447

Attention: Mr Jason Haslett

WC2NH Microbat Habitat Flyway Monitoring Report - June 2018

Introduction

GeoLINK has been engaged by Pacifico to undertake microbat flyway monitoring for the Warrell Creek to Nambucca Heads (WC2NH) Pacific Highway upgrade. In accordance with monitoring requirement *G2 Habitat Monitoring:*

Habitat monitoring would focus on inspections of the riparian zone to assess whether flyways have been constricted as part of construction works. Therefore, on either side of the construction corridor, a photo point would be installed and a visual assessment be undertaken to gauge whether the flyway has been maintained or is in need of corrective actions (i.e. vegetation management). Monitoring of water quality would also be undertaken.

This report presents the findings of the microbat flyway monitoring for the first five months of year 4 of the construction stage of the project (February to June 2018). These results are compared with the previous 6 months monitoring results (August 2017 to January 2018). Monitoring of microbat flyways is to be undertaken monthly during years 1, 3 and 4 of construction as outlined in the *WC2NH Ecological Monitoring Program* (Lewis, 2014).

Methodology

In order to monitor potential microbat flyways, the following riparian zones have been nominated as monitoring sites:

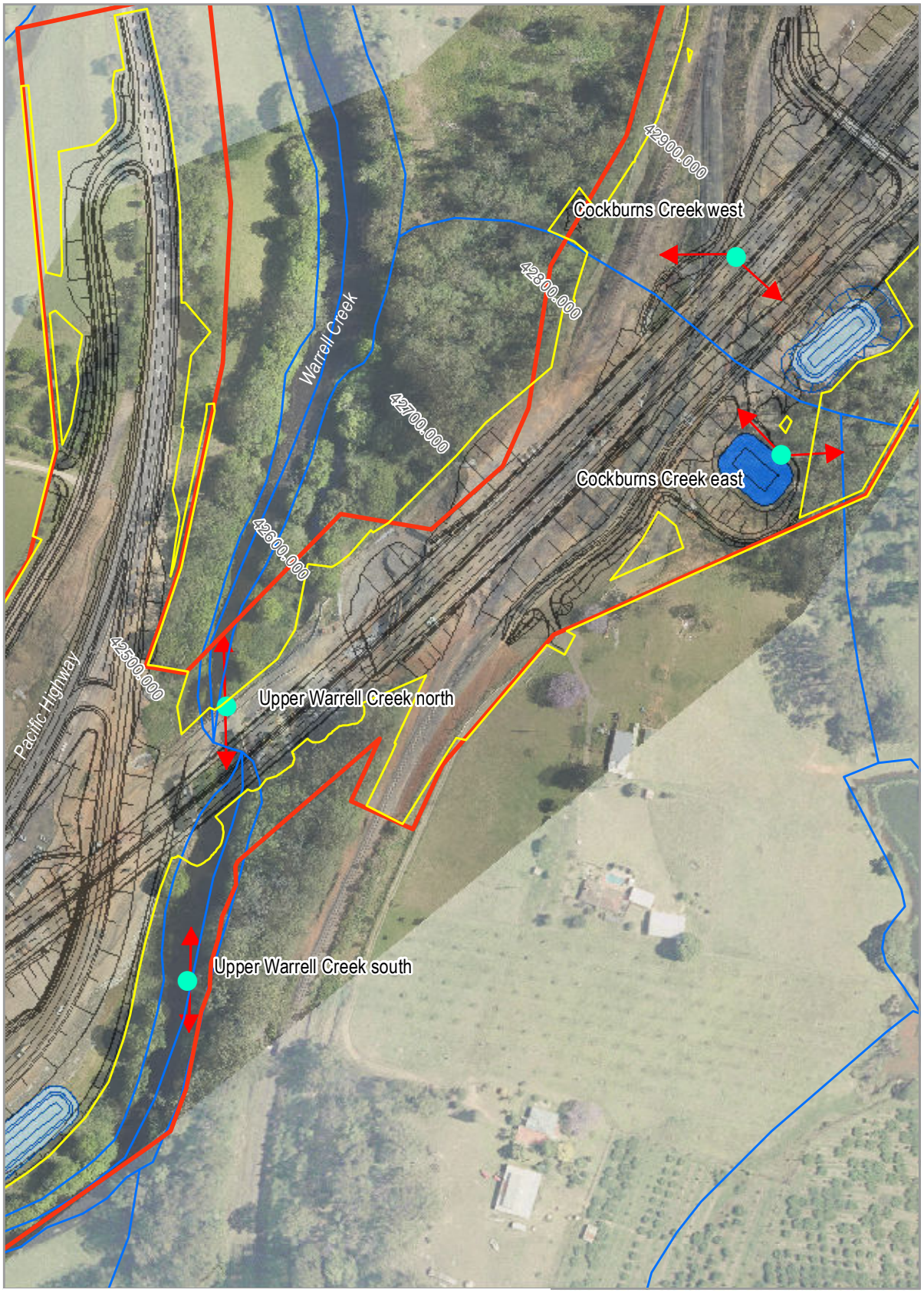
- Crouches Creek;
- Rosewood Creek;
- Butchers Creek;
- Un-named tributary near Cockburns Lane (Cockburns Creek); and
- Upper Warrell Creek (UWC).

Two photo points, one on either side of the nominated creek, have been established. Photographs were taken looking towards the highway construction zone and towards the intact riparian zone adjacent (refer to **Illustrations 1.1** to **1.4** for photo point locations). Global Positioning System (GPS) coordinates for the photo point locations are provided in **Table 1**. The condition of the flyway habitat was recorded, noting changes to the quality of the flyway or any visible obstructions.

Urban and Regional Planning | Environmental Engineering | Civil Design | Environmental Impact Assessment | Ecological Surveys and Monitoring | Landscape Architecture | Urban Design | Coastline and Waterways Management

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 25/06/2018
Source of base data: RMS & AFJV



LEGEND

- Site Boundary
- Clearing Limit
- Watercourse
- Microbat Habitat Flyway Photo Points
- Photopoint direction

0 60

North

Microbat Flyway Photo Locations

GeoLINK environmental management and design

WC2NH Microbat Flyway Monitoring - June 2018
2378-1446

Illustration 1.1

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 25/06/2018
Source of base data: RMS & AFJV

LEGEND

- Site Boundary
- Clearing Limit
- Watercourse
- Microbat Habitat Flyway Photo Points
- Photopoint direction

0 60

North

Microbat Flyway Photo Locations

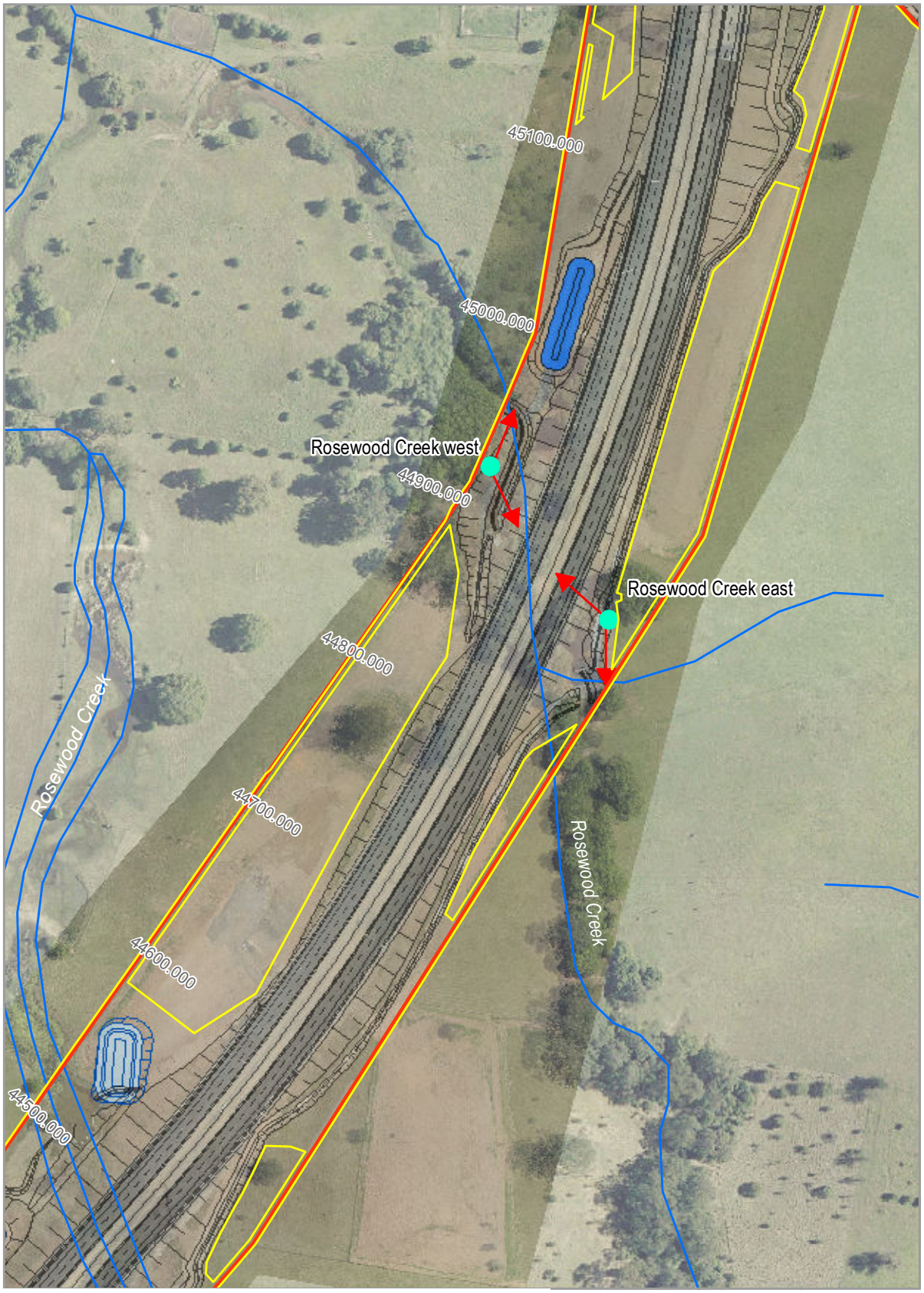
GeoLINK environmental management and design

WC2NH Microbat Flyway Monitoring - June 2018
2378-1446

Illustration 1.2

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 25/06/2018
Source of base data: RMS & AFJV

Information shown is for illustrative purposes only



LEGEND

- Site Boundary
- Clearing Limit
- Watercourse
- Microbat Habitat Flyway Photo Points

0 60

North

Microbat Flyway Photo Locations

GeoLINK environmental management and design

WC2NH Microbat Flyway Monitoring - June 2018
2378-1446

Illustration 1.3

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 25/06/2018
Source of base data: RMS & AFJV

Information shown is for illustrative purposes only

LEGEND

- Site Boundary
- Clearing Limit
- Watercourse
- Microbat Habitat Flyway Photo Points
- Photopoint direction

0 60

North

Microbat Flyway Photo Locations

GeoLINK environmental management and design

WC2NH Microbat Flyway Monitoring - June 2018
2378-1446

Illustration 1.4

Dates on which monthly flyway monitoring occurred during the reporting period are as follows:

- 26 February 2018.
- 26 March 2018.
- 26 March 2018.
- 15 May 2018.
- 14 June 2018.

Table 1 Flyway Photo Point Monitoring GPS Coordinates (GDA 94)

Photo Point Location	*Easting*	*Northing*
Crouches Creek east	491686	6598052
Crouches Creek west	491579	6598035
Rosewood Creek east	490758	6596127
Rosewood Creek west	490696	6596206
Butchers Creek east	489855	6594879
Butchers Creek west	489766	6594934
Cockburns Creek east	489569	6594435
Cockburns Creek west	489546	6594538
Upper Warrell Creek south	489262	6594163
Upper Warrell Creek north	489282	6594305

Results

A total of five riparian sites were monitored, with four photographs taken at each site. A comparison of photos between the first and last monitoring sessions listed below are provided in **Appendix A**.

- Year 1 of construction – April 2015 and January 2016.
- The first six months of year 3 – February 2017 and July 2017.
- The last six months of year 3 – August 2017 and January 2018.
- The first six months of year 4 – February 2018 and June 2018.

Records of all photos taken are available upon request. An assessment of impacts/ changes for each flyway site is provided in the **Table 2**.

Table 2 Flyway Photo Point Monitoring Results

Site	*Impacts/ Changes*	*Weed Control Required*
Crouches Creek	Substantial changes have occurred within the site associated with the Crouches Creek Bridge construction. However, the bridge does not constrict potential flyways and no weed infestations or vegetation overgrowth has been recorded. Crouches Creek remains unobstructed as a potential flyway. No significant change to flyway opportunities has occurred since the January 2018 monitoring report was issued.	No
Rosewood Creek	Construction in this area has substantially altered the riparian zone reducing the quality of the flyway. Whilst the terrain has changed in this area, aerial passage of microbats is possible over the alignment. Under passage options are also possible through the culvert. Batters have now been hydroseeded with native seed mix.	No
Butchers Creek	Despite substantial changes within the construction site associated with the Butchers Creek culvert, the potential flyway associated with Butchers Creek remains unobstructed. Dense Small-leaved Privet and Lantana grow along the riparian zone to the west (outside) of the project boundary at this location.	No
Cockburns Creek	Substantial changes associated with earthworks have reduced the quality of the flyway due to the removal of vegetation and placement of fill. However, the area remains unobstructed and capable of providing aerial passage above the highway alignment for microbats. Where the basin to the east has been hydroseeded, Acacia saplings have grown and are beginning to obstruct the flyway in an east to westerly direction (refer to **Plate 1.104**).	No
Upper Warrell Creek (UWC)	Despite the construction of a temporary crossing (recently removed at beginning of June 2018) over the creek involving minor clearing of the riparian zone and the construction of the UWC Bridge, the potential flyway remains largely unobstructed and capable of supporting microbat aerial passage under the bridge. No significant change to flyway opportunities have occurred since the January 2018 monitoring report was issued.	No

Discussion

The last five months of construction phase microbat flyway monitoring (February to June 2018) has recorded little to no change when compared to the previous six month monitoring event (August 2017 to January 2018). However, the general findings of the monitoring to date indicate substantial changes associated with flyways as a result of highway construction. Due to the required clearing and construction of the highway, the quality of flyways has been reduced; particularly for the Cockburn and Rosewood Creek riparian zones where the previously continuous vegetation has been intercepted by the highway alignment and substantial placement of fill embankments. Although there is limited to no under passage flyway options to adjacent vegetation at Cockburn Creek, flyway passage above the highway alignment is still viable at these locations.

The Rosewood Creek culvert provides under passage options via the single cell box culvert. Over time the hydroseeded batters at Rosewood Creek will grow medium to tall native species which will further restrict the parallel course of the flyway along the riparian zone. Additionally, microbats have been recorded using the culvert structure as roosting habitat during 2016 overwintering structures monitoring undertaken by GeoLINK. No microbats were recorded roosting in this structure during the 2017 overwintering survey. Due to the road height in relation to the adjacent vegetation, there is potential increased risk that microbats will fly over the road in the path of passing vehicles once the highway is operational to traffic.

Butchers Creek culvert offers both under passage and above highway flyways connecting adjacent riparian vegetation. This culvert has recorded the presence of microbats roosting in the joint gaps during 2017 overwintering structures monitoring (GeoLINK, 2017).

UWC and Crouches Creek bridge construction has impacted the flyway through minor clearing, however even with the bridge structures now in place, potential flyways remain viable under the bridge connecting with adjacent vegetation.

Retained areas of vegetation outside the alignment remain unobstructed or as they naturally existed prior to construction and are generally free of weed infestations with the exception of the western side of Butchers Creek, where dense infestations of Lantana and Small-leaved Privet occur outside of the project footprint (as naturally existed prior to construction).

Water quality monitoring for the subject sites (flyways) has been undertaken routinely by Pacifico and is available on request. The water quality of the associated waterways has been managed in accordance with the *Soil and Water Quality Management Plan*.

No remediation measures are currently required for microbat flyways; however, assessment of landscape vegetation may need monitoring for obstruction of flyways as vegetation matures.

Conclusion

Recent monitoring has recorded no significant change to microbat flyway habitat when compared with the previous six-monthly monitoring event. Microbat flyway monitoring to date has indicated that the flyways are largely unobstructed by vegetation overgrowth or weeds and therefore no management actions such as weed control or vegetation management within microbat flyway habitat are required.

Overall, the riparian zones associated with flyway monitoring locations have been altered or intercepted by the highway upgrade construction. The two bridges and two box cell culverts offer unobstructed flyways connecting adjacent riparian vegetation. The Cockburn Creek flyway is the most restricted due to the placement of fill and less favorable crossing opportunities, due to limited underpass options through the narrow pipe culvert. However, aerial passage is still viable above the highway alignment. Currently, no vegetation or weed overgrowth has been noted as an obstruction to microbat flyways in association with the monitoring sites, however over time maturing landscape vegetation may need monitoring for obstruction of flyways as this vegetation matures.

While riparian vegetation is intercepted by construction, flyway opportunities are provided via under passage or viable aerial passage above the highway, hence satisfying the objectives of the *Microchiropteran Bat Management Strategy* (Lewis, 2014).

It is expected that the June 2018 monitoring report may be the last construction phase monitoring report, due to the project completion date forecast for mid-2018. After mid-2018, both Stage 2A and Stage 2B will be operational and open to highway traffic.

Please feel free to contact me should you require any additional information.

Yours sincerely
GeoLINK

Jessica O'Leary
Ecologist

References

Lewis, B (2014). *Warrell Creek to Urunga Microchiropteran Bat Management Strategy.* Unpublished report to *Roads and Maritime Service, NSW.*

Lewis, B (2014). *Warrell Creek to Urunga Pacific Highway Upgrade Ecological Monitoring Program. Stage 2 Warrell creek to Nambucca Heads*. Unpublished report to *Roads and Maritime Service, NSW*.

GeoLINK (2017). *Warrell Creek to Nambucca Heads Microbat Overwintering Structures Monitoring July 2017(Ref: 2378-1367)* Unpublished report for *Acciona and Ferrovial Joint Venture.*

RMS (2014). *Soil and Water Management Sub Plan - Warrell Creek to Nambucca Heads Pacific Highway Upgrade*. Unpublished report for *Road and Maritime Services*.

Appendix A

Microbat Flyway Photos

Crouches Creek – east looking west

Plate 1.1 April 2015

Plate 1.2 January 2016

Plate 1.3 February 2017

Plate 1.4 July 2017

Plate 1.5 August 2017

Plate 1.6 January 2018

Plate 1.7 February 2018

Plate 1.8 June 2018

Crouches Creek – east looking southeast

Plate 1.9 April 2015

Plate 1.10 January 2016

Plate 1.11 February 2016

Plate 1.12 July 2017

Plate 1.13 August 2017

Plate 1.14 January 2018

Plate 1.15 February 2018

Plate 1.16 June 2018

Crouches Creek – west looking east

Plate 1.17 April 2015

Plate 1.18 January 2016

Plate 1.19 February 2017

Plate 1.20 July 2017

Plate 1.21 August 2017

Plate 1.22 January 2018

Plate 1.23 February 2018

Plate 1.24 June 2018

Crouches Creek – west looking west

Plate 1.25 April 2015

Plate 1.26 January 2016

Plate 1.27 February 2017

Plate 1.28 July 2017

Plate 1.29 August 2017

Plate 1.30 January 2018

Plate 1.31 February 2018

Plate 1.32 June 2018

Rosewood Creek – east looking west

Plate 1.33 April 2015

Plate 1.34 January 2016

Plate 1.35 February 2017

Plate 1.36 July 2017

Plate 1.37 August 2017

Plate 1.38 January 2018

Plate 1.39 February 2018

Plate 1.40 June 2018

Rosewood Creek – east looking south-east

Plate 1.41 April 2015

Plate 1.42 January 2016

Plate 1.43 February 2017

Plate 1.44 July 2017

Plate 1.45 August 2017

Plate 1.46 January 2018

Plate 1.47 February 2018

Plate 1.48 June 2018

Rosewood Creek – west looking south-east

Plate 1.49 April 2015

Plate 1.50 January 2016

Plate 1.51 February 2017

Plate 1.52 July 2017

Plate 1.53 August 2017

Plate 1.54 January 2018

Plate 1.55 February 2018

Plate 1.56 June 2018

Rosewood Creek – west looking north-west

Plate 1.57 April 2015

Plate 1.58 January 2016

Plate 1.59 February 2017

Plate 1.60 July 2017

Plate 1.61 August 2017

Plate 1.62 January 2018

Plate 1.63 February 2018

Plate 1.64 June 2018

Butchers Creek – east looking east

Plate 1.65 April 2015

Plate 1.66 January 2016

Plate 1.67 February 2017

Plate 1.68 July 2017

Plate 1.69 August 2017

Plate 1.70 January 2018

Plate 1.71 February 2018

Plate 1.72 June 2018

Butchers Creek – east looking west

Plate 1.73 April 2015

Plate 1.74 January 2016

Plate 1.75 February 2017

Plate 1.76 July 2017

Plate 1.77 August 2017

Plate 1.78 January 2018

Plate 1.79 February 2018

Plate 1.80 June 2018

Butchers Creek – west looking south

Plate 1.81 April 2015

Plate 1.82 January 2016

Plate 1.83 February 2017

Plate 1.84 July 2017

Plate 1.85 August 2017

Plate 1.86 January 2018

Plate 1.87 February 2018

Plate 1.88 June 2018

Butchers Creek – west looking east

Plate 1.89 April 2015

Plate 1.90 January 2016

Plate 1.91 February 2017

Plate 1.92 July 2017

Plate 1.93 August 2017

Plate 1.94 January 2018

Plate 1.95 February 2018

Plate 1.96 June 2018

Cockburns Creek – east looking west

Plate 1.97 April 2015

Plate 1.98 January 2016

Plate 1.99 February 2017

Plate 1.100 July 2017

Plate 1.101 August 2017

Plate 1.102 January 2018

Plate 1.103 February 2018

Plate 1.104 June 2018

Cockburns Creek – east looking east

Plate 1.105 April 2015

Plate 1.106 January 2016

Plate 1.107 February 2017

Plate 1.108 July 2017

Plate 1.109 August 2017

Plate 1.110 January 2018

Plate 1.111 February 2018

Plate 1.112 June 2018

Cockburns Creek – west looking west

Plate 1.113 April 2015

Plate 1.114 January 2016

Plate 1.115 February 2017

Plate 1.116 July 2017

Plate 1.117 August 2017

Plate 1.118 January 2018

Plate 1.119 February 2018

Plate 1.120 June 2018

Cockburns Creek – west looking east

Plate 1.121 April 2015

Plate 1.122 January 2016

Plate 1.123 February 2017

Plate 1.124 July 2017

Plate 1.125 August 2017

Plate 1.126 January 2018

Plate 1.127 February 2018

Plate 1.128 June 2018

Upper Warrell Creek – south looking north

Plate 1.129 April 2015

Plate 1.130 January 2016

Plate 1.131 February 2017

Plate 1.132 July 2017

Plate 1.133 August 2017

Plate 1.134 January 2018

Plate 1.135 February 2018

Plate 1.136 June 2018

Upper Warrell Creek – south looking south

Plate 1.137 April 2015

Plate 1.138 January 2016

Plate 1.139 February 2017

Plate 1.140 July 2017

Plate 1.141 August 2017

Plate 1.142 January 2018

Plate 1.143 February 2018

Plate 1.144 June 2018

Upper Warrell Creek – north looking north

Plate 1.145 April 2015

Plate 1.146 January 2016

Plate 1.147 February 2017

Plate 1.148 July 2017

Plate 1.149 August 2017

Plate 1.150 January 2018

Plate 1.151 February 2018

Plate 1.152 June 2018

Upper Warrell Creek – north looking south

Plate 1.153 April 2015

Plate 1.154 January 2016

Plate 1.155 February 2017

Plate 1.156 July 2017

Plate 1.157 August 2017

Plate 1.158 January 2018

Plate 1.159 February 2018

Plate 1.160 June 2018

Appendix G Microbat roost

ABN 79 896 839 729
ACN 101 084 557

Return address:
PO Box 119
LENNOX HEAD
NSW 2478

LENNOX HEAD
T 02 6687 7666
F 02 6687 7782

COFFS HARBOUR
T 02 6651 7666

ARMIDALE
T 02 6772 0454

LISMORE
T 02 6621 6677

www.geolink.net.au

21 March 2018
Ref No.: 2378-1418

Pacifico
124 Albert Drive
DONNELLYVILLE NSW 2447

Attention: Alex Dwyer

WC2NH Microbat Roost Box Monitoring – Summer 2018

Introduction

GeoLINK has been engaged by Pacifico to undertake microbat roost box monitoring for the Warrell Creek to Nambucca Heads Pacific Highway upgrade (WC2NH). A total of 24 microbat roost boxes were installed in 2014 to provide compensatory roost habitat for hollow-bearing trees removed during clearing for the highway upgrade alignment. This report provides the results of the summer 2018 monitoring undertaken on 8 February 2018. Monitoring of microbat roost boxes is to be undertaken seasonally for four years during the construction phase of the Project as outlined in the *Warrell Creek to Urunga Microchiropteran Bat Management Strategy* (MBMS) (Lewis, 2014). It is now expected that the Project will be delivered during mid-June 2018. Autumn 2018 will likely be the last microbat roost box monitoring event during the Project construction phase.

Methods

Twenty-four (24) microbat roost boxes were inspected for microbats or evidence of microbat usage. Refer to **Appendix A** for microbat roost box locations. The methods of bat box inspection included:

- Inspection by tree climber with a camera to capture images of bats for identification.
- Ladder based observations. This involved looking directly into the bat box from a ladder. Many of the bat boxes with larger openings were able to be directly observed. Once bat boxes were determined to be empty, closer observations were made of the bat box lid and interior of the boxes to search for potential signs of fauna occupancy.
- Ground based inspections with binoculars. This was primarily undertaken at bat boxes which have an open base (dependent on positioning on the supporting tree).

General maintenance (e.g. tightening of cables/ adjusting bat boxes for improved stability; tightening of fixtures and removal of pest invertebrate fauna) and box replacement/ relocation was undertaken where required.

Urban and Regional Planning | Environmental Engineering | Civil Design | Environmental Impact Assessment | Ecological Surveys and Monitoring | Landscape Architecture | Urban Design |

Results

The results from the summer 2018 microbat roost box monitoring event are summarised below and tabulated in **Appendix B**.

Microbat Occupancy

Approximately 29 microbats in total occupying five separate boxes (boxes 10, 12, 18, 20 and 24) were recording, including:

- Box 10 contained six Lesser Long-eared Bats (*Nyctophilus geoffroyi*).
- Box 12 contained two Gould's Wattled Bat (*Chalinolobus gouldii*) (refer to **Plate 1.1**).
- Box 20 contained approximately 20 *Nyctophilus* bats (likely *N. gouldi* or *N. geoffroyi*) that all exited the box on approach. At least one of the microbats entered Box 18 *(note: this box was not inspected due to concern of further disturbance to the recently settled microbat*).
- Box 24 recorded one Gould's Long-eared Bat. This is the first record of this box being occupied by microbats since the commencement of monitoring in summer 2015.
- Three boxes (Box 3, 16 and 19) contained recent signs of bat use by the presence of fresh guano deposits, but were unoccupied.
- Box 4 (single triangle, MB2.6) has not recorded use since installation. The narrow entry hole (<15mm) of this box may be a contributing factor to the lack of recorded occupancy.
- No direct evidence of maternity roosting was detected.

Plate 1.1 Box 12 occupied at time of monitoring by two Gould's Wattled Bats

Structural Integrity and Attachments

One box (Box 8) requires replacement due to the door component of this dome box being broken.

Invertebrate Pests

Invertebrate pests (bees, wasps, ants etc.) were not observed to be an issue at the time of survey. An ant nest was removed from Box 7 during the inspection.

Discussion

A comparison of bat box usage from the monitoring assessments over time is provided in **Table 1.1** and shown in **Figures 1.1** and **1.2**. The total number of microbats recorded (29 microbats) during the current monitoring event (summer 2018) is the highest number of microbats recorded occupying the roost boxes since the commencement of monitoring in summer 2015. This is an increase when compared to the previous monitoring event (spring 2017) which recorded eight microbats. The summer 2017 monitoring event recorded 22 microbats which was the highest number of microbats recorded until the results of summer 2018 observed a new highest record of microbats. The data in **Figures 1.1** shows two potential developing trends:

- Increasing microbat numbers over time (this is likely to plateau at some point).
- Seasonal variation in microbat numbers and numbers of boxes occupied or showing evidence of microbat usage, with higher numbers being recorded in summer/ autumn and lower numbers in winter/ spring. Churchill (2008) notes that the subject Long-eared Bats (*Nyctophilus gouldi* and *N. geoffroyi.*) and Gould's Wattled Bat (the main species recorded during monitoring) select new roosts frequently and select roosts which are cooler during the summer months and warmer roost sites during winter.

These potential trends should be reviewed during future monitoring.

Two of the five occupied microbat boxes observed during this monitoring event were occupied in the last monitoring event. Box 18, 20 and 24 were also occupied by microbats this monitoring event but were not occupied during spring 2017 monitoring. Box 20 contained approximately 20 microbats which is the largest number of microbats recorded occupying a single box to date. Box 24 recorded occupancy by a single microbat which is the first time this box has been recorded as occupied since the commencement of monitoring.

It is plausible that the 20 *Nyctophilus* (*N. gouldi* or *N. geoffroyi*) at Box 20 may have comprised a maternity colony, based on the number of bats and the time of year alone, however capture and assessment of the animals would be required for this to be confirmed (preferably earlier in late October/ early November). Maternity roosts of both Gould's Long-eared Bat and Lesser Long-eared Bats are known to contain 10-30 females (Van Dyck and Strahan, 2008) and roost within more insulated roosts in forest stands (usually tree hollows than under bark). Pups are born mid to late October (Churchill, 2008). Young can fly by December and lactation is complete by February (Van Dyck and Strahan, 2008).

Microbats are making use of a number of boxes within the bat box groupings (refer to **Maps 1-5** of **Appendix A**). This is particularly evident with the Nambucca River roost box groups (bat boxes 1 - 4 and 17 - 20) and the Crouches Creek group (boxes 9 - 12). However, two groupings, Lower Warrell Creek (Boxes 5 - 8) and north of Bald Hill Road Interchange (13 - 16) have not recorded occupancy by microbats since the commencement of monitoring. The exception to this being Box 16 where evidence of usage (indicated by the presence of fresh guano) is regularly observed, though has not been occupied at the time of the monitoring.

Three boxes recorded the presence of guano deposits indicating use since last monitoring. The boxes which recorded guano deposits are the concrete domed box design which is a contained cell with a floor, which retains the guano. It is possible that the alternative box designs also shelter microbats at times however their use goes undetected due to the open bottom design of the box allowing guano to fall away and hence be undetected.

Conclusion

The monitoring undertaken to date has shown a general trend of increased numbers of microbats using the roost boxes and increased numbers of roost boxes being utilised by microbats overtime. Seasonal variations are becoming apparent with higher numbers recorded during summer/ autumn compared to winter/ spring.

The monitoring to date has shown that the microbat roost boxes are being utilised by a range of microbat species (a minimum of four confirmed species), hence satisfying the objectives of installing the boxes as detailed in the *Microchiropteran Bat Management Strategy* (Lewis, 2014).

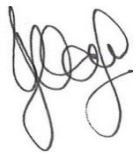
Recommendations

It is recommended that Box 8 is replaced with a dual chamber bottom opening timber roost box during the autumn 2018 monitoring event. It is recommended that Box 4 either be replaced with a dual chamber bottom opening timber roost box or that the entry slot be modified to enlarge the entry hole to improve access for microbats.

As that the box groupings of Lower Warrell Creek and Bald Hill interchange have never recorded occupancy by microbats, it is suggested that a portion of these boxes are relocated to another site to encourage uptake by microbats (excluding Box 16).

Please feel free to contact me if you require any additional information.

Yours sincerely
GeoLINK



Jessica O'Leary
Ecologist

References

Churchill, S. (2008). *Australian Bats (Second Edition)*. Allen & Unwin, NSW.

Van Dyck, S and Strahan, R. (2008). *The Mammals of Australia. (Third Edition)*. Reed New Holland, Sydney.

Lewis, B. (2014). *Warrell Creek to Urunga Microchiropteran Bat Management Strategy*. Unpublished report to Roads and Maritime Service, NSW.

UPR	***Description***	***Date Issued***	***Issued By***
2378-1418	First issue	21/03/2018	Jessica O'Leary

Table 1.1 Microbat box usage 2015-2018

Bat Box No.	2015 Summer	2015 Autumn	2015 Spring	2016 Summer	2016 Autumn	2016 Winter	2016 Spring	2017 Summer	2017 Autumn	2017 Winter	2017 Spring	2018 Summer
1												
2				4 x likely *Myotis* sp.	4 x microbats					*1 x Nyctophilus geoffroyi*		
3	1 x microbat	Guano		Guano	Guano		Guano	Guano	*6 x Nyctophilus geoffroyi*	*1 x Nyctophilus geoffroyi*	Guano	Guano
4												
5		Guano										
6												
7		Guano			Guano							
8		Guano										
9												
10						1 x microbat	10 x *Nyctophilus* sp.		6 x *Nyctophilus geoffroyi*	1 x *Nyctophilus geoffroyi*	6 x *Nyctophilus geoffroyi*	6 x *Nyctophilus geoffroyi*
11												
12			1 x *Myotis macropus*	1 x microbat	3 x microbats	1 x microbat	1 x microbat	1 x *Myotis macropus*	5 x *Chalinolobus gouldii*		2 x *Chalinolobus gouldii*	2 x *Chalinolobus gouldii*
13												
14												
15												
16							Guano	Guano	1 x *Nyctophilus Gouldii*	Guano	Guano	Guano
17					1 x *Nyctophilus* sp.							

Bat Box No.	2015 Summer	2015 Autumn	2015 Spring	2016 Summer	2016 Autumn	2016 Winter	2016 Spring	2017 Summer	2017 Autumn	2017 Winter	2017 Spring	2018 Summer
18								12 x *Nyctophilus* sp.	1 x *Nyctophilus geoffroyi*			Min. of 1 x likely *Nyctophilus sp.* which dispersed from Box 20 (therefore not included in the total count)
19	Guano	Guano	Guano	Guano	2 x *Nyctophilus* sp.	1 x microbat	Guano	Guano	1 x *Chalinolobus gouldii*	4 x *Myotis macropus*	Guano	Guano
20	Guano	Guano	Guano	6 x microbats	1 x *Nyctophilus* sp.	7 x *Nyctophilus* sp.						Approx. 20 likely *Nyctophilus sp.*
21							8 x *Nyctophilus* sp.					
22												
23								9 x *Nyctophilus gouldii* including at least one pup				
24												1 x *Nyctophilus goudlii*
Total Bats	**1**	**0**	**1**	**11**	**11**	**10**	**19**	**22**	**20**	**7**	**8**	**29**
No. of boxes showing evidence of use	**3**	**6**	**3**	**5**	**7**	**4**	**6**	**6**	**6**	**5**	**5**	**8**
No. of boxes occupied	**1**	**0**	**1**	**3**	**5**	**4**	**3**	**3**	**6**	**4**	**2**	**5**

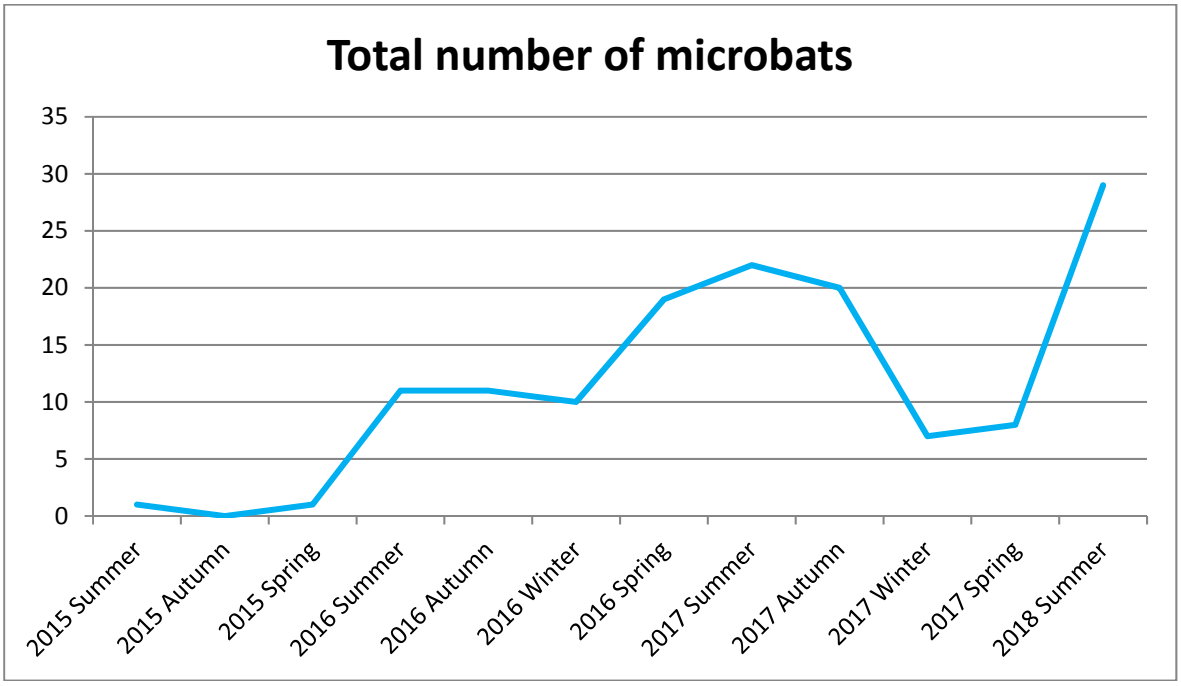


Figure 1.1 Total number of microbats recorded.

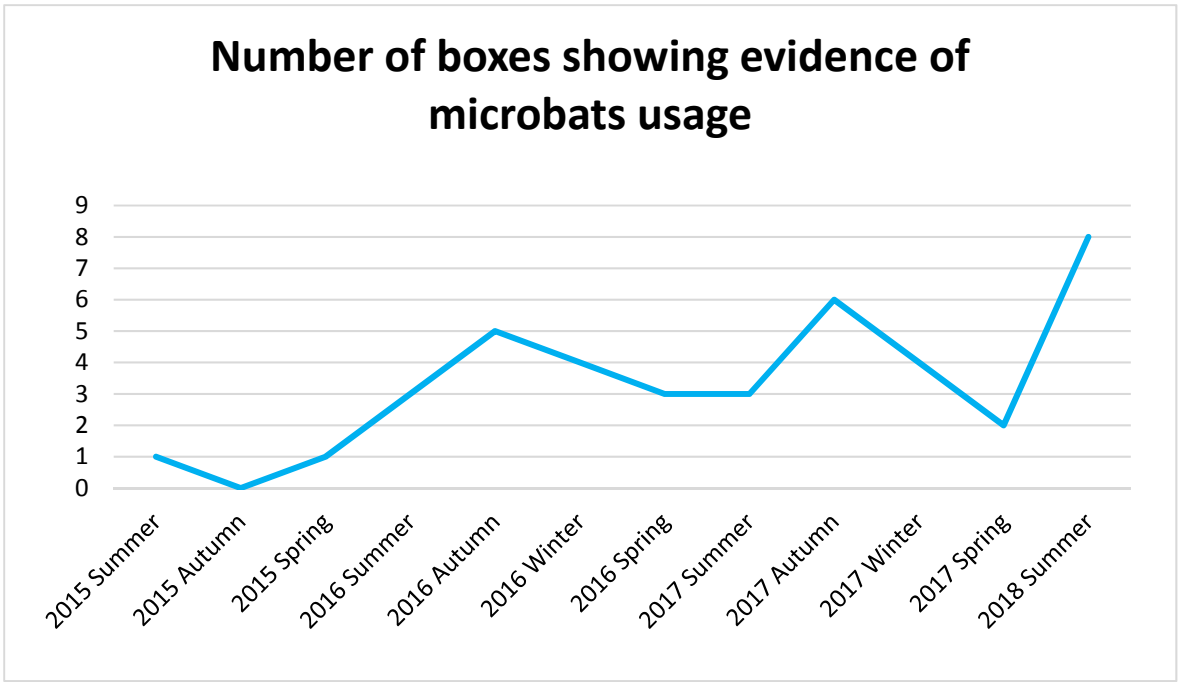


Figure 1.2 Number of boxes occupied or showing evidence of microbat usage.

Appendix A

Microbat Roost Locations

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 9/02/2018
Source of base data: Roads and Maritime Services

0 80

North

Bat Box Locations

Microbat Roost Box Monitoring - Summer 2018
2378-1420

Map 1 of 5

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 9/02/2018
Source of base data: Roads and Maritime Services

0 80

North

Bat Box Locations

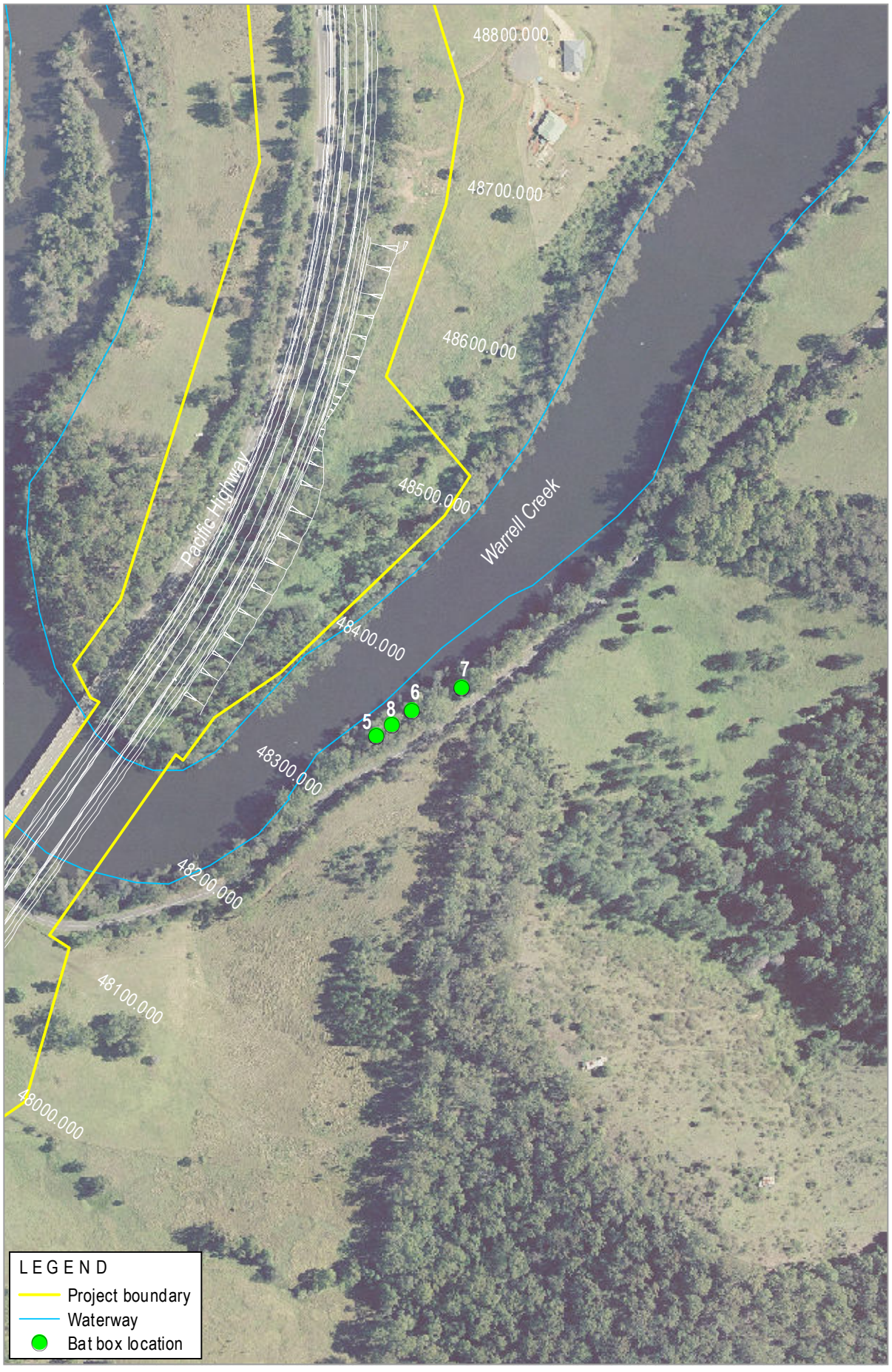
GeoLINK environmental management and design

Microbat Roost Box Monitoring - Summer 2018
2378-1420

Map 2 of 5

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 9/02/2018
Source of base data: Roads and Maritime Services



0 80

North

Bat Box Locations

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 9/02/2018
Source of base data: Roads and Maritime Services

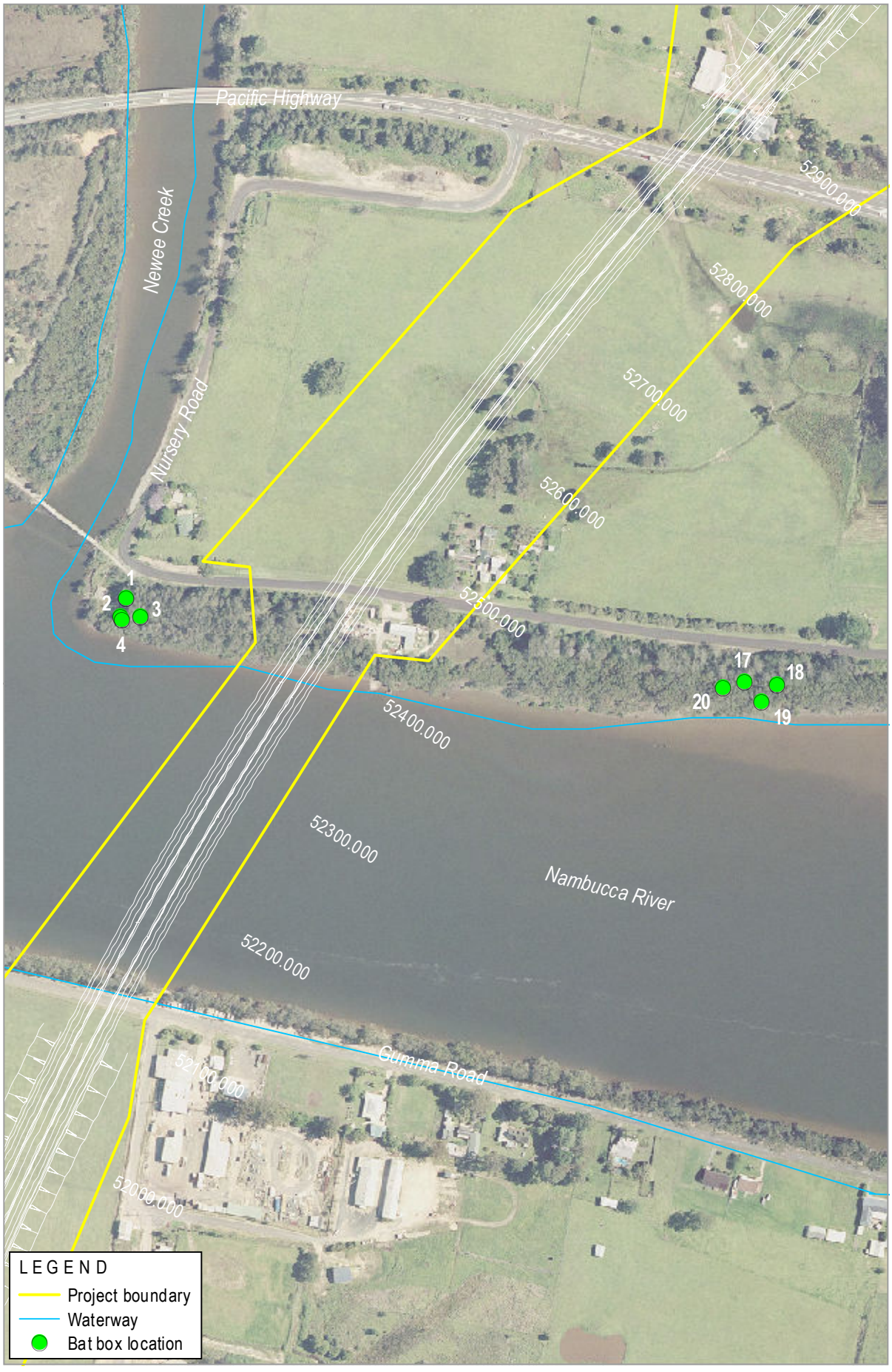
0 80

North

Bat Box Locations

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 9/02/2018
Source of base data: Roads and Maritime Services



0 80

North

Bat Box Locations

GeoLINK environmental management and design

Microbat Roost Box Monitoring - Summer 2018
2378-1420

Map 5 of 5

Appendix B

Microbat Roost Box Monitoring Results – Summer 2018

Bat Box No.	Bat Box Type	Easting	Northing	Tree Common Name	Monitoring Date	Time	Bat Occupancy Evidence	Bat Count	Evidence of Breeding	Structural or Attachment Concerns	Comments/ Maintenance Required/ Undertaken
1	Dual Wedge	493717	6602832	Swamp Oak	8/02/2018	11:45	None	0	N/A	No	None
2	Quad wedge	493713	6602819	River Mangrove	8/02/2018	11:48	None	0	No	No	None
3	Black Dome	493727	6602819	Swamp Oak	8/02/2018	11:50	Guano	0	No	No	Substantial guano deposits emptied from the box
4	Single triangle (MB2.6)	493714	6602817	Swamp Oak	8/02/2018	11:55	None	0	N/A	No	Recommend replacement of this box with dual chamber bottom opening timber roost box. Or modify existing box to increase width of opening, currently too narrow for microbats to enter.
5	Quad Wedge	492499	6599037	Grey Gum	8/02/2018	10:55	None	0	N/A	No	None
6	Quad wedge	492513	6599048	Grey Ironbark	8/02/2018	10:57	None	0	N/A	No	None
7	Black Dome	492549	6599064	Swamp Oak	8/02/2018	10:50	None	0	N/A	No	Ants nest removed
8	White Dome	492499	6599037	Broad-leaved Paperbark	8/02/2018	11:10	None	0	N/A	No	Door component of dome box is broken. Recommend replacing dome box with dual chamber bottom opening timber roost box. This dome box at this location has never recorded occupancy by microbats or evidence of use.
9	Nara Small	491225	6598140	Broad-leaved	8/02/2018	09:38	None	0	N/A	No	None

Bat Box No.	Bat Box Type	Easting	Northing	Tree Common Name	Monitoring Date	Time	Bat Occupancy Evidence	Bat Count	Evidence of Breeding	Structural or Attachment Concerns	Comments/ Maintenance Required/ Undertaken
				Paperbark							
10	Dual Wedge	491252	6598141	Swamp Oak	8/02/2018	09:40	Lesser Long-eared Bat (*Nyctophilus geoffroyi*)	6	N/A	No	None
11	Nara Large	490971	6598088	Camphor Laurel	8/02/2018	09:55	None	N/A	N/A	N/A	None
12	Quad wedge	490929	6598000	Swamp Oak	8/02/2018	09:50	Gould's Wattled Bat (*Chalinolobus gouldii*)	2	N/A	No	None
13	Dual Wedge	494159	6602772	Swamp Mahogany	8/02/2018	11:32	None	0	N/A	No	None
14	Dual Wedge	494182	6602770	Swamp Mahogany	8/02/2018	11:35	None	0	N/A	No	None
15	Quad Wedge	494171	6602758	Tallowwood	8/02/2018	11:38	None	0	N/A	No	None
16	Black Dome	494143	6602768	Tallowwood	8/02/2018	11:30	Guano	0	N/A	No	Substantial guano deposit within box not emptied as also large active mud wasp nest present within box, not removed.
17	Dual Wedge	492371	6600444	Grey Mangrove	8/02/2018	12:22	None	0	N/A	No	None
18	Dual Wedge	492333	6600445	Grey Mangrove	8/02/2018	12:18	Yes – see comments	Minimum of 1	N/A	No	A minimum of 1 bat entered this box at time of inspection from Box 20. Box 18 was not inspected as did not want to further disturb the bats.
19	Black Dome	492416	6600455	Grey Mangrove	8/02/2018	12:25	Guano	0	No	No	None

Bat Box No.	Bat Box Type	Easting	Northing	Tree Common Name	Monitoring Date	Time	Bat Occupancy Evidence	Bat Count	Evidence of Breeding	Structural or Attachment Concerns	Comments/ Maintenance Required/ Undertaken
20	Quad wedge	492406	6600426	Grey Mangrove	8/02/2018	12:15	Yes - likely *Nyctophilus* bats exited the roost box as the ecologist approached the box for inspection. Suspected *Nyctophilus geoffroyi* due to smaller size, light tan/ grey colouration, and their regularly recorded occupancy of nest boxes at this location.	Approx. 20	Unknown	No	All microbats roosting within box 20 exited to box as the Ecologist approached the box for inspection. A minimum of 1 microbat took refuge within Box 18.
21	Twin Wedge	488455	6593550	Water Gum	8/02/2018	09:15	None	0	N/A	No	None
22	Quad Wedge	488456	6593568	Rose Walnut	8/02/2018	09:20	None	0	N/A	No	Mud Wasp nests with the narrow opening of 1 of 4 of the chambers, not removed.
23	Twin Wedge	488408	6593494	Red Ash	8/02/2018	09:10	None	0	N/A	No	None
24	Nara Small	488322	6593386	Water Gum	8/02/2018	09:05	*Nyctophilus* species	1	No	No	First record of occupancy for this box since the commencement of monitoring.

ABN 79 896 839 729
ACN 101 084 557

Return address:
PO Box 119
LENNOX HEAD
NSW 2478

LENNOX HEAD
T 02 6687 7666
F 02 6687 7782

COFFS HARBOUR
T 02 6651 7666

ARMIDALE
T 02 6772 0454

LISMORE
T 02 6621 6677

www.geolink.net.au

25 May 2018
Ref No.: 2378-1442

Pacifico
124 Albert Drive
DONNELLYVILLE NSW 2447

Attention: Jason Haslett

Dear Jason

WC2NH Microbat Roost Box Monitoring – Autumn 2018

Introduction

GeoLINK has been engaged by Pacifico to undertake microbat roost box monitoring for the Warrell Creek to Nambucca Heads Pacific Highway upgrade (WC2NH). A total of 24 microbat roost boxes were installed in 2014 to provide compensatory roost habitat for hollow-bearing trees removed during clearing for the highway upgrade alignment. This report provides the results of the autumn 2018 monitoring undertaken on 19 April 2018. Monitoring of microbat roost boxes is undertaken seasonally for four years during the construction phase of the Project as outlined in the *Warrell Creek to Urunga Microchiropteran Bat Management Strategy* (MBMS) (Lewis, 2014). It is expected that the Project will be completed in mid to late 2018. This report may be the last microbat roost box monitoring event during the Project construction phase.

Methods

Twenty-four (24) microbat roost boxes were inspected for microbats or evidence of microbat usage on 19 April 2018. Refer to **Appendix A** for microbat roost box locations. The methods of bat box inspection included:

- Inspection by tree climber with a camera to capture images of bats for identification.
- Ladder based observations. This involved looking directly into the bat box from a ladder. Many of the bat boxes with larger openings were able to be directly observed. Once bat boxes were determined to be empty, closer observations were made of the bat box lid and interior of the boxes to search for potential signs of fauna occupancy.
- Ground based inspections with binoculars. This was primarily undertaken at bat boxes which have an open base (dependent on positioning on the supporting tree).

General maintenance (e.g. tightening of cables/ adjusting bat boxes for improved stability; tightening of fixtures and removal of pest invertebrate fauna) and box replacement/ relocation was undertaken where required.

Urban and Regional Planning | Environmental Engineering | Civil Design | Environmental Impact Assessment | Ecological Surveys and Monitoring | Landscape Architecture | Urban Design |

Results

The results from the autumn 2018 microbat roost box monitoring event are summarised below and tabulated in **Appendix B**.

Microbat Occupancy

A total of 14 microbats occupying three separate boxes (Boxes 2, 10 and 12) were recorded, including:

- Box 2 contained one Lesser Long-eared Bat (*Nyctophilus geoffroyi*).
- Box 10 contained seven Lesser Long-eared Bats (*Nyctophilus geoffroyi*) (refer to **Plate 1.1**).
- Box 12 contained six Gould's Wattled Bat (*Chalinolobus gouldii*) (refer to **Plate 1.2**).
- Two boxes (Box 16 and 19) contained recent signs of bat use by the presence of fresh guano deposits, but were unoccupied.
- No direct evidence of maternity roosting was detected.

Plate 1.1 **Box 10 occupied at time of monitoring by seven Lesser Long-eared Bats**

Plate 1.2 **Box 12 occupied at time of monitoring by six Gould's Wattled Bats**

Structural Integrity and Attachments

- Box 4 (single triangle, MB2.6) was modified to open the entry slot of the box to improve ease of access to this box (refer to **Plate 1.3** and **1.4**).
- Box 8 (damaged, white dome design) was replaced with a dual wedge bottom opening timber box.

Plate 1.3 **Box 4 (MB2.6) before modification of the roost box entry point**

Plate 1.4 **Box 4 (MB2.6) after modification of the roost box entry point, widened by approximately 10mm.**

Invertebrate Pests

Invertebrate pests (bees and wasps) were not observed to be an issue at the time of survey. An ant nest was removed from Box 3 during the inspection.

Discussion

A comparison of bat box usage from the monitoring assessments over time is provided in **Table 1.1** and shown in **Figures 1.1** and **1.2**. The total number of microbats recorded (14 microbats) during the current monitoring event (autumn 2018) is lower than that recorded during the previous monitoring event undertaken in summer 2018 where 29 microbats were recorded occupying five separate boxes. It is also lower than the number of microbats recorded during the previous autumn monitoring event in 2017 where 20 microbats were recorded. The autumn 2018 results however are higher than the recorded number of microbats recorded in autumn 2016 (11 microbats). No microbats were recorded in autumn 2015.

The data in **Figures 1.1** and **1.2** shows two general trends:

- An initial increasing trend in microbat numbers over time between summer 2015 and summer 2017, microbat numbers have fluctuated.
- Seasonal variation in microbat numbers and numbers of boxes occupied or showing evidence of microbat usage, with higher numbers typically being recorded in summer and lower numbers in winter/ spring. Churchill (2008) notes that the subject Long-eared Bats (*Nyctophilus gouldi* and *N. geoffroyi.*) and Gould's Wattled Bat (the main species recorded during monitoring) select new roosts frequently and select roosts which are cooler during the summer months and warmer roost sites during winter.

These potential trends should be reviewed during future monitoring.

Two of the three occupied microbat boxes observed during this monitoring event were occupied in the last monitoring event (10 and 12). Box 2 was also occupied by microbats this monitoring event but was not occupied during autumn 2018 monitoring. Box 12 was occupied by microbats for the tenth time (78 per cent of monitoring events) since the commencement monitoring with Box 12 occupied for the seventh time (54 per cent of monitoring events) since the commencement of monitoring from a total of 13 monitoring events to date.

Microbats are making use of a number of boxes within the bat box groupings (refer to **Maps 1-5** of **Appendix A**). This is particularly evident with the Nambucca River roost box groups (bat Boxes 1 - 4 and 17 - 20) and the Crouches Creek group (Boxes 9 - 12). However, two groupings, Lower Warrell Creek (Boxes 5 - 8) and north of Bald Hill Road Interchange (13 - 16) have not recorded occupancy by microbats since the commencement of monitoring. The exception to this being Box 16 where evidence of usage (indicated by the presence of fresh guano) is regularly observed, though has not been occupied at the time of the monitoring.

Two boxes recorded the presence of guano deposits indicating use since last monitoring. The boxes which recorded guano deposits are the concrete domed box design which is a contained cell with a floor, which retains the guano. It is possible that the alternative box designs also shelter microbats at times however their use goes undetected due to the open bottom design of the box allowing guano to fall away and hence be undetected.

Conclusion

The monitoring undertaken to date has shown:

- An initial increasing trend in the number of microbats using the roost boxes between summer 2015 and summer 2017.
- A general increased number of roost boxes being utilised by microbats overtime.
- Seasonal variations in roost box usage, with higher microbat usage recorded during summer compared to winter/ spring.
- Varying usage levels between bat box grouping.

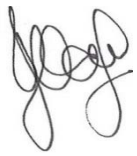
The monitoring to date has shown that the microbat roost boxes are being utilised by a range of microbat species (a minimum of four confirmed species), hence satisfying the objectives of installing the boxes as detailed in the *Microchiropteran Bat Management Strategy* (Lewis, 2014).

Recommendations

As the box groupings of Lower Warrell Creek and Bald Hill interchange have not recorded occupancy by microbats during construction phase monitoring, it is suggested that these boxes could be rearranged within the site or once these boxes require maintenance investigate replacement with an alternative roost box design to encourage uptake by microbats (excluding Box 16).

Please feel free to contact me if you require any additional information.

Yours sincerely
GeoLINK



Jessica O'Leary
Ecologist

References

Churchill, S. (2008). *Australian Bats (Second Edition)*. Allen & Unwin, NSW.

Van Dyck, S and Strahan, R. (2008). *The Mammals of Australia. (Third Edition)*. Reed New Holland, Sydney.

Lewis, B. (2014). *Warrell Creek to Urunga Microchiropteran Bat Management Strategy*. Unpublished report to Roads and Maritime Service, NSW.

UPR	*Description*	*Date Issued*	*Issued By*
2378-1440	First issue	04/05/2018	Jessica O'Leary
2378-1442	Second issue	25/05/2018	Jessica O'Leary

Table 1.1 Microbat box usage 2015-2018

Bat Box No.	2015 Summer	2015 Autumn	2015 Spring	2016 Summer	2016 Autumn	2016 Winter	2016 Spring	2017 Summer	2017 Autumn	2017 Winter	2017 Spring	2018 Summer	2018 Autumn
1													
2				4 x likely *Myotis* sp.	4 x microbats					*1 x Nyctophilus geoffroyi*			*1 x Nyctophilus geoffroyi*
3	1 x microbat	Guano		Guano	Guano		Guano	Guano	*6 x Nyctophilus geoffroyi*	*1 x Nyctophilus geoffroyi*	Guano	Guano	
4													
5		Guano											
6													
7		Guano			Guano								
8		Guano											
9													
10						1 x microbat	10 x *Nyctophilus* sp.		6 x *Nyctophilus geoffroyi*	1 x *Nyctophilus geoffroyi*	6 x *Nyctophilus geoffroyi*	6 x *Nyctophilus geoffroyi*	7 x *Nyctophilus geoffroyi*
11													
12			1 x *Myotis macropus*	1 x microbat	3 x microbats	1 x microbat	1 x microbat	1 x *Myotis macropus*	5 x *Chalinolobus gouldii*		2 x *Chalinolobus gouldii*	2 x *Chalinolobus gouldii*	6 x *Chalinolobus gouldii*
13													
14													
15													
16							Guano	Guano	1 x *Nyctophilus Gouldii*	Guano	Guano	Guano	Guano
17					1 x *Nyctophilus* sp.								

Bat Box No.	2015 Summer	2015 Autumn	2015 Spring	2016 Summer	2016 Autumn	2016 Winter	2016 Spring	2017 Summer	2017 Autumn	2017 Winter	2017 Spring	2018 Summer	2018 Autumn
18								12 x *Nyctophilus* sp.	1 x *Nyctophilus geoffroyi*			Min. of 1 x likely *Nyctophilus sp.* which dispersed from Box 20 (therefore not included in the total count)	
19	Guano	Guano	Guano	Guano	2 x *Nyctophilus* sp.	1 x microbat	Guano	Guano	1 x *Chalinolobus gouldii*	4 x *Myotis macropus*	Guano	Guano	Guano
20	Guano	Guano	Guano	6 x microbats	1 x *Nyctophilus* sp.	7 x *Nyctophilus* sp.						Approx. 20 likely *Nyctophilus sp.*	
21							8 x *Nyctophilus* sp.						
22													
23								9 x *Nyctophilus gouldii* including at least one pup					
24												*1 x Nyctophilus gouldii*	
Total Bats	1	0	1	11	11	10	19	22	20	7	8	29	14
No. of boxes showing evidence of use	3	6	3	5	7	4	6	6	6	5	5	8	5
No. of boxes occupied	1	0	1	3	5	4	3	3	6	4	2	5	3

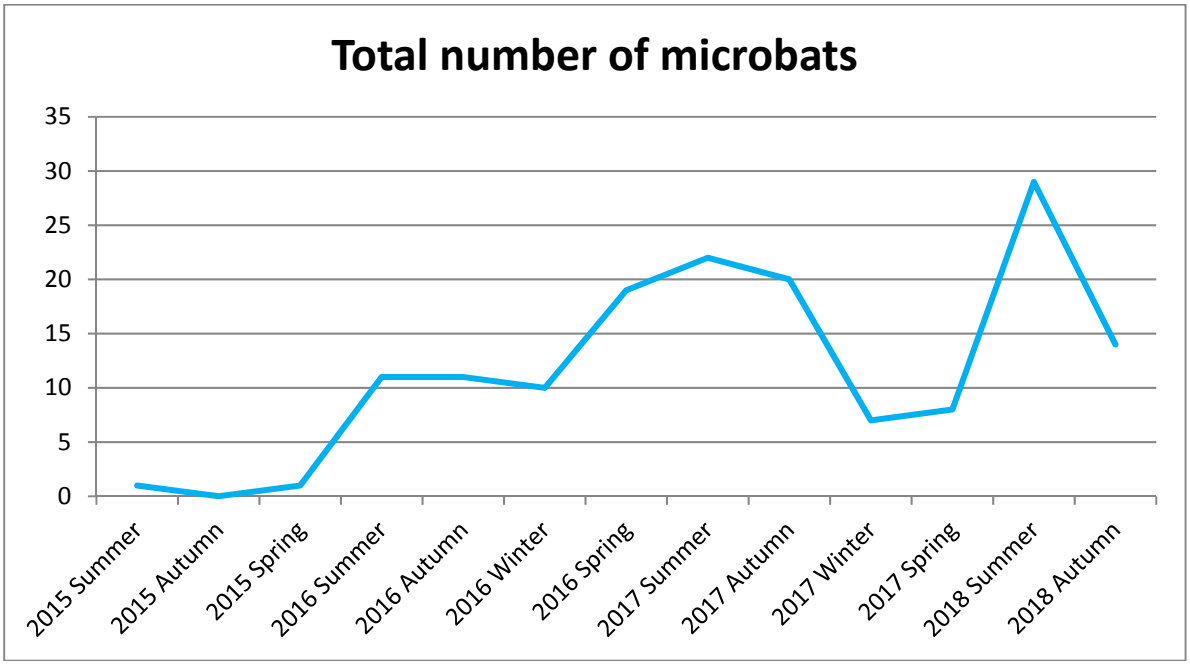


Figure 1.1 Total number of microbats recorded.

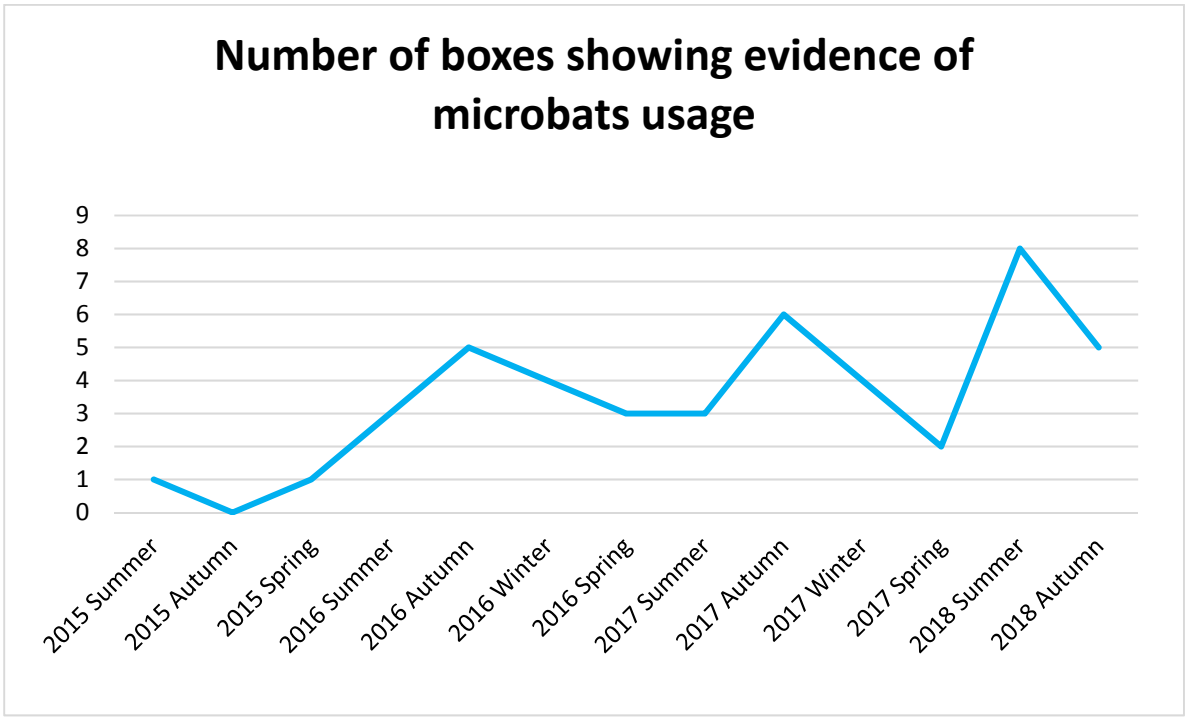


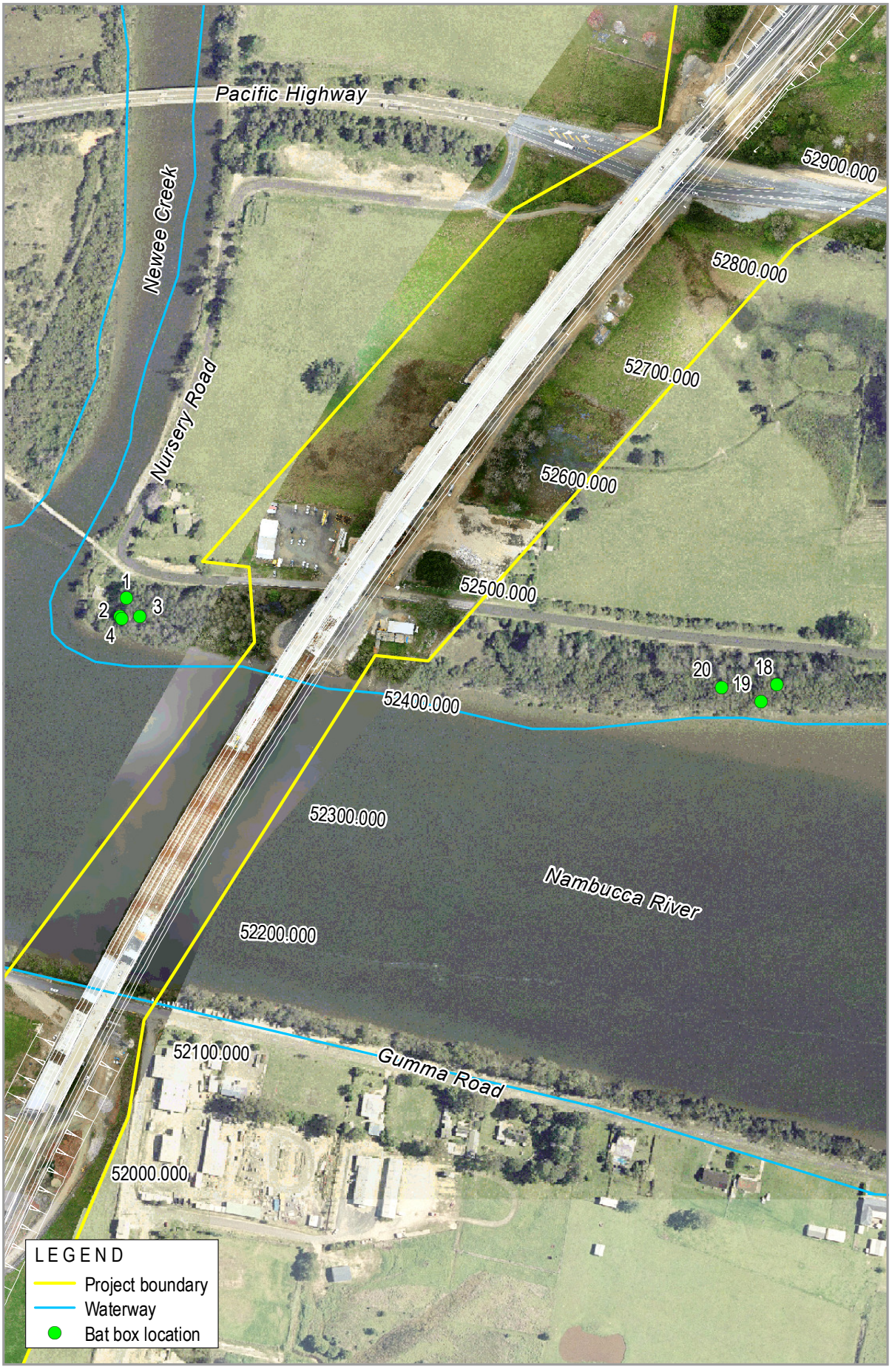
Figure 1.2 Number of boxes occupied or showing evidence of microbat usage.

Appendix A

Microbat Roost Locations

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 20/04/2018
Source of base data: Roads and Maritime Services



0 80

North

Bat Box Locations

GeoLINK environmental management and design

Microbat Roost Box Monitoring - Autumn 2018
2378-1439

Map 1 of 5

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 20/04/2018
Source of base data: Roads and Maritime Services

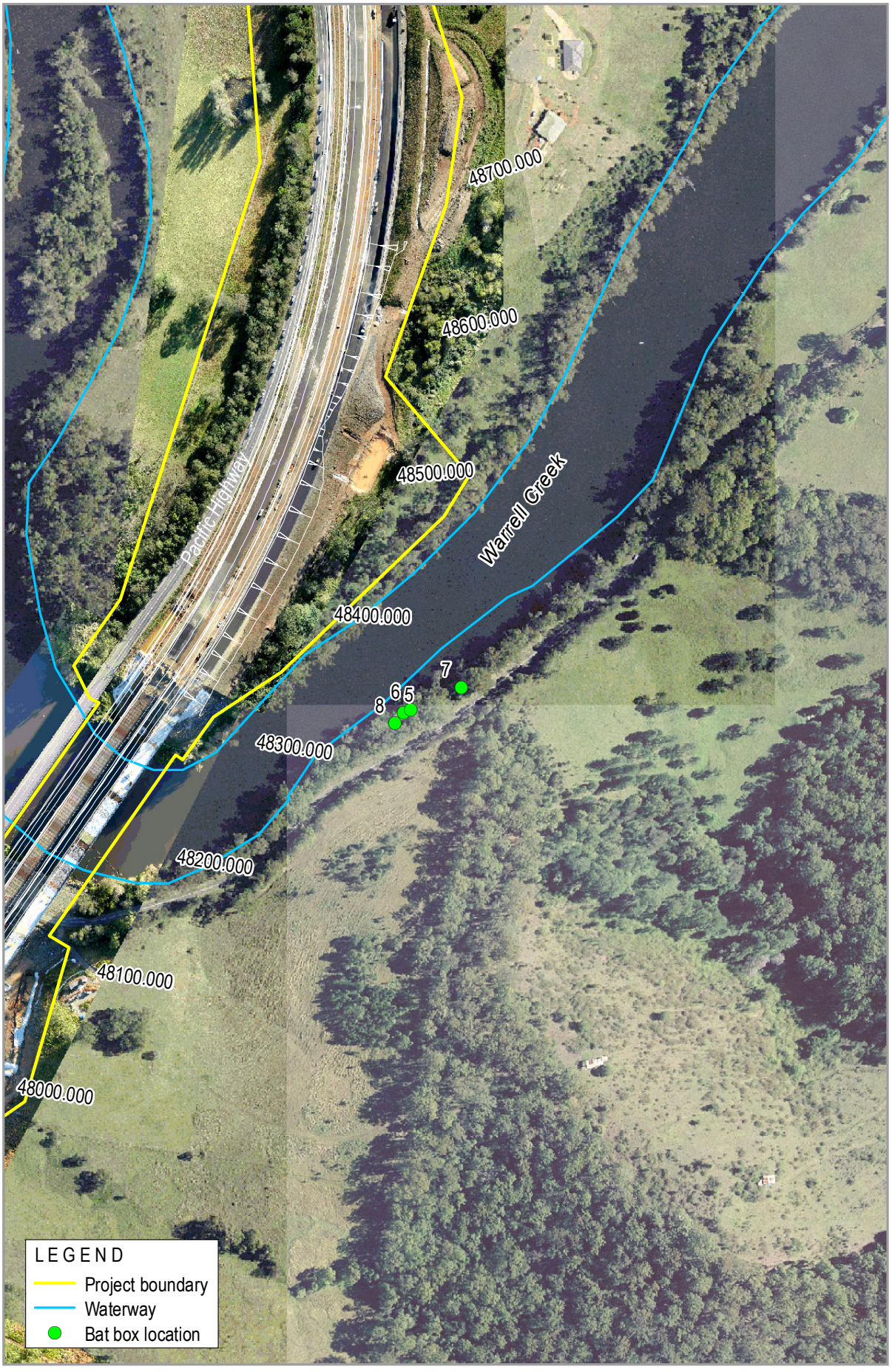
0 80

North

Bat Box Locations

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 20/04/2018
Source of base data: Roads and Maritime Services



0 80

North

Bat Box Locations

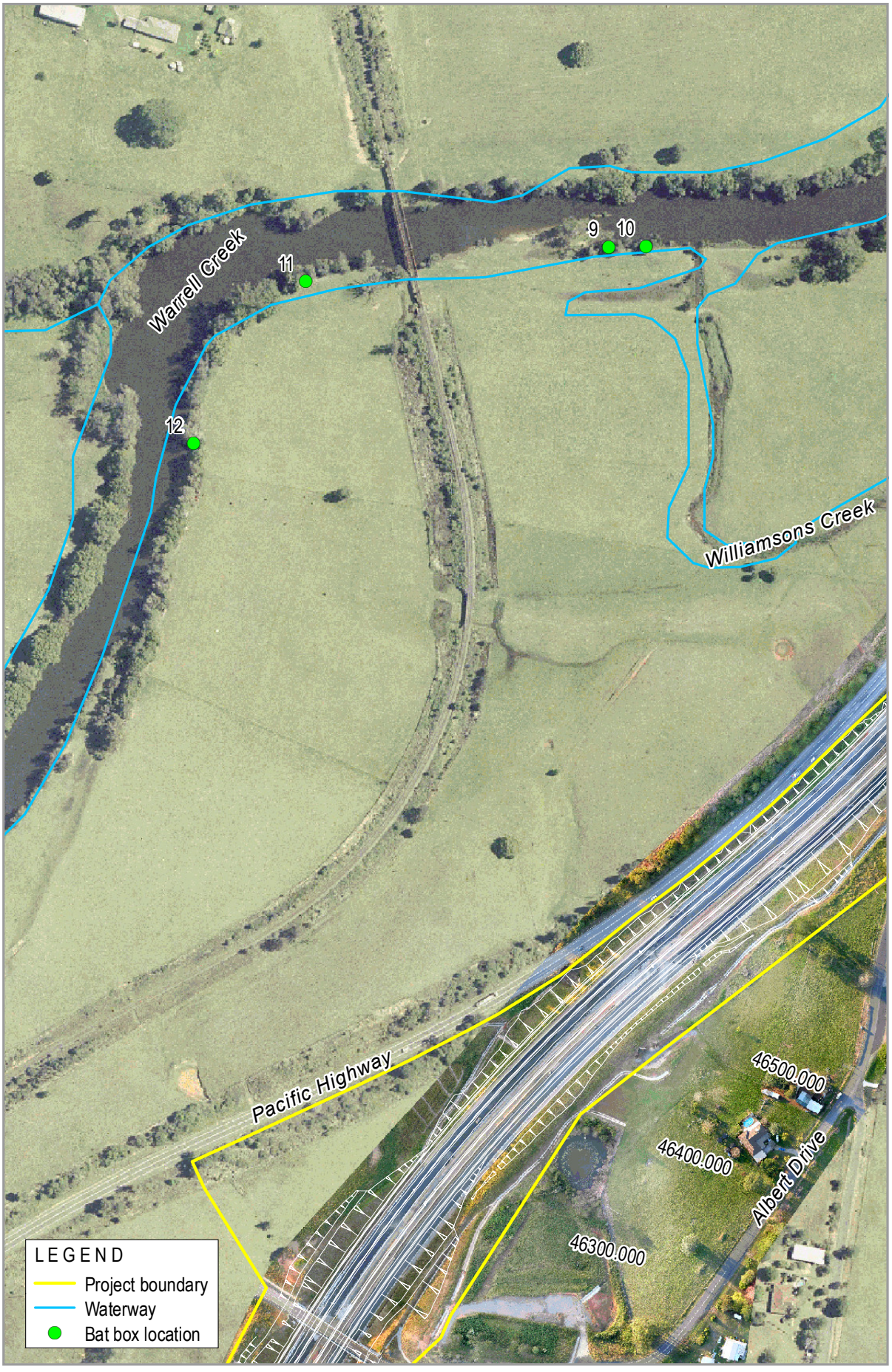
GeoLINK environmental management and design

Microbat Roost Box Monitoring - Autumn 2018
2378-1439

Map 3 of 5

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 20/04/2018
Source of base data: Roads and Maritime Services



0 80

North

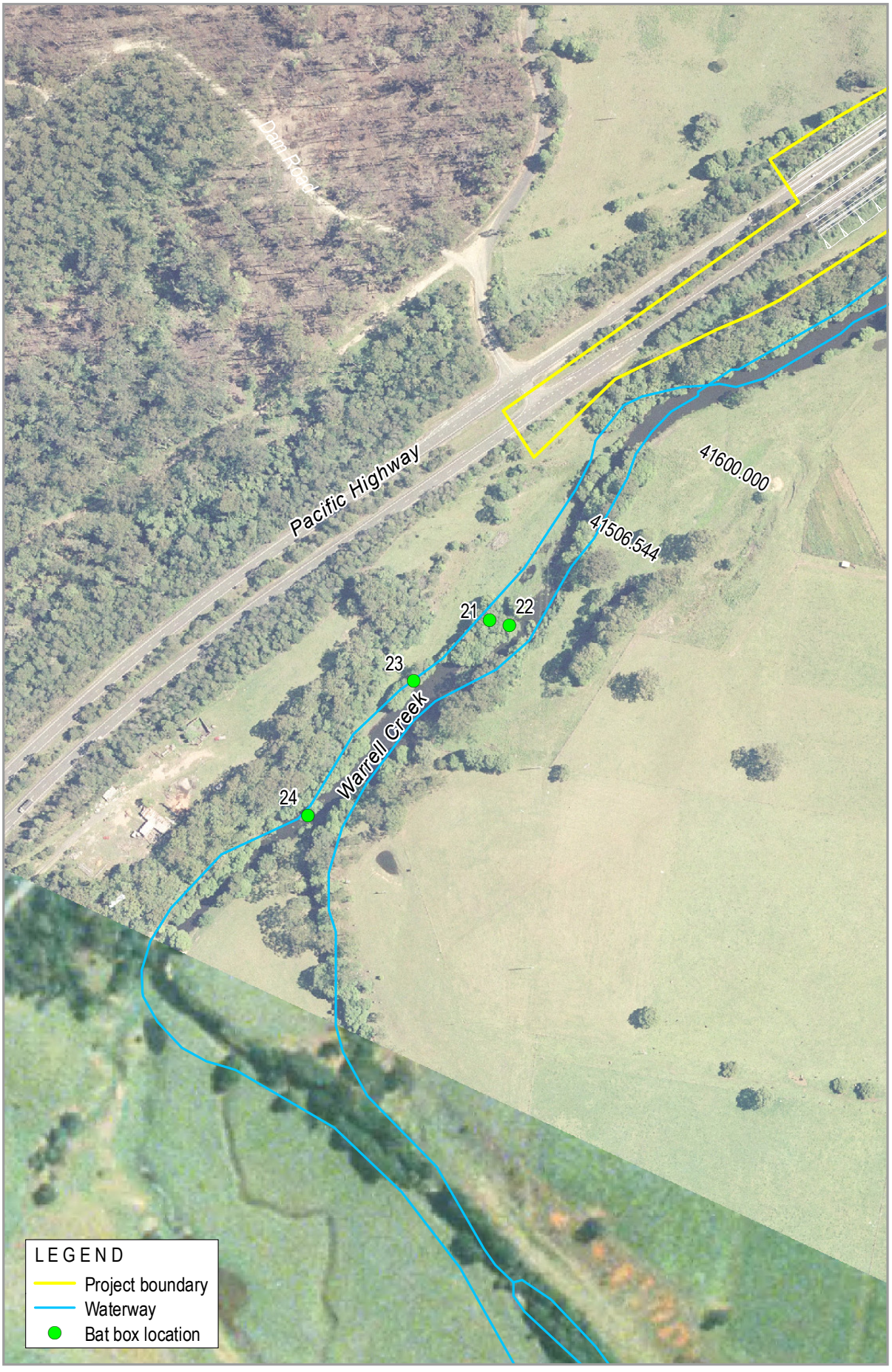
Bat Box Locations

GeoLINK environmental management and design

Microbat Roost Box Monitoring - Autumn 2018
2378-1439

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 20/04/2018
Source of base data: Roads and Maritime Services



0 80

North

Bat Box Locations

Appendix B

Microbat Roost Box Monitoring Results – Autumn 2018

Bat Box No.	Bat Box Type	Easting	Northing	Tree Common Name	Monitoring Date	Time	Bat Occupancy Evidence	Bat Count	Evidence of Breeding	Structural or Attachment Concerns	Comments/ Maintenance Required/ Undertaken
1	Dual Wedge	493717	6602832	Swamp Oak	19/04/2018	13:34	None	0	N/A	No	None
2	Quad Wedge	493713	6602819	River Mangrove	19/04/2018	13:40	1 x Lesser Long-eared Bat	1	No	No	None
3	Black Dome	493727	6602819	Swamp Oak	19/04/2018	13:38	None	0	N/A	No	Small Black Ant nest within this box. Nest was removed.
4	Single triangle (MB2.6)	493714	6602817	Swamp Oak	19/04/2018	13:45	None	0	N/A	No	As per recommendations from Summer 2018 monitoring report, the entry point to this box has been modified to increase entry slot by ~ 10 mm previously the entry slot was too narrow for microbats to easily enter.
5	Quad Wedge	492508	6599046	Grey Gum	19/04/2018	11:40	None	0	N/A	No	None
6	Quad Wedge	492513	6599048	Grey Ironbark	19/04/2018	11:36	None	0	N/A	No	None
7	Black Dome	492549	6599064	Swamp Oak	19/04/2018	11:25	None	0	N/A	No	None
8	Dual Wedge	492501	6599038	Broad-leaved Paperbark	19/04/2018	12:00	None	0	N/A	No	The concrete white dome design (damaged) has been replaced with a dual wedge bottom opening timber box and attached to the same tree but now attached to the main trunk of the tree.
9	Nara Small	491226	6598141	Broad-leaved Paperbark	19/04/2018	10:08	None	0	N/A	No	None
10	Dual Wedge	491252	6598141	Swamp Oak	19/04/2018	10:14	Lesser Long-eared Bat (*Nyctophilus geoffroyi*)	7	N/A	No	None
11	Dual Wedge	491009	6598116	Camphor Laurel	19/04/2018	10:33	None	N/A	N/A	N/A	None

Bat Box No.	Bat Box Type	Easting	Northing	Tree Common Name	Monitoring Date	Time	Bat Occupancy Evidence	Bat Count	Evidence of Breeding	Structural or Attachment Concerns	Comments/ Maintenance Required/ Undertaken
12	Quad Wedge	490929	6598000	Swamp Oak	19/04/2018	10:56	Gould's Wattled Bat (*Chalinolobus gouldii*)	6	N/A	No	None
13	Dual Wedge	494159	6602772	Swamp Mahogany	19/04/2018	13:14	None	0	N/A	No	None
14	Dual Wedge	494182	6602770	Swamp Mahogany	19/04/2018	13:16	None	0	N/A	No	None
15	Quad Wedge	494171	6602758	Tallowwood	19/04/2018	13:34	None	0	N/A	No	None
16	Black Dome	494143	6602768	Tallowwood	19/04/2018	13:45	Guano	0	N/A	No	Substantial guano deposit within the box not emptied as also large active mud wasp nest present within box, not removed.
17	Dual Wedge	492371	6600444	Grey Mangrove	19/04/2018	14:00	None	0	N/A	No	None
18	Dual Wedge	492333	6600445	Grey Mangrove	19/04/2018	14:10	None	0	N/A	No	None
19	Black Dome	492416	6600455	Grey Mangrove	19/04/2018	14:05	Guano	0	No	No	None
20	Quad wedge	492406	6600426	Grey Mangrove	19/04/2018	14:20	None	0	N/A	No	None
21	Quad Wedge	488455	6593550	Water Gum	19/04/2018	09:35	None	0	N/A	No	Mud Wasp nests with the narrow opening of 1 of 4 of the chambers, not removed.
22	Dual Wedge	488469	6593547	Rose Walnut	19/04/2018	09:32	None	0	N/A	No	None
23	Dual Wedge	488401	6593507	Red Ash	19/04/2018	09:27	None	0	N/A	No	None
24	Nara Small	488325	6593411	Water Gum	19/04/2018	09:20	None	0	N/A	No	Repositioned box within the same tree due to dislodgement by recent floodwaters.

ABN 79 896 839 729
ACN 101 084 557

Return address:
PO Box 119
LENNOX HEAD
NSW 2478

LENNOX HEAD
T 02 6687 7666
F 02 6687 7782

COFFS HARBOUR
T 02 6651 7666

ARMIDALE
T 02 6772 0454

LISMORE
T 02 6621 6677

www.geolink.net.au

16 August 2018
Ref No.: 2378-1452

Pacifico
124 Albert Drive
DONNELLYVILLE NSW 2447

Attention: Jason Haslett

Dear Jason

WC2NH Microbat Roost Box Monitoring – Winter 2018

Introduction

GeoLINK has been engaged by Pacifico to undertake microbat roost box monitoring for the Warrell Creek to Nambucca Heads Pacific Highway upgrade (WC2NH). A total of 24 microbat roost boxes were installed in 2014 to provide compensatory roost habitat for hollow-bearing trees removed during clearing for the highway upgrade alignment. This report provides the results of the winter 2018 monitoring undertaken on 26 July 2018. Monitoring of microbat roost boxes is to be undertaken seasonally for four years during the construction phase of the Project as outlined in the *Warrell Creek to Urunga Microchiropteran Bat Management Strategy* (MBMS) (Lewis, 2014). It is expected that the Project will be completed during late 2018. The spring 2018 report may be the last microbat roost box monitoring event during the Project construction phase.

Methods

Twenty-four (24) microbat roost boxes were inspected for microbats or evidence of microbat usage on 26 July 2018. Refer to **Appendix A** for microbat roost box locations. The methods of bat box inspection included:

- Inspection by tree climber with a camera to capture images of bats for identification.
- Ladder based observations. This involved looking directly into the bat box from a ladder. Many of the bat boxes with larger openings were able to be directly observed. Once bat boxes were determined to be empty, closer observations were made of the bat box lid and interior of the boxes to search for potential signs of fauna occupancy.
- Ground based inspections with binoculars. This was primarily undertaken at bat boxes which have an open base (dependent on positioning on the supporting tree).

General maintenance (e.g. tightening of cables/ adjusting bat boxes for improved stability; tightening of fixtures and removal of pest invertebrate fauna) and box replacement/ relocation was undertaken where required.

Urban and Regional Planning | Environmental Engineering | Civil Design | Environmental Impact Assessment | Ecological Surveys and Monitoring | Landscape Architecture | Urban Design |

Results

The results from the winter 2018 microbat roost box monitoring event are summarised below and tabulated in **Appendix B**.

Microbat Occupancy or Evidence of Use

No microbats were recorded occupying boxes during the winter 2018 monitoring event. This is the first monitoring event where no microbats have been recorded using the boxes since autumn 2015. A total of four microbat boxes recorded the presence of guano (Boxes 3, 7, 16 and 19) (refer to **Plate 1.1 to 1.2**).

Plate 1.1 **Box 16 microbat guano deposit in a black dome.**

Plate 1.2 **Box 19 significant guano deposit observed within a black dome.**

Structural Integrity and Attachments

No microbat roost boxes required maintenance or adjustments during the winter 2018 monitoring event.

Invertebrate Pests

Invertebrate pests (ants, bees, wasps or obstructive spider webs) were not observed to be an issue at the time of survey.

Discussion

A comparison of bat box usage from the monitoring events over time is provided in **Table 1.1** and shown in **Figures 1.1** and **1.2**. No microbats were recorded occupying the roost boxes during the current monitoring event (winter 2018). A complete absence of microbats occupying the boxes has not been recorded since the autumn 2015 monitoring event. Since the installation of the boxes, 14 of 16 monitoring events have recorded occupancy of boxes by microbats.

The data in **Figures 1.1** and **1.2** shows two general trends:

- An initial increasing trend in microbat numbers over time between summer 2015 and summer 2017, microbat numbers have fluctuated.
- Seasonal variation in microbat numbers and numbers of boxes occupied or showing evidence of microbat usage, with higher numbers typically being recorded in summer and lower numbers in winter/ spring.

These potential trends should be reviewed during future monitoring.

The absence of recorded microbat occupancy is not considered to be a result of construction or operational highway related impacts. The observation of four boxes recording evidence of use by the presence of guano deposits suggests that microbats have been recently present within some boxes. Four boxes recorded the presence of guano deposits indicating use since last monitoring (autumn 2018). The boxes which recorded guano deposits are the concrete domed box design which is a contained cell with a floor, which retains the guano. It is possible that the alternative box designs also shelter microbats at times however their use goes undetected due to the open bottom design of the box allowing guano to fall away and hence be undetected.

Churchill (2008) notes that Long-eared and Gould's Wattled Bats (the main species recorded during monitoring) select new roosts frequently and select roosts which are warmer during the winter months than cooler summer selected roosts, particularly in more protected roosts within forest stands. Several species of microbats are known to migrate to warmer climate roosts or hibernate for periods of time (e.g. Long-eared Bats) sometimes not emerging from their roosts for several days (Van Dyck and Strahan, 2008).

Microbats are making use of a number of boxes within the bat box groupings (refer to **Maps 1-5** of **Appendix A**). This is particularly evident for the Nambucca River roost box groups (bat Boxes 1 - 4 and 17 - 20) and the Crouches Creek group (Boxes 9 - 12). However, two groupings, Lower Warrell Creek (Boxes 5 - 8) and north of Bald Hill Road Interchange (13 - 16) have not recorded occupancy by microbats since the commencement of monitoring. The exception to this being Box 16 where evidence of usage (indicated by the presence of fresh guano) is regularly observed, though has not been occupied at the time of the monitoring. Box 7 recorded the presence of guano for the first time since autumn 2016 (> 2 years ago).

Conclusion

The monitoring undertaken to date has shown:

- An initial increasing trend in the number of microbats using the roost boxes between summer 2015 and summer 2017.
- A general increase in the number of roost boxes being utilised by microbats over time.
- Seasonal variations in roost box usage, with higher microbat usage recorded during summer compared to winter/ spring.
- Varying usage levels between bat box groupings.

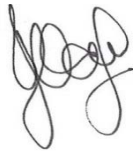
The monitoring to date has shown that the microbat roost boxes are being utilised by a range of microbat species (a minimum of four confirmed species), hence meeting the objectives of installing the boxes as detailed in the *WC2NH Microchiropteran Bat Management Strategy* (Lewis, 2014).

Recommendations

As the box groupings of Lower Warrell Creek and Bald Hill interchange have not recorded occupancy by microbats during the construction phase monitoring, it is suggested that these boxes could be rearranged within the site or once these boxes require maintenance, investigate replacement with an alternative roost box design to encourage uptake by microbats (excluding Box 16 and 7).

Please feel free to contact me if you require any additional information.

Yours sincerely
GeoLINK



Jessica O'Leary
Ecologist

References

Churchill, S. (2008). *Australian Bats (Second Edition)*. Allen & Unwin, NSW.

Van Dyck, S and Strahan, R. (2008). *The Mammals of Australia. (Third Edition)*. Reed New Holland, Sydney.

Lewis, B. (2014). *Warrell Creek to Urunga Microchiropteran Bat Management Strategy*. Unpublished report to Roads and Maritime Service, NSW.

UPR	*Description*	*Date Issued*	*Issued By*
2378-1452	First issue	16/08/2018	Jessica O'Leary

Table 1.1 Microbat box usage 2015-2018

Bat Box No.	2015 Summer	2015 Autumn	2015 Spring	2016 Summer	2016 Autumn	2016 Winter	2016 Spring	2017 Summer	2017 Autumn	2017 Winter	2017 Spring	2018 Summer	2018 Autumn	2018 Winter
1														
2				4 x likely *Myotis* sp.	4 x microbats					*1 x Nyctophilus geoffroyi*			*1 x Nyctophilus geoffroyi*	
3	1 x microbat	Guano		Guano	Guano		Guano	Guano	*6 x Nyctophilus geoffroyi*	*1 x Nyctophilus geoffroyi*	Guano	Guano		Guano
4														
5		Guano												
6														
7		Guano			Guano									Guano
8		Guano												
9														
10						1 x microbat	10 x *Nyctophilus* sp.		6 x *Nyctophilus geoffroyi*	1 x *Nyctophilus geoffroyi*	6 x *Nyctophilus geoffroyi*	6 x *Nyctophilus geoffroyi*	7 x *Nyctophilus geoffroyi*	
11														
12			1 x *Myotis macropus*	1 x microbat	3 x microbats	1 x microbat	1 x microbat	1 x *Myotis macropus*	5 x *Chalinolobus gouldii*		2 x *Chalinolobus gouldii*	2 x *Chalinolobus gouldii*	6 x *Chalinolobus gouldii*	
13														
14														
15														
16							Guano	Guano	1 x *Nyctophilus Gouldii*	Guano	Guano	Guano	Guano	Guano
17					1 x *Nyctophilus* sp.									
18								12 x *Nyctophilus* sp.	1 x *Nyctophilus geoffroyi*			Min. of 1 x likely *Nyctophilus sp.* which dispersed from Box 20 (therefore not included in the total count)		
19	Guano	Guano	Guano	Guano	2 x *Nyctophilus* sp.	1 x microbat	Guano	Guano	1 x *Chalinolobus gouldii*	4 x *Myotis macropus*	Guano	Guano	Guano	Guano
20	Guano	Guano	Guano	6 x microbats	1 x *Nyctophilus* sp.	7 x *Nyctophilus* sp.						Approx. 20 likely *Nyctophilus sp.*		
21							8 x *Nyctophilus* sp.							
22														
23								9 x *Nyctophilus gouldii* including at least one pup						
24												*1 x Nyctophilus gouldii*		
Total Bats	1	0	1	11	11	10	19	22	20	7	8	29	14	0
No. of boxes showing evidence of use	3	6	3	5	7	4	6	6	6	5	5	8	5	4
No. of boxes occupied	1	0	1	3	5	4	3	3	6	4	2	5	3	0

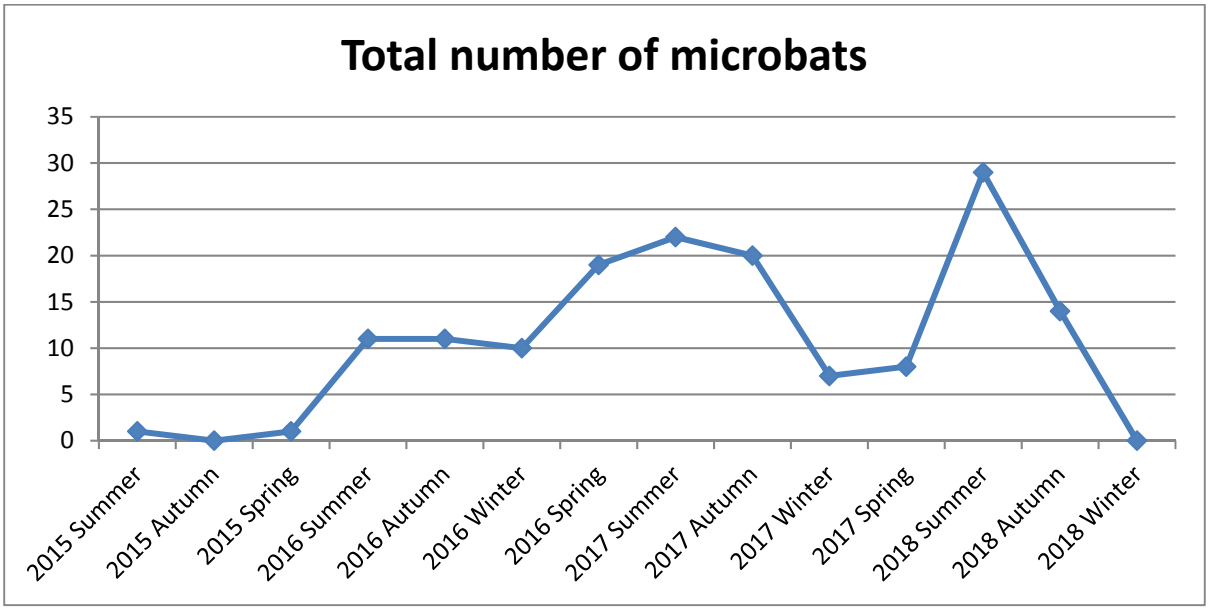


Figure 1.1 Total number of microbats recorded.

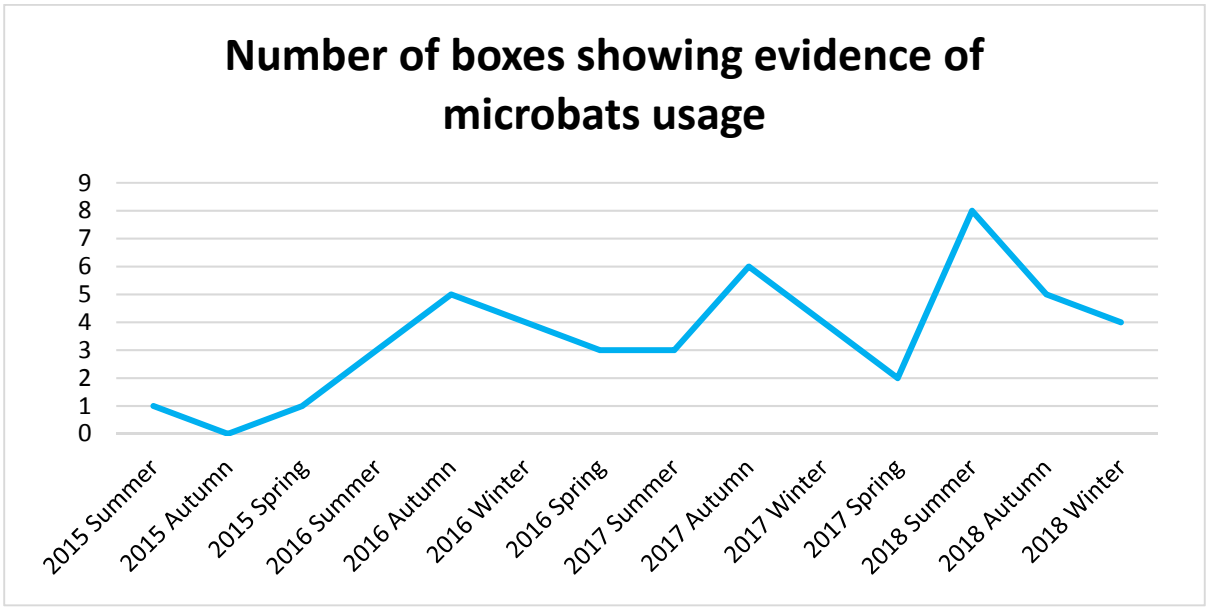


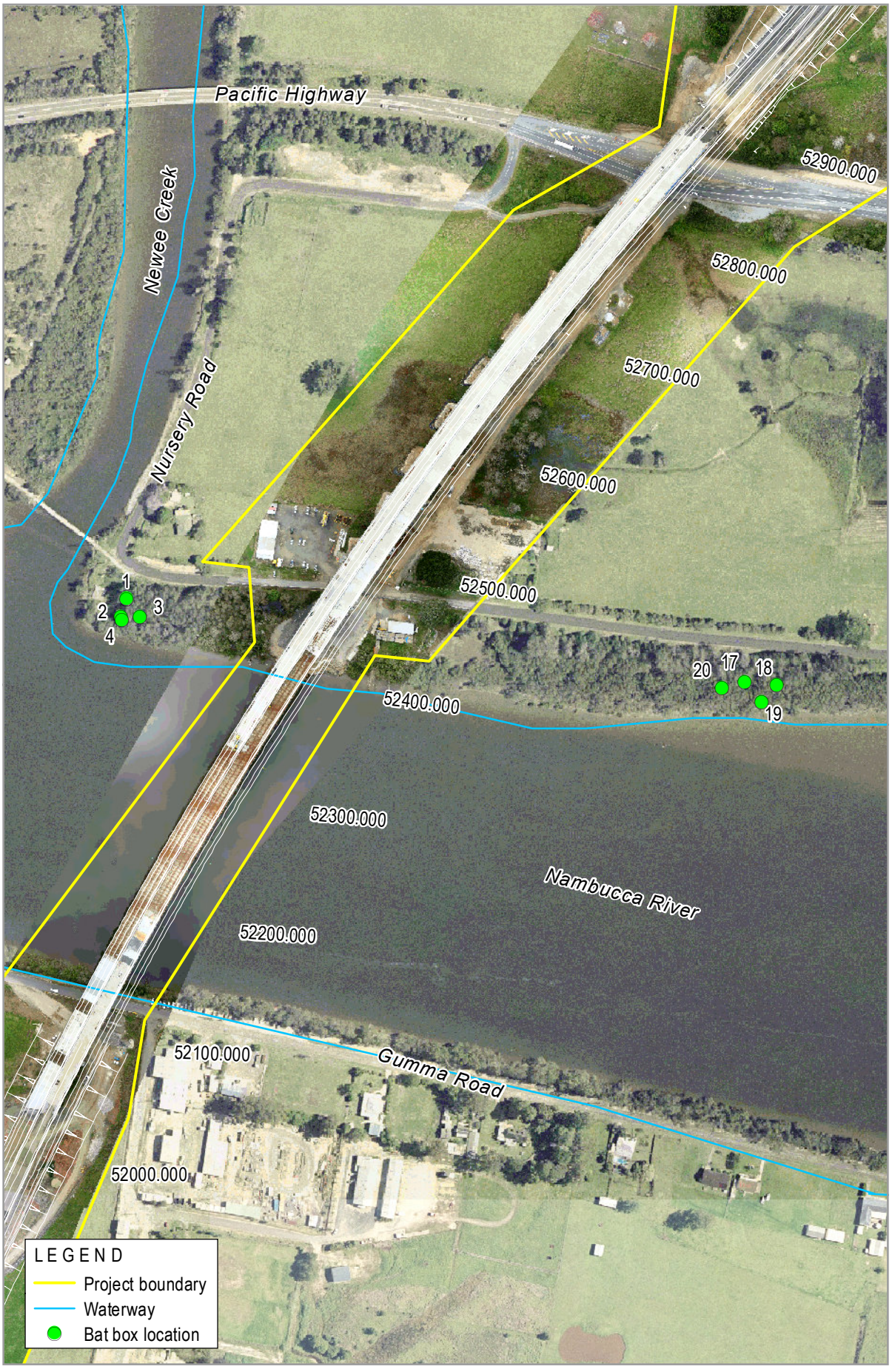
Figure 1.2 Number of boxes occupied or showing evidence of microbat usage.

Appendix A

Microbat Roost Locations

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 8/08/2018
Source of base data: Roads and Maritime Services



0 80

North

Bat Box Locations

GeoLINK environmental management and design

Microbat Roost Box Monitoring - Winter 2018
2378-1455

Map 1 of 5

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 8/08/2018
Source of base data: Roads and Maritime Services

0 80

North

Bat Box Locations

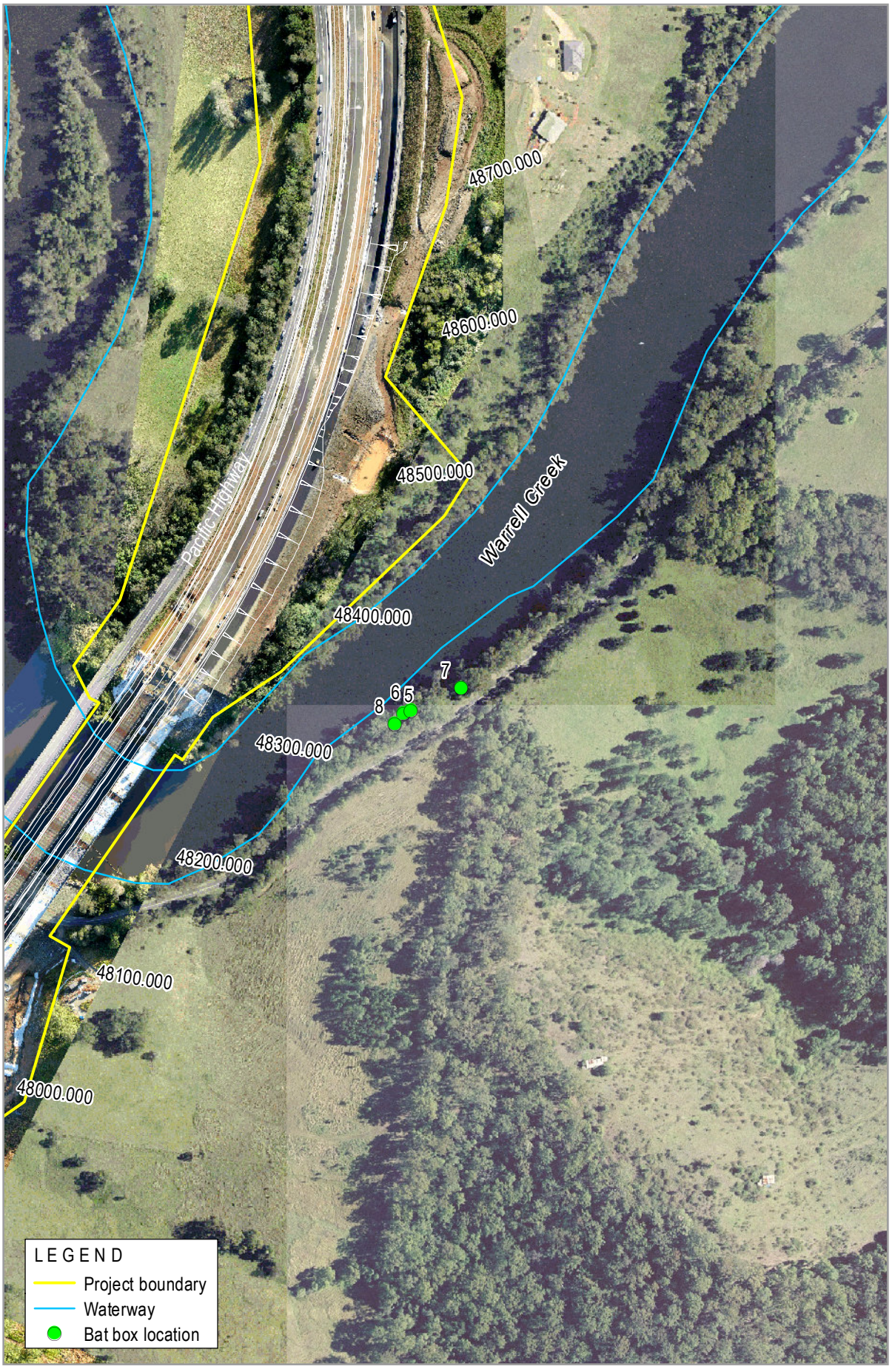
GeoLINK environmental management and design

Microbat Roost Box Monitoring - Winter 2018
2378-1455

Map 2 of 5

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 8/08/2018
Source of base data: Roads and Maritime Services



0 80

North

Bat Box Locations

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 8/08/2018
Source of base data: Roads and Maritime Services

0 80

North

Bat Box Locations

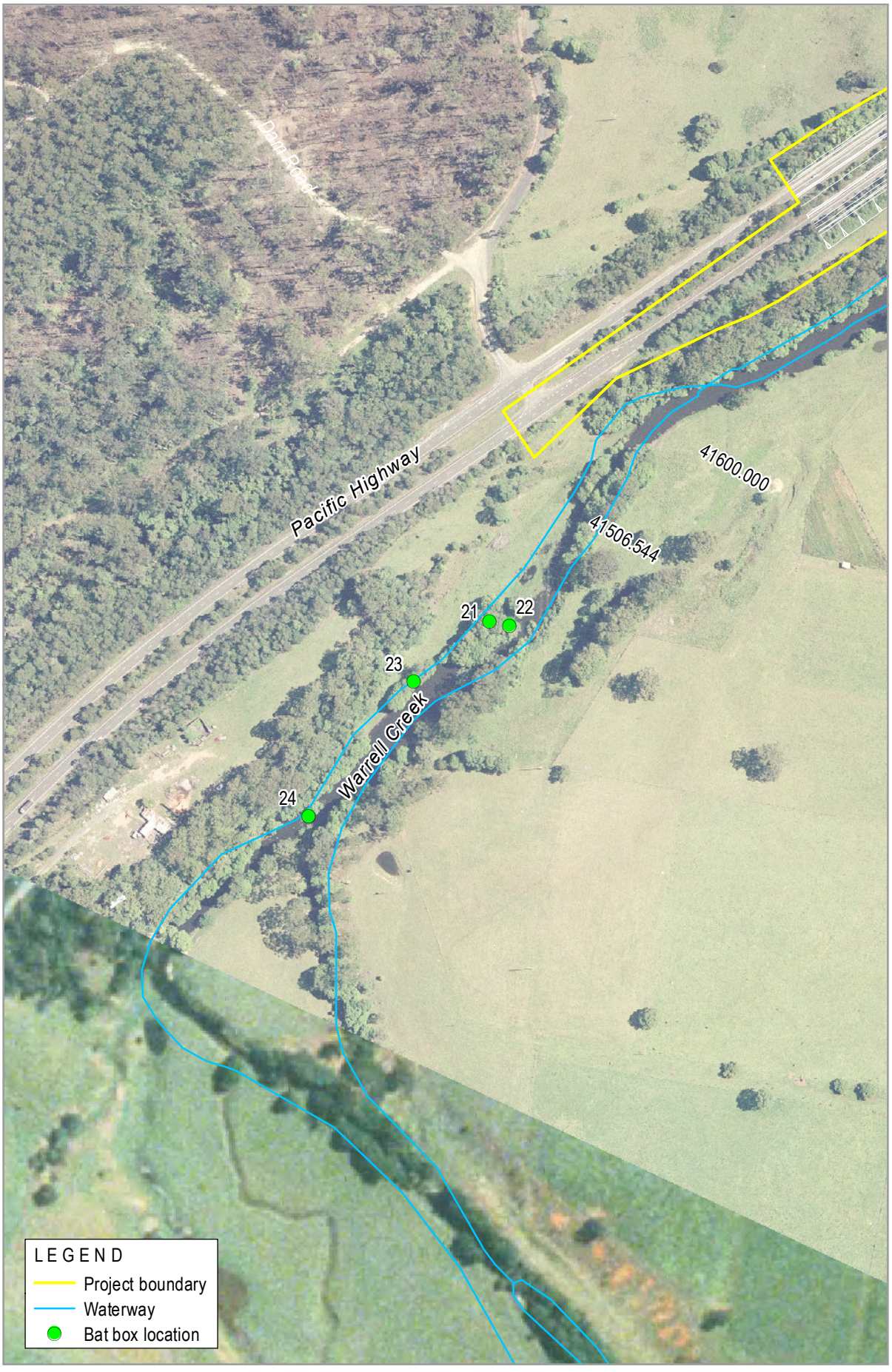
GeoLINK environmental management and design

Microbat Roost Box Monitoring - Winter 2018
2378-1455

Map 4 of 5

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 8/08/2018
Source of base data: Roads and Maritime Services



0 80

North

Bat Box Locations

GeoLINK environmental management and design

Microbat Roost Box Monitoring - Winter 2018
2378-1455

Map 5 of 5

Appendix B

Microbat Roost Box Monitoring Results – Winter 2018

Bat Box No.	Bat Box Type	Easting	Northing	Tree Common Name	Monitoring Date	Time	Bat Occupancy Evidence	Bat Count	Evidence of Breeding	Structural or Attachment Concerns	Comments/ Maintenance Required/ Undertaken
1	Dual Wedge	493717	6602832	Swamp Oak	26/07/2018	14:05	None	0	N/A	No	None
2	Quad Wedge	493713	6602819	River Mangrove	26/07/2018	13:55	None	0	N/A	No	None
3	Black Dome	493727	6602819	Swamp Oak	26/07/2018	14:08	Guano	0	N/A	No	Recent guano deposits observed since autumn 2018 monitoring event.
4	Single triangle (MB2.6)	493714	6602817	Swamp Oak	26/07/2018	13:50	None	0	N/A	No	None
5	Quad Wedge	492508	6599046	Grey Gum	26/07/2018	10:45	None	0	N/A	No	None
6	Quad Wedge	492513	6599048	Grey Ironbark	26/07/2018	10:55	None	0	N/A	No	None
7	Black Dome	492549	6599064	Swamp Oak	26/07/2018	10:58	Guano	0	N/A	No	Recent guano deposits observed since autumn 2018 monitoring event.
8	Dual Wedge	492501	6599038	Broad-leaved Paperbark	26/07/2018	11:03	None	0	N/A	No	None
9	Nara Small	491226	6598141	Broad-leaved Paperbark	26/07/2018	9:45	None	0	N/A	No	None
10	Dual Wedge	491252	6598141	Swamp Oak	26/07/2018	9:50	None	0	N/A	No	None
11	Dual Wedge	491009	6598116	Camphor Laurel	26/07/2018	10:10	None	0	N/A	No	None
12	Quad Wedge	490929	6598000	Swamp Oak	26/07/2018	10:20	None	0	N/A	No	None
13	Dual Wedge	494159	6602772	Swamp Mahogany	26/07/2018	11:38	None	0	N/A	No	None
14	Dual Wedge	494182	6602770	Swamp Mahogany	26/07/2018	11:45	None	0	N/A	No	None

Bat Box No.	Bat Box Type	Easting	Northing	Tree Common Name	Monitoring Date	Time	Bat Occupancy Evidence	Bat Count	Evidence of Breeding	Structural or Attachment Concerns	Comments/ Maintenance Required/ Undertaken
15	Quad Wedge	494171	6602758	Tallowwood	26/07/2018	11:50	None	0	N/A	No	None
16	Black Dome	494143	6602768	Tallowwood	26/07/2018	11:55	Guano	0	N/A	No	Recent guano deposits observed since autumn 2018 monitoring event.
17	Dual Wedge	492371	6600444	Grey Mangrove	26/07/2018	14:40	None	0	N/A	No	None
18	Dual Wedge	492333	6600445	Grey Mangrove	26/07/2018	14:35	None	0	N/A	No	None
19	Black Dome	492416	6600455	Grey Mangrove	26/07/2018	14:25	Guano	0	No	No	Recent guano deposits observed since autumn 2018 monitoring event.
20	Quad wedge	492406	6600426	Grey Mangrove	26/07/2018	14:30	None	0	N/A	No	None
21	Quad Wedge	488455	6593550	Water Gum	26/07/2018	9:12	None	0	N/A	No	None
22	Dual Wedge	488469	6593547	Rose Walnut	26/07/2018	9:10	None	0	N/A	No	None
23	Dual Wedge	488401	6593507	Red Ash	26/07/2018	9:05	None	0	N/A	No	None
24	Nara Small	488325	6593411	Water Gum	26/07/2018	8:55	None	0	N/A	No	None

Appendix H Road Kill

Pacific Highway Upgrade

Warrell Creek to Nambucca Heads

Operational Road Kill Monitoring Report

Roads and Maritime Services

NSW GOVERNMENT

THIS PAGE LEFT INTENTIONALLY BLANK

Document control

Report name	Pacific Highway Upgrade Warrell Creek to Nambucca Heads Operational Road Kill Monitoring Report
Date	15 February 2019
Revision 1	Section 2A initial 12 week monitoring report
Revision 2	Section 2A Autumn (April) 2018 monitoring report
Revision 3	Section 2A Winter (July) 2018 monitoring report
Revision 4	Section 2B initial 12 week monitoring report
Revision 5	Annual report 2018 including Spring (October) 2018 monitoring
Revision 6	Summer (January) 2019 monitoring report

Contents

Introduction 1

Purpose of this report 1

Appendix 1 WC2NH Road Kill Monitoring Program

Appendix 2 Road Kill Monitoring Report – Stage 2A initial 12 week monitoring.

Appendix 3 Road Kill Monitoring Report – Section 2A Autumn (April) 2018 monitoring.

Appendix 4 Road Kill Monitoring Report – Section 2A Winter (July) 2018 monitoring.

Appendix 5 Road Kill Monitoring Report – Section 2B initial 12 week monitoring

Appendix 6 Road Kill Monitoring Report – Annual report 2018 inc. Spring (October) 2018 monitoring.

Appendix 7 Road Kill Monitoring Report – Summer (January) 2019 monitoring.

Introduction

Road kill monitoring is a requirement of the approved Warrell Creek to Nambucca Heads Koala, Spotted-tailed Quoll and Grey-headed Flying-fox management plans and the Ecological Monitoring Program.

The aim of the monitoring program is to;

- report on any animal road kill on the project following the opening to traffic; and
- assess the effectiveness of the presence of fauna fencing to prevent fauna being killed by vehicles while attempting to cross the WC2NH Upgrade.

Timing of road kill surveys for the WC2NH Project is described in following table.

Project Phase	Timing of Survey	Location
Upon opening of each stage of the project to traffic (operational phase)	Weekly for 12 weeks commencing the week of opening each stage to traffic.	Entire length of opened stage.
Upon completion of the Project (operation phase)	Excluding the season/s covered by the initial 12 week monitoring period (refer above), weekly during October (spring), January (summer), April (autumn) and July (Winter) for up to 5 consecutive years post construction, or until mitigation measures have been demonstrated to be effective.	Entire length of completed Project

The approved road kill monitoring strategy is provided in Appendix 1.

Purpose of this report

The purpose of this report is to provide the monitoring data for the ongoing road monitoring following the opening of Stage 2A to traffic.

This report is updated with the results of the monitoring as Appendices as they become available.

Appendix 1 WC2NH Road Kill Monitoring Program

Timing of Monitoring

Timing of road kill surveys for the WC2NH Project is described in Table 1.

Table 1 – Timings and locations of road kill surveys

Project Phase	Timing of Survey	Location
During clearing operations	Daily	Portion of existing Pacific Hwy adjacent to clearing operations
One month following clearing operations	Daily	Portion of existing Pacific Hwy adjacent to clearing operations
Duration of construction	Weekly	Entire length of existing Hwy in Project area
Upon opening of each stage of the project to traffic (operational phase)	Weekly for 12 weeks commencing the week of opening each stage to traffic.	Entire length of opened stage.
Upon completion of the Project (operation phase)	Excluding the season/s covered by the initial 12 week monitoring period (refer above), weekly during October (spring), January (summer), April (autumn) and July (Winter) for up to 5 consecutive years post construction, or until mitigation measures have been demonstrated to be effective.	Entire length of completed Project

Monitoring Program Objectives

The aim of the monitoring program is to;

- report on any animal road kill on the project following the opening to traffic; and
- assess the effectiveness of the presence of fauna fencing to prevent fauna being killed by vehicles while attempting to cross the WC2NH Upgrade.

Monitoring Procedure

A two-person team vehicle being driven along the entire length of the highway in the Project area and identifying dead wildlife (road kill) seen on the road and within three metres of the road edge. The passenger will search the road and its verge for road kill. When a road kill is observed from the vehicle, a closer visual inspection of the carcass will be undertaken where safe access is available. If safe access is not possible, due to local traffic conditions, binoculars will be us ed to try to identify and provide as detailed information as is possible on the carcass.

Road kill fauna will be identified to species level where possible, with reference to field guides. Where there is any doubt to the identification of the carcass, photographs will be taken and forwarded to a qualified ecologist for identification /confirmation of species. Those too seriously damaged to be accurately identified will be recorded as “unknown”.

To assist with the correct identification of road kills, the following will be undertaken –

a. The provision of a qualified ecologist (shall be a recognised expert in mammal identification in coastal northern NSW) to undertake the initial phase of operational monitoring (first season) with relevant Roads and Maritime team members providing appropriate detailed training and a baseline of expert monitoring of road kills;

b. The provision of specialist training (to be provided by an expert as above in point a) in fauna identification for Contractors and Roads & Maritime staff involved in the construction phase monitoring of road kill; and

c. Where there is any doubt to the identification of the carcass, the provision of photographs of road kill to be sent to a qualified ecologist (an expert as above in point a) to confirm the identity of road kill and to maintain a permanent record of road kill for further comparisons, if needed.

Monitoring Methodology

1. The highway will be monitored using the method previously indicated (section 1.3) consisting of a two-person team traversing the Upgrade in a vehicle to locate and identify road kills;

2. The speed of travel will be the same in all cases to avoid confounding the data collection, and should be as slow as is safely possible;

3. The highway will be surveyed weekly for four weeks in Spring, Summer, Autumn and Winter (see Table 1);

4. Where possible, each survey shall be completed within two hours of sunrise in order to maximise the potential to record road kills before either carrion eating animals or traffic render any road kill unidentifiable;

5. if possible, each survey will be carried out on the same day of the week to remove the influence of varying environmental conditions and to ensure consistent temporal spacing;

6. For each road kill observed, the following attributes will be recorded

    a. Geographic Coordinates of any road kill.

    b. Whether fauna fencing was installed at/near the location.

    c. Species of road kill where possible, however, where there is any doubt as to the identification of the carcass, photographs shall be forwarded to a qualified ecologist for identification /confirmation of the species.

If the animal is identified as an EPBC Act threatened species, the carcass will be photographed and the following information will also be recorded where possible and safety considerations permit

a. Sex and age class (juvenile or adult).

b. Presence of pouch young (for marsupials).

c. Presence of flightless young (for flying-foxes or other bats).

d. Distance to a fauna connectivity structure.

e. Distance to drop down structure.

f. If fauna fencing was installed, is there any damage to the fence in the vicinity.

g. Weather conditions at the time of the monitoring (from the Bureau of Meteorology) – including temperature, rainfall in the last 24 hours, moon phase.

h. If the animal is identified as a flying-fox:
    - Distance to nearest camp,
    - Distance to nearest canopy vegetation,

- Presence of flowering food trees in neighbouring median or roadside vegetation; plants identified to species and referenced with diet list.

Analysis of data

The data to be collected will be analysed using a suitable nonparametric test such as a Kruskal-Wallis test. The aim will be to test both whether the fenced and unfenced locations have different mean numbers of road kills and if the amount of road kill varies through time in either or both of the two types of areas. Associations with other measured variables will be described as data allow, including sex, age class, presence of dependent young and, in the case of flying-foxes, proximity to roost sites or flowering food trees. Such information will indicate if the mitigation measures in the area are working as expected to keep road kills to acceptable levels and that none of the target species are killed.

Reporting

Quarterly reports

A report will be prepared by the ecologist following the initial 12 week monitoring period (after opening for each stage) to identify any roadkill hotspots and review the mitigation measures. The initial report and ongoing seasonal reports of the data collected will be provided to Roads and Maritime. This will include graphs of the data and any previously collected data to provide simple visual comparisons of road kill. This will also include overall road kill counts as well as separate graphs for each of the target species (if deaths have occurred).

Anecdotal road kill information collected on days that are not monitored as part of this program may be added as a note for discussion.

Annual Reports

The annual report will be prepared in consultation with a qualified ecologist and provided to DoEE and EPA within one month of completion of the fourth monitoring season. From then on it will be provided within one month of the same monitoring season in subsequent years until monitoring is completed (Table 1).

Analysis of the data itself shall be included in an annual monitoring report. This report will include a statistical analysis of all of the data collected to that time including graphical representations of the road kill that is recorded.

Annual reports will record any potential or obvious failures in road kill mitigation identified in the monitoring program and provide a date by which meetings will take place to discuss any such adverse findings. This will include at least:

- where statistically larger number numbers of road killed animals are detected on fenced sections compared to unfenced sections;
- where any of the target threatened fauna are recorded as killed;
- where there is a clear pattern of unexpected road kill at any point on the Upgrade.

Performance Measures

Lower rates of road kill in proximity to fauna fencing (ie areas of the main carriageways within areas adjacent to installed fauna fencing) than in sections of the upgrade not near fauna fencing during monitoring events up to 5 years post construction phase, or until such time as mitigation measures have been demonstrated to be effective.

Adaptive Management

Where any annual report identifies a significant difference between the road kill numbers of the fenced and unfenced areas, DoEE and EPA shall be notified, and a meeting will be set to discuss such differences with the relevant agencies & Roads and Maritime.

Such a meeting would occur within one month of completion of the annual report, which should ensure sufficient time to consider/review the response to any recorded significant differences.

Appendix 2 Stage 2A Initial 12 Week Monitoring Report.

Road Kill Monitoring Report

WC2NH Stage 2A

PO Box 119
Lennox Head NSW 2478
T 02 6687 7666

PO Box 1446
Coffs Harbour NSW 2450
T 02 6651 7666

PO Box 1267
Armidale NSW 2350
T 02 6772 0454

PO Box 229
Lismore NSW 2480
T 02 6621 6677

info@geolink.net.au

Prepared for: Roads and Maritime Services

© GeoLINK, 2018

UPR	Description	Date Issued	Issued By
2692-1088	First Issue	22/03/2018	Jessica O'Leary
2692-1092	Second Issue	10/04/2018	David Andrighetto

Table of Contents

1. Introduction 1

2. Methodology 11

2.1 Road Kill Monitoring 11

2.2 Analysis of Data 12

3. Results 13

3.1 Number and Species of Fauna Road Kills 13

3.2 Distribution of Fauna Road Kill Records 15

4. Discussion 17

4.1 Discussion 17

4.2 Comparison with Construction Road Kill Monitoring 17

4.3 Analysis of Data 18

4.4 Observations 19

5. Conclusion 20

Illustrations

Illustration 1-1 Road Kill Fauna Locations 2

Illustration 1-2 Road Kill Fauna Locations 3

Illustration 1-3 Road Kill Fauna Locations 4

Illustration 1-4 Road Kill Fauna Locations 5

Illustration 1-5 Road Kill Fauna Locations 6

Illustration 1-6 Road Kill Fauna Locations 7

Illustration 1-7 Road Kill Fauna Locations 8

Illustration 1-8 Road Kill Fauna Locations 9

Illustration 1-9 Road Kill Fauna Locations 10

Appendices

Appendix A Stage 2A Road Kill Monitoring Results

Executive Summary

GeoLINK was engaged by NSW Roads and Maritime Services to undertake weekly Road Kill Monitoring for the first 12 weeks of the operational phase of the Stage 2A section of the Warrell Creek to Nambucca Heads Pacific Highway Upgrade (WC2NH). A number of road kill mitigation measures were implemented for WC2NH with the aim to minimise vehicle collisions with native wildlife. The types of structures which were constructed to mitigate traffic impacts to fauna consist of:

- The installation of fauna fencing to exclude fauna from the road corridor or as a guide towards connectivity structures.
- Fauna Drop Down Structures (escape ramps) along the fauna fencing.
- Fauna connectivity structures, including fauna culvert underpasses, bridge underpasses, rope bridges and glider poles.

The aim of the monitoring program is to:

- Report on any animal road kill within the Stage 2A section of operational highway since open to traffic; and
- Assess the effectiveness of the presence of fauna fencing to prevent fauna being killed by vehicles while attempting to cross the WC2NH Upgrade.

Road kill monitoring for Stage 2A of WC2NH was undertaken weekly (each Thursday) for the first 12 weeks after the opening of Stage 2A to traffic. The Stage 2A site covers 13.3 km of dual carriageway highway extends from Scott's Heads Road in the south (Chainage 48100) to Nambucca Heads, connecting to the Nambucca Head to Urunga Pacific Highway upgrade in the north (Chainage 61250). The survey area covered the north and southbound carriageways and has a combined length of 26.6 km of road.

One road kill of a *Biodiversity Conservation Act 2016* (BC Act) listed species was recorded during the monitoring, which comprised a Masked Owl. No *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) listed species were recorded during the monitoring period. No road kill recordings of target threatened species known to occur within habitat adjacent to the highway alignment that the fencing aims to protect were recorded. Such species include the Koala, Spotted-tailed Quoll, Grey Headed Flying-fox or Green-thighed Frog.

Of the 96 road kill recordings, medium to large terrestrial native mammals comprise the main species group to which the fence design provides a barrier for. Recordings of these species were relatively low (8) over the reporting period. No arboreal mammal road kills were recorded. Species diversity included 24 native species and five introduced species.

Three road kill hotspots were identified across Stage 2A including the Gumma Floodplain, north of the Nambucca River Bridge and to a lesser degree the section from north of Lower Warrell Creek to the Bald Hill overpass.

No flying-fox road kill records were made in the vicinity of the Type 4 fauna fencing (flying-fox fencing) between chainage 49700 and 50200, though the camp was not occupied during the monitoring.

The results show a declining trend in the number of road kills across the survey area for all fauna classes over time. This may be attributed to a number of factors including reduction of roadside food sources which attract fauna to the corridor, habituation of the road to fauna or local populations of certain species have temporarily declined as a direct result of vehicle collisions.

Statistical analysis to determine the effectiveness of the fauna fencing does not contain strong statistical power due to the small results data pool, particularly of relevant fauna groups (i.e. medium to large sized terrestrial mammals). This may be attributed to the effectiveness of the fencing in reducing fauna access to the roadway. The results of future monitoring should be consolidated to develop a larger data set to allow for future statistical analysis.

A number of observations and suggestions have been made as lessons learnt in preparation for the opening of Stage 2B of the WC2NH Pacific Highway Upgrade.

1. Introduction

GeoLINK was engaged by NSW Roads and Maritime Services to undertake weekly Road Kill Monitoring for the first 12 weeks of the operational phase of the Stage 2A section of the Warrell Creek to Nambucca Heads Pacific Highway Upgrade (WC2NH). A number of road kill mitigation measures were implemented for WC2NH with the aim to minimise vehicle collisions with native wildlife. The types of structures which were constructed to mitigate traffic impacts to fauna consist of:

- The installation of fauna fencing to exclude fauna from the road corridor or as a guide towards connectivity structures.
- Fauna Drop Down Structures (escape ramps) along the fauna fencing.
- Fauna connectivity structures, including fauna culvert underpasses, bridge underpasses, rope bridges and glider poles.

Several fauna fence designs were installed to target threatened species including:

- **Type 1** - Chainmesh fence 1.8 m tall with floppy top feature which is designed to exclude a range of native mammal species such as macropods, possums, Spotted-tail Quoll (*Dasyurus maculatus*) and Koala (*Phascolarctos cinereus*). 18.03 km of this fence type occurs at the site.
- **Type 3** - Small gauge mesh fence with sheet metal return angled away from the highway (combined with fauna floppy top fence) which is designed to exclude Green-thighed Frog (*Litoria brevipalmata*) from the road corridor. 1.32 km of type 3 fauna fence occurs at the site, overlapping with the type 1 fencing.
- **Type 4** - Chainmesh fence 4 m tall through the Macksville Flying-fox camp Paperbark Swamp Forest community designed to discourage Grey Headed Flying-fox (*Pteropus poliocephalus*) from flying within range of passing traffic when exiting/ entering the roost. 1 km of type 4 fence occurs at the site.

The locations of fauna fences and design types are presented within **Illustration 1.1 - 1.9**.

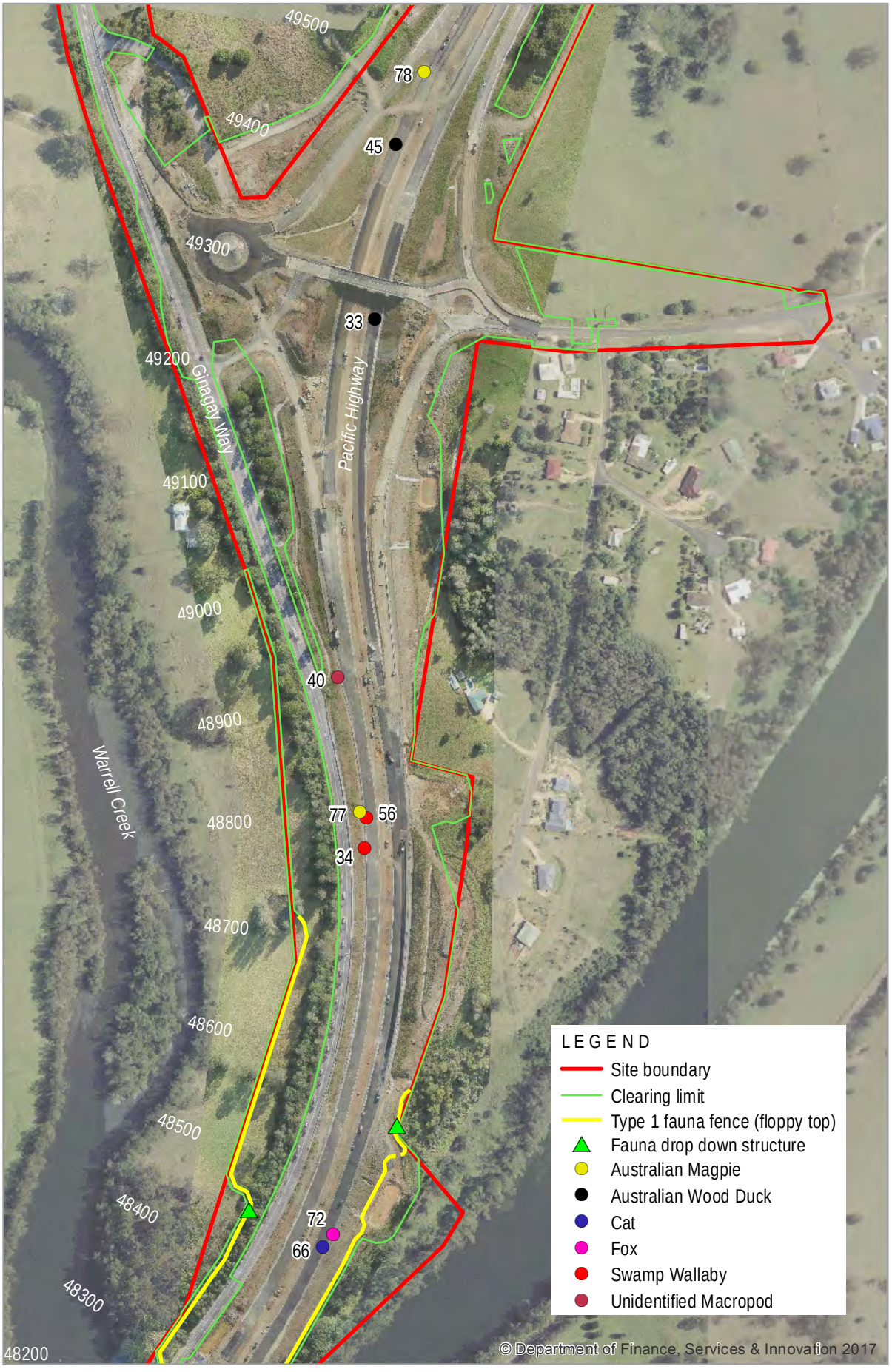
The aim of the monitoring program is to:

- Report on any animal road kill within the Stage 2A section of operational highway since open to traffic; and
- Assess the effectiveness of the presence of fauna fencing to prevent fauna being killed by vehicles while attempting to cross the WC2NH Upgrade.

This report provides the results of the first 12 weeks of road kill monitoring.

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 23/03/2018
Source of base data: Roads and Maritime Services and AFJV



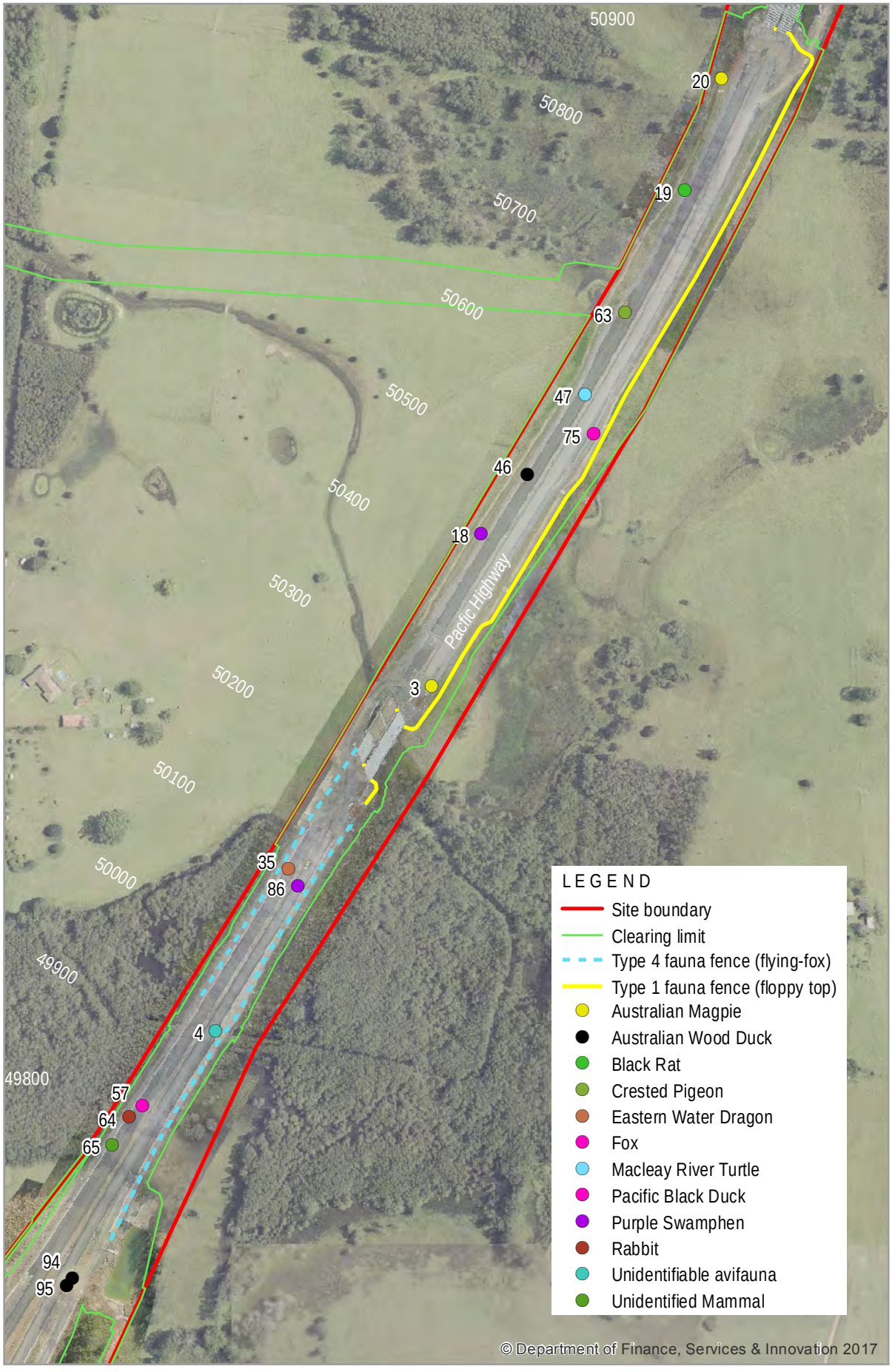
0 100

North

Road Kill Fauna Locations

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 23/03/2018
Source of base data: Roads and Maritime Services and AFJV



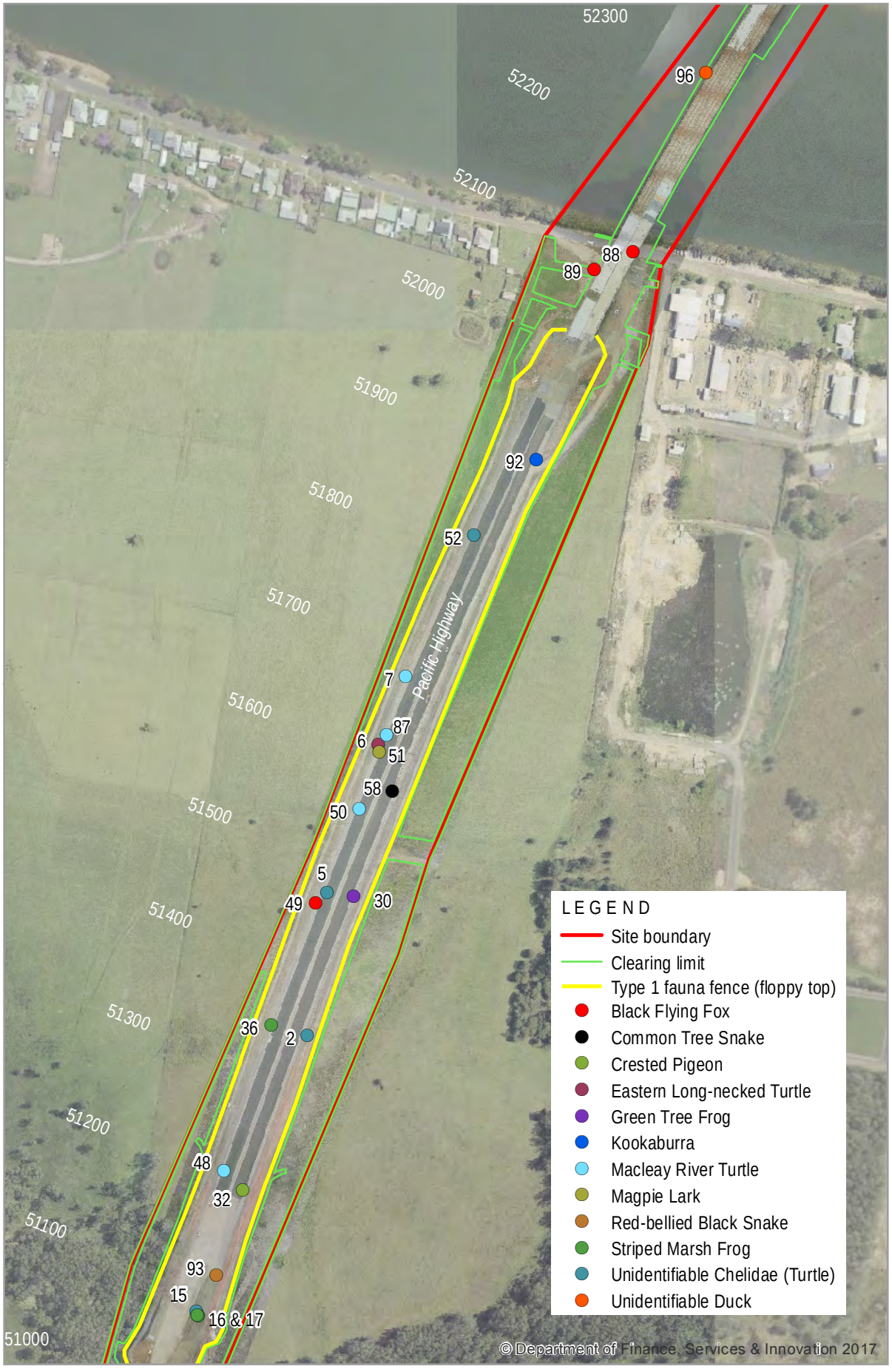
North

0 100

Road Kill Fauna Locations

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 23/03/2018
Source of base data: Roads and Maritime Services and AFJV



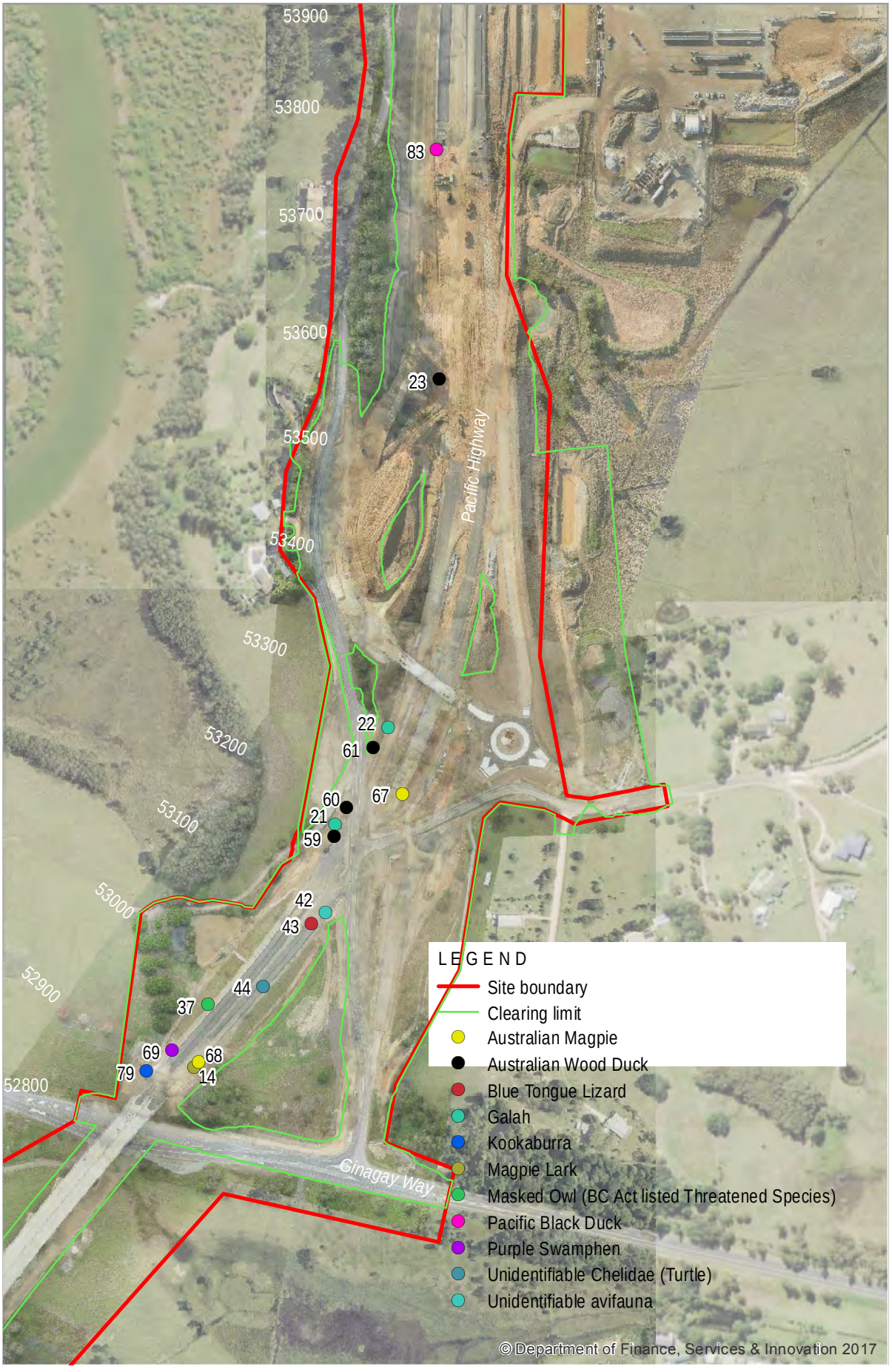
0 100

North

Road Kill Fauna Locations

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 23/03/2018
Source of base data: Roads and Maritime Services and AFJV



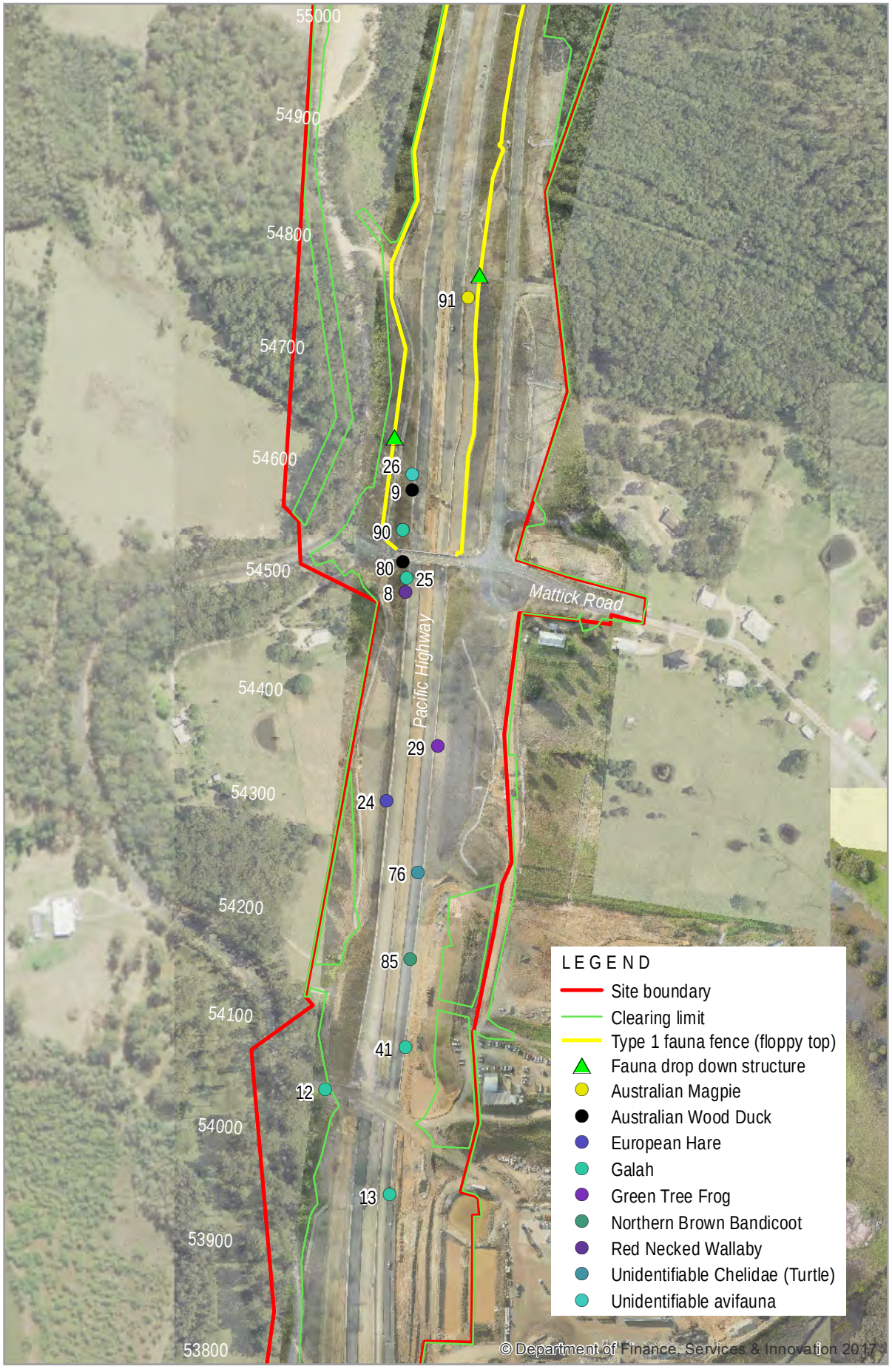
0 100

North

Road Kill Fauna Locations

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 23/03/2018
Source of base data: Roads and Maritime Services and AFJV



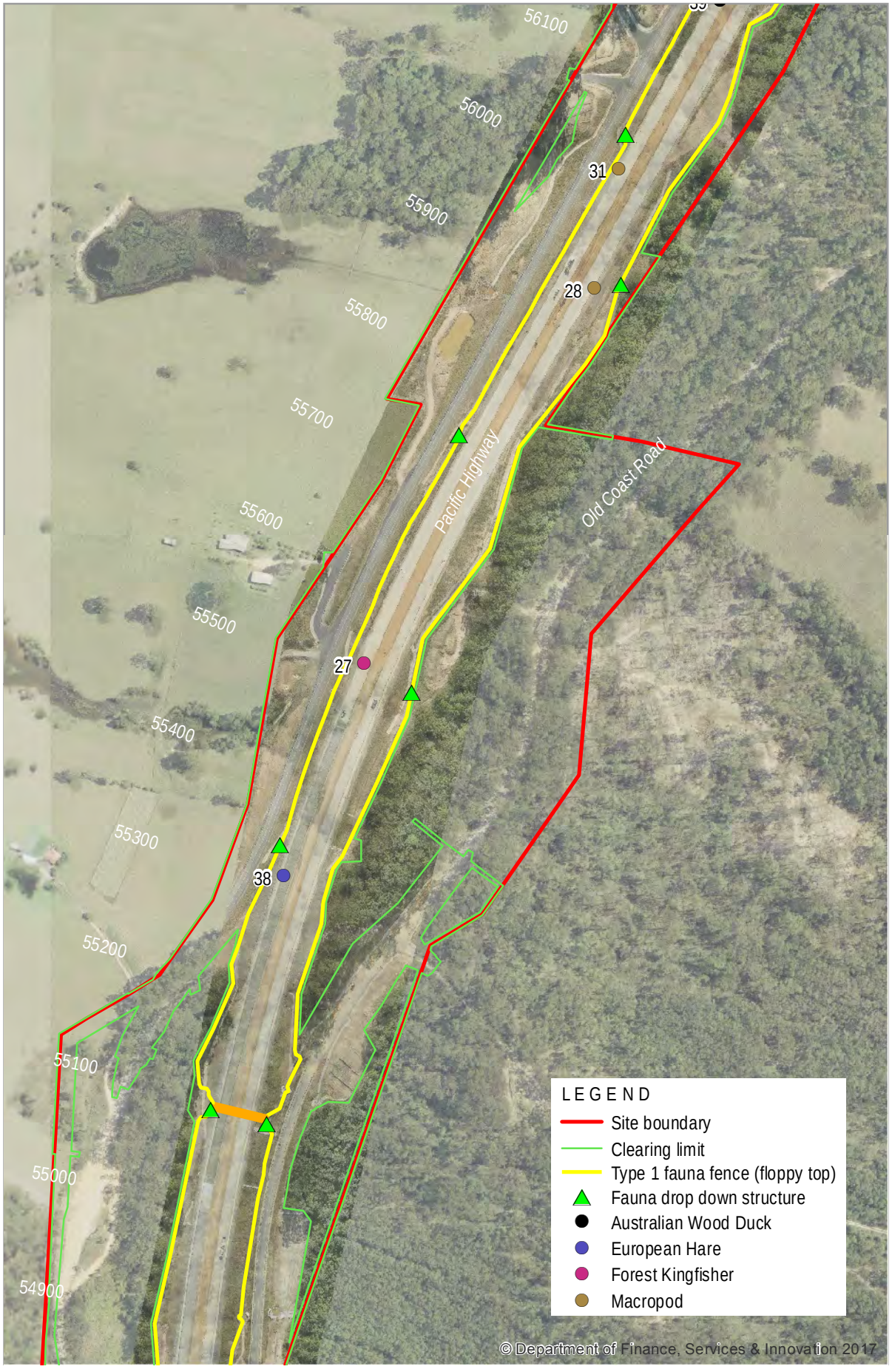
0 100

North

Road Kill Fauna Locations

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 23/03/2018
Source of base data: Roads and Maritime Services and AFJV



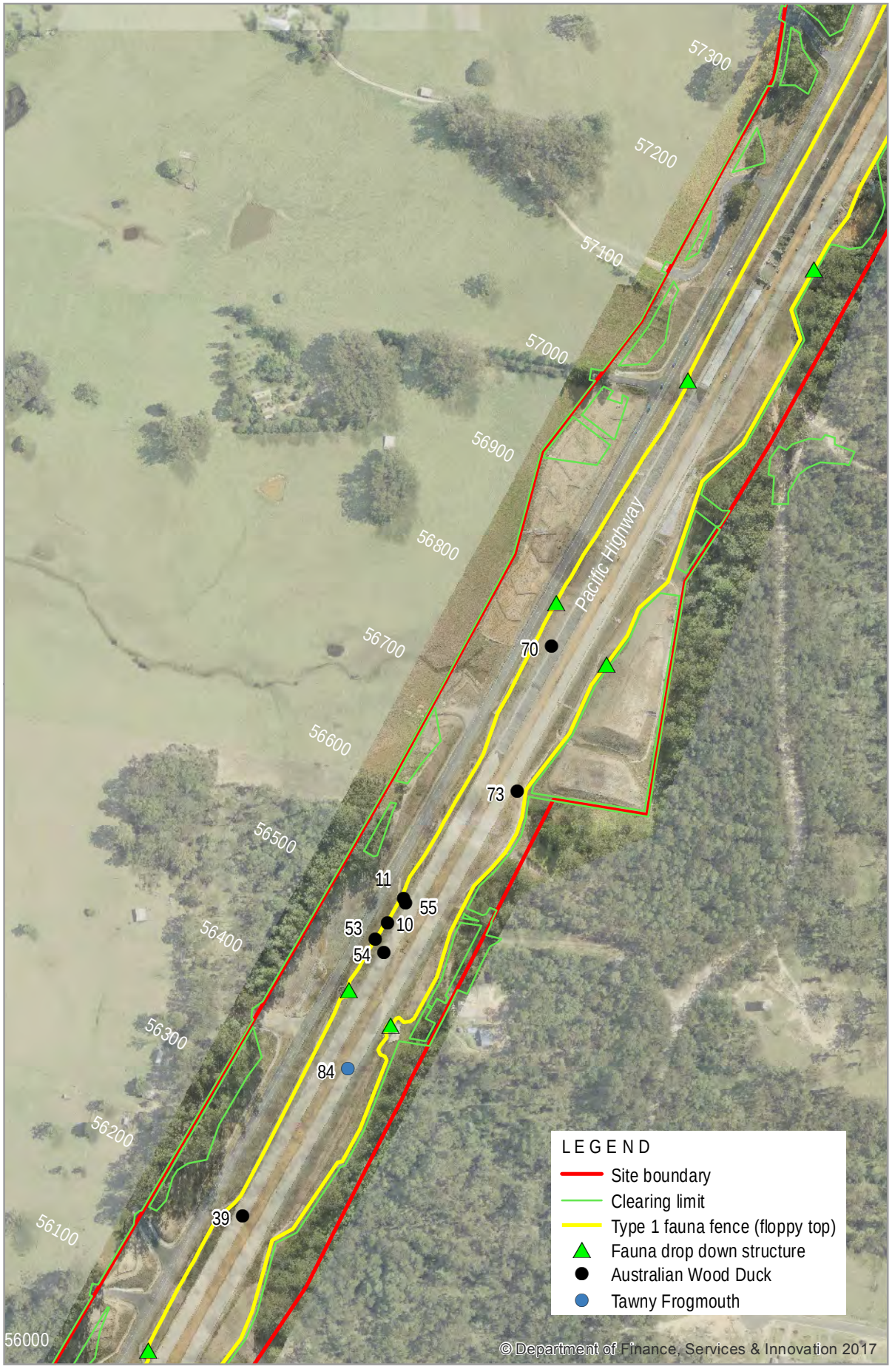
0 100

North

Road Kill Fauna Locations

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 23/03/2018
Source of base data: Roads and Maritime Services and AFJV



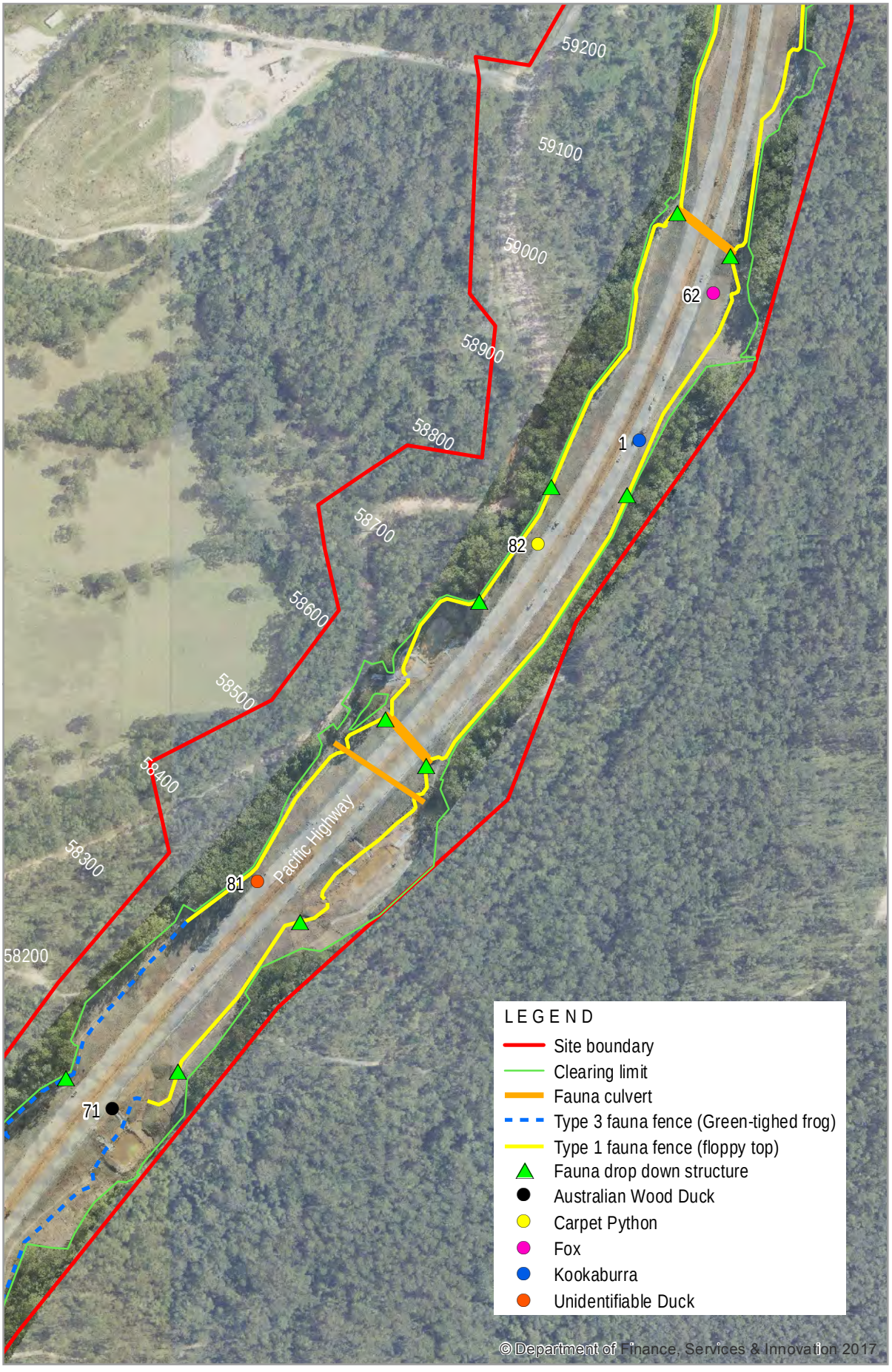
0 100

North

Road Kill Fauna Locations

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 23/03/2018
Source of base data: Roads and Maritime Services and AFJV



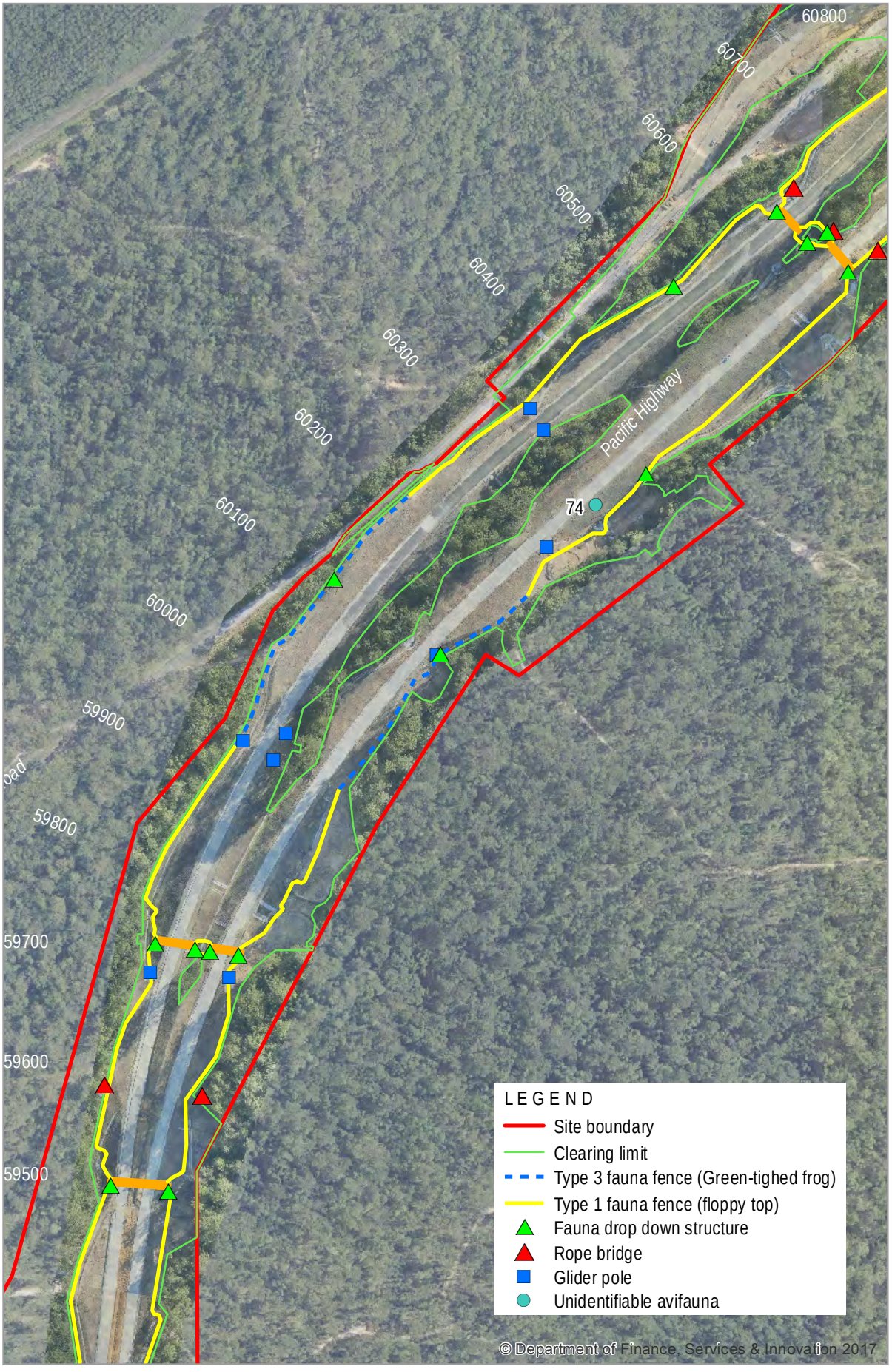
0 100

North

Road Kill Fauna Locations

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 23/03/2018
Source of base data: Roads and Maritime Services and AFJV



0 100

North

Road Kill Fauna Locations

2. Methodology

2.1 Road Kill Monitoring

Road kill monitoring for Stage 2A of WC2NH was undertaken weekly (each Thursday) for the first 12 weeks after the opening of Stage 2A to traffic. The Stage 2A site covers 13.3 km of dual carriageway highway extends from Scott's Heads Road in the south (Chainage 48100) to Nambucca Heads, connecting to the Nambucca Heads to Urunga Pacific Highway upgrade in the north (Chainage 61250). The survey area covered the north and southbound carriageways and has a combined length of 26.6 km of road (refer to **Illustration 1.1 - 1.9**). Of this, 19.04 km is fenced (71.5%) with either type 1 or type 4 fauna exclusion fencing. Type 3 fauna exclusion fencing (GTF exclusion fencing) occurs along 1.32 kms of the Type 1 fence length (GTF exclusion fencing is affixed to the bottom of the Type 1 fence).

The 12 weekly monitoring events commenced on 21 December 2017 and ended on 8 March 2018. The first pass of the survey area was undertaken within the first two hours of sunrise. The second and occasionally a third pass was undertaken to collect data not recorded during the first pass due to inaccessibility, no place to safely collect data at the time of observation or the record not being observed during the first pass.

Opportunistic road kill records were also observed on two days outside of the nominated weekly monitoring event. These records were collected on 9 January and 25 February 2018, and were grouped together with week 4 and 10 results respectively.

The following monitoring methodology was adopted:

- A two-person team drove the length of Stage 2A in a vehicle to locate and identify fauna road mortalities, as a result of vehicle strike.
- The speed of travel averaged 60-70 kilometres per hour, with both the driver and ecologist visually searching for fauna road kill along the highway alignment and within 3m from the fog line.
- A minimum of two passes of the survey area was completed to ensure that all records were accurately detected and could be safely recorded.

For each road kill observed, the following attributes were recorded:

- Species of animal.
- Date of record.
- Global Positioning System (GPS) coordinates.
- Location of road kill record with in either the south or northbound carriageway.
- The presence of fauna fencing at/near to the road kill record.
- Distance to the nearest fauna fence if not installed adjacent to the road kill record.
- Photographic record of the animal.
- Comments.

If the animal was identified as an *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) listed threatened species, the carcass was photographed and the following information recorded:

- Sex and age class (juvenile or adult).
- Presence of pouch young (for marsupials).
- Presence of flightless young (for flying-foxes or other bats).

- Distance to a fauna connectivity structure.
- Distance to drop down structure.
- If fauna fencing was installed, was there any damage to the fence in the vicinity.
- Weather conditions at the time of the monitoring (from the Bureau of Meteorology) – including temperature, rainfall in the last 24 hours, moon phase.
- For flying-foxes:
    - Distance to nearest camp.
    - Distance to nearest canopy vegetation
    - Presence of flowering food trees in neighbouring median or roadside vegetation; plants identified to species and referenced with diet list.

2.2 Analysis of Data

The data collected was analysed using two nonparametric tests: G-test and Kruskal-Wallis. The analysis aimed to determine:

- Whether the fenced and unfenced locations have different frequencies of road kills.
- If the amount of road kill varies through time for fenced and unfenced areas.

The G-test has been shown to be superior to the Chi-squared test for comparing frequency data where the expected proportions were not derived from the data. The G-test is a non-parametric log-likelihood test that conforms to a Chi-squared distribution. It tests the null hypothesis that the observed and expected frequencies do not differ (Dytham 2003). A G-test was applied to frequency data by pooling monitoring periods for both fenced and non-fenced areas. Expected proportions were taken from the proportion of total highway length (26.6 km) that was fenced (76.5%) versus unfenced (23.5%). A two-tailed G-test was conducted by programming the G-test into an Excel spreadsheet.

A Kruskal-Wallis (KW) test is a non-parametric equivalent of the one-way ANOVA. It is used when the assumptions of an ANOVA are violated (e.g. normality). The KW is a rank test that uses the null hypothesis that the samples are taken from populations with the same median (Dytham 2003). The KW test was used to compare the number of road kill over time by pooling fenced and non-fenced sites. Twelve monitoring periods were available for analysis. A two-tailed KW test using K independent samples was undertaken in SPSS.

3. Results

3.1 Number and Species of Fauna Road Kills

The results of the road kill surveys during the first 12 weeks of Stage 2A being operational are provided in **Appendix A**. A total of 94 fauna road mortalities were recorded during the 12 weekly monitoring events. Species diversity included 24 native species and five introduced species. The road kill recordings included:

- Fifty-five (59%) native avifauna (birds) comprising a minimum 11 confirmed species/species groups. This included one *Biodiversity Conservation Act 2016* (BC Act) listed threatened species, the Masked Owl (*Tyto novaehollandiae*) (refer to **Plates 1.1** and **1.2**).
- Nine (10%) native mammal comprising a minimum of four confirmed species/species groups including six macropod (including Red-necked Wallaby (*Macropus rufogriseus*) and Swamp Wallaby (*Wallabia biclour*)), three Black Flying-Fox (*Pteropus alecto*) and one Northern Brown Bandicoot (*Isoodon macrourus*) records.
- Eight (9%) introduced mammals comprising five species including three European Foxes (*Vulpes vulpes*), one cat (*Felis catus*), two European Hares (*Lepus europaeus*), a Rabbit (*Oryctolagus cuniculus*) and a Black Rat (*Rattus rattus*) record.
- Sixteen (17%) native reptiles comprising seven confirmed species, including 11 records of two turtle species, one record of two lizard species and one record of three snake species.
- Six (6%) frogs comprising two confirmed species (Striped March Frog (*Limnodynastes peronii*) and Green Tree Frog (*Litoria cerulea*)) and one record that was unidentifiable.

Two additional opportunistic road kill mortalities were recorded on two occasions with the following recordings:

- Macropod (9/01/2018).
- Black-flying Fox (25/02/2018).

Figures 3.1 and **3.2** shows the number of fauna road kills recorded each monitoring event over the 12 week monitoring period. The number of fauna mortality records peaked during week 2 of Stage 2A being operational with 20 road kill fauna records observed. Results indicate a general trend with the number of fauna road kill records declining over time. The last monitoring event of week 12 was the only monitoring event where no fauna mortalities were recorded. Heavy rainfall at the site during the week preceding this monitoring event is likely to have contributed to this result.

No road kill recordings of EPBC Act listed threatened species occurred during the monitoring.

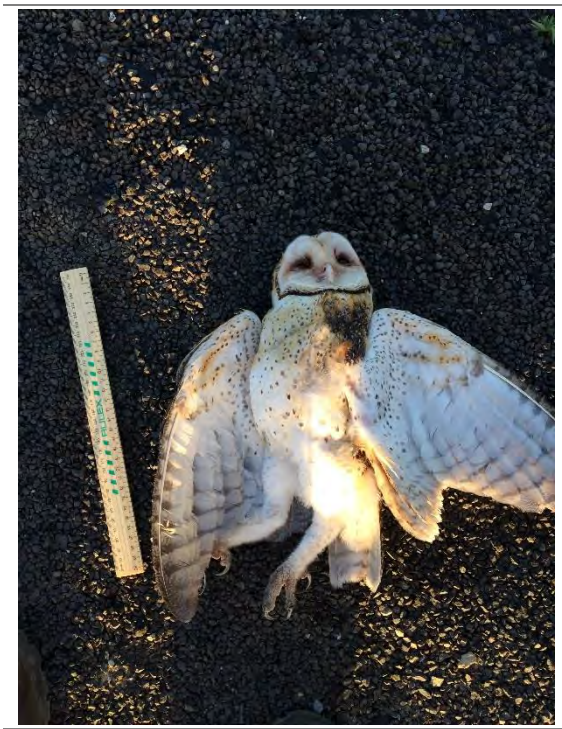


Plate 1.1
Masked Owl road kill recorded 4 January 2018

Plate 1.2
Close up photo of Masked Owl road kill recorded 4 January 2018

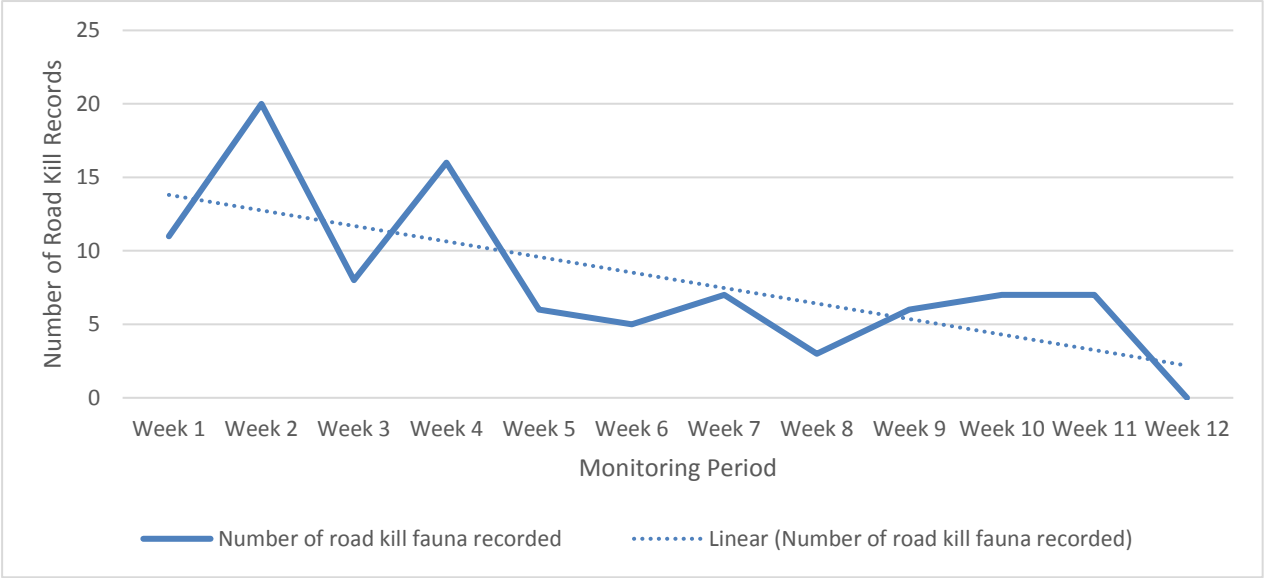


Figure 3-1

Number of fauna road kills recorded during each monitoring event and trend line

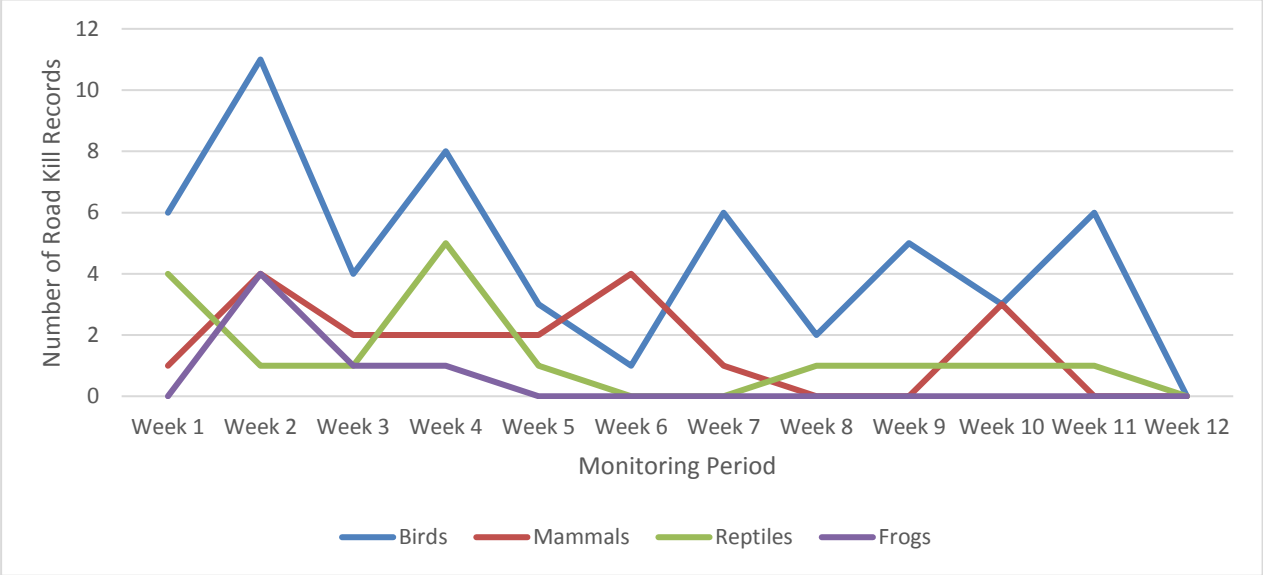


Figure 3-2

Number of road kill chordate class recorded over time

3.2 Distribution of Fauna Road Kill Records

Illustration 1.1 - 1.9 shows the location of the road kill recording, including opportunistic results. Three main concentrations of road kill records were observed:

- Chainages 48300 to 49000 north from Lower Warrell Creek to the Macksville off-ramp at Bald Hill Road, where the majority of records were mammal species both native and introduced.
- Chainages 49700 and 52000 throughout the Gumma Floodplain. The majority of records were reptile and bird species.
- Chainages 52800 to 54900 from the north abutment of the Nambucca River Bridge to approximately 200 m north of the Mattick Road overpass, where the majority of records were birds particularly Galah and Australian Wood Duck.

Of the 96 road kill fauna records (including opportunistic recordings), 58 records (60%) were located along the highway carriageway where fauna exclusion fence is installed. Twenty-nine of the 58 records (50%) were birds which are not prevented from entering the road corridor by fauna exclusion fencing due to their ability to fly. Thirty-eight (40%) of road kill records were located where no fauna exclusion fencing was installed, of which 26 records (68%) were birds.

A number of road kill fauna such as lizards, amphibians and snakes were also located within an area where fauna fencing is installed, outside the Type 3 (frog exclusion) fauna fenced area. The fauna fencing where these species were recorded comprised chainmesh fence holes and therefore would not restrict these species from accessing the road corridor. As with birds, the fencing does not restrict flying-foxes from flying over the fence, with three road kill records being observed (Black Flying-fox *Pteropus alecto*).

No flying-fox road kill records were made in the vicinity of the Type 4 fauna fencing (flying-fox fencing) between chainage 49700 and 50200. Flying-foxes were not recorded roosting in the adjacent swamp sclerophyll forest during the monitoring period (GeoLINK 2017/ 2018).

A concentration of turtle road kill records were observed within the Gumma Floodplain area which has fauna exclusion fencing installed the entire length from chainage 49650 to the southern abutment of the Nambucca River Bridge at chainage 52000).

4. Discussion

4.1 Discussion

One road kill of a BC Act listed species was recorded during the monitoring, which comprised a Masked Owl. No EPBC Act listed species were recorded during the monitoring period. No road kill recordings of target threatened species known to occur within habitat adjacent to the highway alignment that the fencing aims to protect were recorded. Such species include the Koala, Spotted-tailed Quoll, Grey Headed Flying-fox or Green-thighed Frog.

Of the 96 road kill recordings, medium to large terrestrial native mammals comprise the main species group to which the fence design provides a barrier for. Recordings of these species were relatively low (7) over the reporting period. No arboreal mammal road kills were recorded.

The majority of animals impacted by traffic have been bird species (55 individuals or 57%). Fauna exclusion fencing does not effectively mitigate against vehicle strike to birds due to their ability to fly over fauna fencing and into the road corridor. The recent application of hydroseed and hand seed to the newly topsoiled batters has attracted birds that consume seeds to the roadside (including ducks and Galah), particularly between Chainages 52800 to 54900. This area has recorded the largest concentration of birds which feed on grain and seeds initially attracted to the roadside.

The high number of turtles recorded within the Gumma Floodplain area compared to elsewhere on the project is likely attributable to suitable habitat on either side of the alignment, the source of the turtle population. Additionally, it is expected that the turtles affected by vehicle strike were located within the vegetation and low lying areas adjacent to the road when the fauna exclusion fence was installed, effectively trapping the turtles within the road side of the fenced highway corridor. A recommendation to undertake a pre-clearing walkthrough prior to opening roads to traffic in similar habitats has been suggested (refer to **Section 4.4)**.

Results indicate that over the 12 week monitoring period numbers of recorded road kill fauna have reduced. This may be attributed to:

- Some species habituating to the presence of the road and associated traffic.
- Local population declines. This mainly applies to species with low mobility/small home range sizes. For example, the population of turtles within the fencing is likely to have reduced.
- Reductions in roadside food resources (e.g. recently applied seed mix germinating).

Several recommendations have been suggested (refer to **Section 4.4**) with the aim to further reduce fauna road kills in preparation for opening of Stage 2B to operational traffic.

4.2 Comparison with Construction Road Kill Monitoring

The road kill monitoring during February 2015 and February 2017 (25 months) undertaken during construction by the WC2NH contractor recorded 62 road kill mortalities. One EPBC Act listed road kill was recorded. It is not possible to make a meaningful comparison between this construction monitoring data and the subject operational monitoring data due to:

- Differences in survey methodologies, data collected and personnel skill levels.

- Construction monitoring targeting different locations (i.e. subject sections of WC2NH follows a different alignment to the old Pacific Highway).

Notwithstanding, when pooling the 52 construction phase roadkill monitoring results where chainages were recorded into 1km segments, the data anecdotally shows roadkill 'hotspots' at:

- Chainage 41001-42000 (Upper Warrell Creek locality): 6 roadkill recordings
- Chainage 44001-45000 (Rosewood Creek locality): 8 roadkill recordings.
- Chainage 49001-50000 (Warrell Creek locality): 7 roadkill recordings.

4.3 Analysis of Data

As few data were available, native and non-native non-flying mammals were pooled to increase sample size. Small ground mammals, such as rodents, were excluded because the exclusion mesh fencing does not provide a barrier to their movement. The data shown in **Table 4.1** was available for analysis.

Table 4.1 Summary of Road Kill Data Used in the Analyses

Survey Date	*No. Mammal Road Kill (Fauna Fence)*	*No. Mammal Road Kill (No Fauna Fence)*
21/12/2017	0	1
28/12/2017	2	1
4/01/2018	1	1
11/01/2018	0	0
18/01/2018	1	1
25/01/2018	3	0
1/02/2018	1	0
8/02/2018	0	0
15/02/2018	0	0
22/02/2018	0	1
1/03/2018	0	0
8/03/2018	0	0
Total	8	5

The G-test comparing fenced versus unfenced road kill frequencies produced $\chi^2 = 1.44$, df = 1, p =0.22. The KW examining whether the amount of road kill changed over time for fenced and unfenced areas produced $\chi^2 = 14.44$, df = 11, p = 0.21. Thus, for both tests, the null hypothesis was accepted – that there was no difference between road kill numbers between fenced and non-fenced sections of the carriageway.

However, while the null hypothesis was accepted, this does not necessarily mean that there was no difference between fence and non-fenced areas or no change over time. Few road kill data were available for analysis and the test results could simply be an artefact of low statistical power. This could be remedied if more data were able to be collected, or to use additional data from other highway monitoring sites in a meta-analysis. To demonstrate that there is truly no difference in the data, the burden of proof is reversed and an equivalence test using the null hypothesis that there is a difference due to fencing or a change over time would be required. Equivalence tests use two one-tailed tests to determine whether the data fall within specific bounds that are assumed to indicate that there is no

true difference (Quertemont 2011). The few road kill results may be attributed to the effectiveness of the fencing in preventing fauna access to the road way.

4.4 Observations

The following observations are provided to further augment road kill mitigations on WC2NH (including the upcoming Stage 2B opening) or to incorporate into future road kill mitigation strategies:

- Should the trend of mammal road kill records continue at Lower Warrell Creek continue a review of the fauna fence and fauna drop down structure configuration on the south-eastern side of the Lower Warrell Creek Bridge northern abutment is suggested. The design could be improved by:
  - Constructing an additional fauna drop down structure on the south-eastern side of the Lower Warrell Creek Bridge northern abutment. This will allow fauna which access the road corridor a second more accessible option to escape into adjoining vegetation and away from the road corridor; and/or
  - Extend fauna fence on western side to chainage 49000.
- In response to relatively high levels of bird strike north of the Nambucca river bridge allow sufficient time for seed applications in proximity to the roadway to grow prior to opening WC2NH Stage 2B to public traffic.
- To reduce the potential for road kill records similar to the Gumma Floodplain, it is suggested that an ecologist inspection would be undertaken to capture and relocate any fauna contained within the fauna fencing prior to opening the highway. This would include salvage of turtles in aquatic habitats contained within the fencing to reduce similar incidences of turtle mortalities as observed throughout the Gumma Floodplain area.

5. Summary and Conclusion

One road kill of a BC Act listed species was recorded during the monitoring, which comprised a Masked Owl. No EPBC Act listed species were recorded during the monitoring period. No road kill recordings of target threatened species known to occur within habitat adjacent to the highway alignment that the fencing aims to protect were recorded. Such species include the Koala, Spotted-tailed Quoll, Grey Headed Flying-fox or Green-thighed Frog.

Of the 96 road kill recordings, medium to large terrestrial native mammals comprise the main species group to which the fence design provides a barrier for. Recordings of these species were relatively low (7) over the reporting period. No arboreal mammal road kills were recorded.

Three road kill hotspots were identified across Stage 2A including the Gumma Floodplain, north of the Nambucca River Bridge and to a lesser degree the section from north of Lower Warrell Creek to the Bald Hill overpass.

No flying-fox road kill records were made in the vicinity of the Type 4 fauna fencing (flying-fox fencing) between chainage 49700 and 50200, though the camp was not occupied during the monitoring.

The results show a declining trend in the number of road kills across the survey area for all fauna classes over time. This may be attributed to a number of factors including reduction of roadside food sources which attract fauna to the corridor, habituation of the road to fauna or local populations of certain species have temporarily declined as a direct result of vehicle collisions.

Statistical analysis to determine the effectiveness of the fauna fencing does not contain strong statistical power due to the small results data pool, particularly of relevant fauna groups (i.e. medium to large sized terrestrial mammals). The results of future monitoring should be consolidated to develop a larger data set to allow for future statistical analysis.

A number of recommendations have been suggested as lessons learnt in preparation for the opening of Stage 2B of the WC2NH Pacific Highway Upgrade.

References

Dytham, C. (2003). *Choosing and Using Statistics: A Biologist's Guide, Second Edition*. Blackwell Publishing, Oxford.

GeoLINK, (2017). *Flying-fox Monitoring Report December 2017 (ref. 2692-1073)* for Warrell Creek to Nambucca Heads Pacific Highway Upgrade. Unpublished report for Roads and Maritime Services, NSW.

GeoLINK, (2018). *Flying-fox Monitoring Report January 2018 (ref. 2692-1077)* for Warrell Creek to Nambucca Heads Pacific Highway Upgrade. Unpublished report for Roads and Maritime Services, NSW.

GeoLINK, (2018). *Flying-fox Monitoring Report February 2018 (ref. 2692-1084)* for Warrell Creek to Nambucca Heads Pacific Highway Upgrade. Unpublished report for Roads and Maritime Services, NSW.

Quertemont, E. (2011). How to statistically show the absence of an effect. *Psychologica Belgica* **51-2**: 109-127.

Copyright and Usage

©GeoLINK, 2018

This document, including associated illustrations and drawings, was prepared for the exclusive use of Roads and Maritime Services to report compliance with WC2NH Project ecological monitoring requirements. It is not to be used for any other purpose or by any other person, corporation or organisation without the prior consent of GeoLINK. GeoLINK accepts no responsibility for any loss or damage suffered howsoever arising to any person or corporation who may use or rely on this document for a purpose other than that described above. This document, including associated illustrations and drawings, may not be reproduced, stored, or transmitted in any form without the prior consent of GeoLINK. This includes extracts of texts or parts of illustrations and drawings.

The information provided on illustrations is for illustrative and communication purposes only. Illustrations are typically a compilation of data supplied by others and created by GeoLINK. Illustrations have been prepared in good faith, but their accuracy and completeness are not guaranteed. There may be errors or omissions in the information presented. In particular, illustrations cannot be relied upon to determine the locations of infrastructure, property boundaries, zone boundaries, etc. To locate these items accurately, advice needs to be obtained from a surveyor or other suitably-qualified professional.

The dimensions, number, size and shape of lots shown on drawings are subject to detailed engineering design, final survey and Council conditions of consent. Topographic information presented on the drawings is suitable only for the purpose of the document as stated above. No reliance should be placed upon topographic information contained in this report for any purpose other than that stated above.

Appendix A

Stage 2A Road Kill Monitoring Results

Monitoring Week	No. of Records	Species	Class of Chordate	Date	Easting	Northing	North or southbound lane	Location Description	Fauna fence installed adjacent Y/N	Distance to nearest fauna fence	Comments
Week 1	1	Kookaburra (*Dacelo novaeguineae*)	Bird	21/12/2017	496419	6608561	South	Near old Gate 17	Yes	-	
	2	Unidentifiable *Chelidae* (Turtle) species (*Emydura macquarii* subsp.*dharra) or (Chelodina longicollis)*	Reptile	21/12/2017	493414	6601843	South	Gumma Floodplain sth of NR Bridge	Yes	-	-
	3	Australian Magpie (*Cracticus tibicen*)	Bird	21/12/2017	492952	6600885	South	Gumma Floodplain north of southbound Bald Hill off ramp	Yes	-	
	4	Unidentifiable black avifauna	Bird	21/12/2017	492759	6600577	South	Flying Fox Swamp Forest Community	Yes	-	Very damaged and inaccessible due to location in the fast lane
	5	Unidentifiable *Chelidae* (Turtle) species (*Emydura macquarii* subsp.*dharra) or (Chelodina longicollis)*	Reptile	21/12/2017	493431	6601971	North	Gumma Floodplain	Yes	-	Very damaged shell fragments only
	6	Eastern Long-necked Turtle (*Chelodina longicollis*) (probable)	Reptile	21/12/2017	493477	6602102	North	Gumma Floodplain	Yes	-	-

Monitoring Week	No. of Records	Species	Class of Chordate	Date	Easting	Northing	North or south bound lane	Location Description	Fauna fence installed adjacent Y/N	Distance to nearest fauna fence	Comments
	7	Macleay River Turtle (*Emydura macquarii subsp.dharra*) (possible)	Reptile	21/12/2017	493501	6602163	North	Gumma Floodplain	Yes	-	-
	8	Red Necked Wallaby (*Macropus rufogriseus*)	Mammal	21/12/2017	494438	6604735	North	Beneath Mattick Road overpass	No	50m	Adult male
	9	Australian Wood Duck (*Chenonetta jubata*)	Bird	21/12/2017	494445	6604826	North	North of Mattick Road overpass	Yes	-	-
	10	Australian Wood Duck	Bird	21/12/2017	495082	6606572	North	Near Sheather property	Yes	-	-
	11	Australian Wood Duck (possible)	Bird	21/12/2017	495097	6606594	North	Near Sheather property	Yes		-
Week 2	12	Galah (*Eolophus roseicapilla*)	Bird	28/12/2017	494367	6604291	South	North Compound	No	>100 m n/a to birds	-
	13	Galah	Bird	28/12/2017	494424	6604196	South	North Compound	No	>100 m n/a to birds	-

Monitoring Week	No. of Records	Species	Class of Chordate	Date	Easting	Northing	North or south bound lane	Location Description	Fauna fence installed adjacent Y/N	Distance to nearest fauna fence	Comments
	14	Magpie Lark (*Grallina cyanoleuca*)	Bird	28/12/2017	494168	6603197	South	North of Nambucca River Bridge	No	>100 m n/a to birds	-
	15	Unidentifiable *Chelidae* (Turtle) species (*Emydura macquarii* subsp.*dharra) or (Chelodina longicollis)*	Reptile	28/12/2017	493314	6601597	South	Near Floodplain Bridge 2 Gumma Floodplain	Yes	-	Very damaged fragments remain
	16 & 17	Two x Striped Marsh Frog (*Limnodynastes peronii*)	Amphibian	28/12/2017	493316	6601593	South	Near Floodplain Bridge 2 Gumma Floodplain	Yes	-	-
	18	Purple Swamphen (*Porphyrio porphyrio*)	Bird	28/12/2017	492996	6601021	south	Gumma Floodplain near Flying Fox camp	Yes	-	-
	19	Black Rat (*Rattus rattus*)	Mammal*	28/12/2017	493177	6601328	North	Gumma Floodplain	Yes	-	-
	20	Australian Magpie	Bird	28/12/2017	493211	6601427	North	Near Floodplain Bridge 2 Gumma Floodplain	Yes	-	-
	21	Galah	Bird	28/12/2017	494295	6603413	North	South of Old Coast Road Overpass	No	>100 m n/a to birds	-

Monitoring Week	No. of Records	Species	Class of Chordate	Date	Easting	Northing	North or south bound lane	Location Description	Fauna fence installed adjacent Y/N	Distance to nearest fauna fence	Comments
	22	Galah	Bird	28/12/2017	494341	6603499	North	South of Old Coast Road Overpass	No	>100 m n/a to birds	-
	23	Australian Wood Duck (likely)	Bird	28/12/2017	494387	6603811	North	Macksville north facing on ramp	No	>100 m n/a to birds	Smeared feathers consistent colours with Wood Duck
	24	European Hare (*Lepus europaeus*)	Mammal*	28/12/2017	494422	6604549	North	South of Mattick Road	No	>100 m	-
	25	Australian Wood Duck	Bird	28/12/2017	494437	6604762	North	Beneath Mattick Road overpass	No	~10m	-
	26	Unidentifiable avifauna	Bird	28/12/2017	494445	6604839	North	North Mattick Road overpass	Yes	-	Only a wing fragment remains
	27	Forest Kingfisher (*Todiramphus macleayii*)	Bird	28/12/2017	494634	6605718	North	Near Hartman property	Yes	-	-
	28	Macropod (likely, large blood stain)	Mammal	28/12/2017	494840	6606053	North	South of Sheather property	Yes	-	Fauna Drop Down Structure approximately 15 m from record (eastern side). Fauna drop down structure

Monitoring Week	No. of Records	Species	Class of Chordate	Date	Easting	Northing	North or south bound lane	Location Description	Fauna fence installed adjacent Y/N	Distance to nearest fauna fence	Comments
											on the western side of highway was not open and functioning at time of monitoring
	29	Green Tree Frog (*Litoria caerulea*)	Amphibian	28/12/2017	494467	6604598	South	South of Mattick Road	No	>100 m n/a to frogsnot applicable	-
	30	Green Tree Frog	Amphibian	28/12/2017	493455	6601967	South	Gumma Floodplain	Yes	-	-
	31	Macropod (likely, large blood stain)	Mammal	28/12/2017	494862	6606159	South	South of Sheather property	Yes	-	Fauna Drop Down Structure approximately 20 m from record however not open and functioning at time of monitoring

Monitoring Week	No. of Records	Species	Class of Chordate	Date	Easting	Northing	North or south bound lane	Location Description	Fauna fence installed adjacent Y/N	Distance to nearest fauna fence	Comments
Week 3	32	Crested Pigeon (*Ocyphaps lophotes*)	Bird	4/01/2018	493356	6601705	South	Near Floodplain Bridge 2 Gumma Floodplain	Yes	-	-
	33	Australian Wood Duck	Bird	4/01/2018	492476	6600014	South	Bald Hill Road overpass	No	>100 m and n/a to birds	-
	34	Swamp Wallably (*Wallabia bicolor*)	Mammal	4/01/2018	492467	6599542	North	South of Bald Hill Road overpass	No	~100 m	-
	35	Eastern Water Dragon (*Intellagama lesueurii*)	Reptile	4/01/2018	492824	6600722	North	Gumma Floodplain near Flying Fox camp	Yes	-	-
	36	Striped Marsh Frog	Amphibian	4/01/2018	493381	6601852	North	South of Nambucca River Bridge	Yes	-	-
	37	**Masked Owl** (*Tyto novaehollandiae*)	Bird	4/01/2018	494181	6603252	North	Near Mrs. Woods north of Nambucca River Bridge	No	>100 m n/a to birds	Listed as Vulnerable in NSW
	38	European Hare	Mammal*	4/01/2018	494563	6605528	North	South of Hartman Property	Yes	-	-

Monitoring Week	No. of Records	Species	Class of Chordate	Date	Easting	Northing	North or south bound lane	Location Description	Fauna fence installed adjacent Y/N	Distance to nearest fauna fence	Comments
	39	Australian Wood Duck	Bird	4/01/2018	494952	6606310	North	Nambucca State Forest	Yes	-	-
Opportunistic	40	Macropod	Mammal	9/01/2018	492443	6599694	North	Macksville off ramp 300 m south of Bald Hill overpass	No	>100 m to LWC fauna fence	Badly damaged likely hit over the weekend
Week 4	41	Galah	Bird	11/01/2018	494439	6604328	South	North Compound	No	>100 m	-
	42	Unidentifiable black and white avifauna	Bird	11/01/2018	494286	6603334	South	South of Nambucca River Bridge	No	>100 m	-
	43	Blue Tongue Lizard (*Tiliqua sp.*)	Reptile	11/01/2018	494274	6603324	South	South of Nambucca River Bridge	No	>100 m	-
	44	Unidentifiable *Chelidae* (Turtle) species (*Emydura macquarii* subsp.*dharra) or (Chelodina longicollis)*	Amphibian	11/01/2018	494230	6603269	South	Southern abutment of Nambucca River Bridge	No	>100 m	Badly damaged skin fragments only
	45	Australian Wood Duck	Bird	11/01/2018	492495	6600170	North	North of Bald Hill on ramp	No	>100 m	-
	46	Australian Wood Duck	Bird	11/01/2018	493037	6601074	Centre of median	Gumma Floodplain	Yes	-	-

Monitoring Week	No. of Records	Species	Class of Chordate	Date	Easting	Northing	North or south bound lane	Location Description	Fauna fence installed adjacent Y/N	Distance to nearest fauna fence	Comments
	47	Macleay River Turtle (*Emydura macquarii subsp.dharra*) possible	Reptile	11/01/2018	493088	6601146	South	Gumma Floodplain south of Flood Plain Bridge 2	Yes	-	Inaccessible within the fast lane
	48	Macleay River Turtle (*Emydura macquarii subsp.dharra*) possible	Reptile	11/01/2018	493339	6601722	Centre of median	Gumma Floodplain south of Flood Plain Bridge 2	Yes	-	
	49	Black Flying Fox (*Pteropus alecto*)	Mammal	11/01/2018	493421	6601962	North	Gumma Floodplain	Yes	-	Inaccessible within the centre median
	50	Macleay River Turtle (*Emydura macquarii subsp.dharra*) (possible)	Reptile	11/01/2018	493460	on6602045	North	Gumma Floodplain 200 m south of Nambucca River Bridge	Yes	-	-
	51	Magpie Lark possible	Bird	11/01/2018	493478	6602096	North	Gumma Floodplain 200 m south of Nambucca River Bridge	Yes	-	-
	52	Unidentifiable *Chelidae* (Turtle) species (*Emydura macquarii* subsp*.dharra) or (Chelodina longicollis)*	Reptile	11/01/2018	493563	6602290	North	Gumma Flooplain 100m south of Nambucca River Bridge	Yes	-	-
	53	Australian Wood Duck	Bird	11/01/2018	495071	6606557	North	Near Sheather property	Yes	-	-

Monitoring Week	No. of Records	Species	Class of Chordate	Date	Easting	Northing	North or south bound lane	Location Description	Fauna fence installed adjacent Y/N	Distance to nearest fauna fence	Comments
	54	Australian Wood Duck (possible)	Bird	11/01/2018	495078	6606545	North	Near Sheather property	Yes	-	Not clearly visible although waterbird feet are discernible
	55	Australian Wood Duck (possible)	Bird	11/01/2018	495097	6606589	North	Near Sheather property	Yes	-	Not clearly visible although waterbird feet are discernible
Week 5	56	Swamp Wallaby (possible)	Mammal	18/01/2018	492468	6599568	North	South of Bald Hill off ramp	No	100 m to the south west	Very badly damaged skin, fur and feet remain.
	57	Fox (*Vulpes vulpes*)	Mammal*	18/01/2018	492693	6600511	North	Flying Fox Swamp Forest Community	Yes	-	Badly damaged and dry and flat
	58	Common Tree Snake (*Dendrelaphis punctulatus*)	Reptile	18/01/2018	493490	6602061	South	Gumma 200m south of Nambucca River Bridge	yes	n/a	-
	59	Australian Wood Duck (possible)	Bird	18/01/2018	494294	6603402	North	North of Nambucca River Bridge	No	>100 m n/a to birds	Very flat/ damaged

Monitoring Week	No. of Records	Species	Class of Chordate	Date	Easting	Northing	North or south bound lane	Location Description	Fauna fence installed adjacent Y/N	Distance to nearest fauna fence	Comments
	60	Australian Wood Duck (possible)	Bird	18/01/2018	494304	6603428	North	North of Nambucca River Bridge	No	>100 m n/a to birds	Very flat/ damaged
	61	Australian Wood Duck (possible)	Bird	18/01/2018	494328	6603482	North	North of Nambucca River Bridge	No	>100 m n/a to birds	Very flat/ damaged
Week 6	62	Fox	Mammal*	25/01/2018	496485	6608693	South bound	Nambucca State Forest	Yes	-	Flat Fox
	63	Crested Pigeon	Bird	25/01/2018	493124	6601219	North bound	Gumma south of Flood Plain Bridge 2	Yes	-	-
	64	Rabbit (*Oryctolagus cuniculus*) (possible)	Mammal*	25/01/2018	492682	6600500	North bound	Flying Fox Swamp Forest Community	Yes	-	Very damaged possible Rabbit
	65	Unidentifiable terrestrial mammal	Mammal	25/01/2018	492667	6600476	North bound	Flying Fox Swamp Forest Community	Yes	-	Very badly damaged undiscernible mammal species
	66	Cat (*Felis catus*)	Mammal*	25/01/2018	492430	6599185	South bound	Lower Warrell Creek northern abutment	Yes	-	-

Monitoring Week	No. of Records	Species	Class of Chordate	Date	Easting	Northing	North or south bound lane	Location Description	Fauna fence installed adjacent Y/N	Distance to nearest fauna fence	Comments
Week 7	67	Australian Magpie	Bird	1/02/2018	494354	6603440	South bound	200 m north of northern abutment of Nambucca River Bridge	No	>100 m n/a to birds	3m east of fog line
	68	Australian Magpie	Bird	1/02/2018	494173	6603201	South bound	North abutment Nambucca River Bridge	No	>100 m n/a to birds	-
	69	Purple Swamphen	Bird	1/02/2018	494149	6603211	North bound	Near Mrs Woods house	No	>100 m n/a to birds	-
	70	Australian Wood Duck	Bird	1/02/2018	495228	6606818	North bound	North of Sheather property	Yes	-	-
	71	Australian Wood Duck	Bird	1/02/2018	495949	6607964	South bound	State forest near perm basin	Yes	-	-
	72	Fox	Mammal*	1/02/2018	492439	6599197	South bound	North of Lower Warrell Creek	Yes	-	Also very damaged but reddish fur and back feet shape indicate Fox
	73	Australian Wood Duck (possible)	Bird	1/02/2018	495197	6606689	South bound	Old Selection Drive property	Yes	-	Very damaged but feather colour indicates

Monitoring Week	No. of Records	Species	Class of Chordate	Date	Easting	Northing	North or south bound lane	Location Description	Fauna fence installed adjacent Y/N	Distance to nearest fauna fence	Comments
											Australian Wood Duck
Week 8	74	Unidentifiable avifauna	Bird	8/02/2018	496964	6609797	South bound	State forest near widened median	Yes	-	Not accessible due to location at edge of southbound fast lane. Badly damaged dark brown feathers with tan barring. Possibly bird of prey (e.g. brown falcon) or tawny frogmouth
	75	Pacific Black Duck (*Anas superciliosa*)	Bird	8/02/2018	493096	6601110	South bound/ Centre median	Gumma Flood Plain 300 m north of Flying Fox Swamp Forest Community	Yes	-	Not accessible due to position within the centre median
	76	Unidentifiable *Chelidae* (Turtle) species (*Emydura macquarii*	Reptile	8/02/2018	494450	6604485	South bound	Near the North Compound	No	>100 m n/a to birds	Very badly damaged shell remains

Monitoring Week	No. of Records	Species	Class of Chordate	Date	Easting	Northing	North or south bound lane	Location Description	Fauna fence installed adjacent Y/N	Distance to nearest fauna fence	Comments
		subsp.*dharra) or (Chelodina longicollis)*									
Week 9	77	Australian Magpie	Bird	15/02/2018	492462	6599574	North bound	200 m south of Bald Hill Road overpass	No	~100 m and n/a to birds	-
	78	Australian Magpie	Bird	15/02/2018	492520	6600235	North bound	150 m north of Bald Hill Road overpass	No	n/a to birds	-
	79	Kookaburra	Bird	15/02/2018	494126	6603193	North bound	South abutment of Nambucca River Bridge	No	>100 m n/a to birds	Not accessible due to location at edge of northbound fast lane
	80	Galah	Bird	15/02/2018	494439	6604747	North bound	10 m south of Mattcik Road Overpass	No	~10m n/a to birds	Not accessible due to location at edge of northbound fast lane
	81	Unidentifiable duck	Bird	15/02/2018	496078	6608168	North bound	100 m south of old Gate 13 access	Yes	-	-
	82	Carpet Python (*Morelia spilota*)	Reptile	15/02/2018	496329	6608469	North bound	Nambucca State Forest	Yes	n/a to snakes	-
Week 10	83	Pacific Black Duck	Bird	22/02/2018	494385	6604016	North bound	Old Coast Road on ramp	No	>100 m n/a to birds	In drain grate washed in from pavement

Monitoring Week	No. of Records	Species	Class of Chordate	Date	Easting	Northing	North or south bound lane	Location Description	Fauna fence installed adjacent Y/N	Distance to nearest fauna fence	Comments
	84	Tawny Frogmouth (*Podargus strigoides*)	Bird	22/02/2018	495046	6606441	South bound	Near Sheather property	Yes	-	Quite fresh 1-2 days old
	85	Northern Brown Bandicoot (*Isoodon macrourus*)	Mammal	22/02/2018	494443	6604407	South bound	North Compound	No	>100 m	Identified by toe arrangement, and fur colouration otherwise very damaged carcass
	86	Purple Swamphen	Bird	22/02/2018	492832	6600707	South bound	Fying Fox Swamp Forest Community	Yes	-	Quite fresh 1-2 days old
	87	Macleay River Turtle (*Emydura macquarii subsp.dharra*) (possible)	Reptile	22/02/2018	493484	6602111	North bound	Gumma Floodplain 200m south of Nambucca River Bridge	Yes	-	-
	88	Black Flying Fox	Mammal	22/02/2018	493704	6602543	South bound	Southern abutment of Nambucca River Bridge	No	>100 m n/a to Flying-fox	No pic due to location not safe to stop
Opportunistic	89	Black Flying Fox	Mammal	25/02/2018	493670	6602527	North bound	Southern abutment of Nambucca River Bridge	No	~100 m n/a to Flying-fox	Appeared to be juvenile, no pic due to location not safe to stop

Monitoring Week	No. of Records	Species	Class of Chordate	Date	Easting	Northing	North or south bound lane	Location Description	Fauna fence installed adjacent Y/N	Distance to nearest fauna fence	Comments
Week 11	90	Galah	Bird	1/03/2018	494436	6604790	North bound	10 m north of Mattick Road overpass	Yes	-	Clear Galah record
	91	Australian Magpie	Bird	1/03/2018	494495	6604998	South bound	200 m north of Mattick Road O/P	Yes	-	Clear Magpie record, no access to remove carcass due to location at edge of fast lane
	92	Kookaburra	Bird	1/03/2018	493618	6602357	South bound	100 m south of south abutement of Nambucca River Bridge	Yes	-	Very damaged record
	93	Red-bellied Black Snake (*Pseudechis porphyriacus*)	Reptile	1/03/2018	493332	6601629	South bound	50 m north of Flood Plain Bridge 2 Gumma Floodplain	Yes	n/a to snakes	Younger animal, approximately <1m long
	94	Australian Wood Duck	Bird	1/03/2018	492631	6600356	South bound	400 m north of Bald Hill Road overpass	No	>50m n/a to birds	No access, carcass in middle of the traffic lane
	95	Australian Wood Duck	Bird	1/03/2018	492626	6600350	North bound	395 m north of Bald Hill Road overpass	No	>50m n/a to birds	Smear of feathers likely to be Duck species. No access carcass in

Monitoring Week	No. of Records	Species	Class of Chordate	Date	Easting	Northing	North or south bound lane	Location Description	Fauna fence installed adjacent Y/N	Distance to nearest fauna fence	Comments
											middle of the traffic lane
	96	Unidentifiable duck	Bird	1/03/2018	493770	6602703	North bound	Crest of Nambucca River Bridge	No	>100 m n/a to birds	No access or stopping on the bridge
Week 12	No new road kill records during this monitoring event (8/03/2018). Heavy rainfall occurred during the week preceding the week 12 monitoring event.										

Appendix 3 Section 2A Autumn (April) 2018 Monitoring Report.

.

ABN 79 896 839 729
ACN 101 084 557

Return address:
PO Box 119
LENNOX HEAD
NSW 2478

LENNOX HEAD
T 02 6687 7666
F 02 6687 7782

COFFS HARBOUR
T 02 6651 7666

ARMIDALE
T 02 6772 0454

LISMORE
T 02 6621 6677

www.geolink.net.au

21 May 2018
Ref No: 2692-1103

Roads and Maritime Services
124 Albert Drive
DONNELLYVILLE NSW 2447

Attention: Kris Hincks

Road Kill Monitoring Summary Report – Autumn (April) 2018

GeoLINK was engaged by NSW Roads and Maritime Services to undertake stage 2A operational phase road kill monitoring during Autumn (April) 2018 for the Warrell Creek to Nambucca Heads Pacific Highway Upgrade project (WC2NH). This constitutes the second seasonal roadkill monitoring event for the Stage 2A section.

The aim of the road kill monitoring program is to:

- Report on any animal road kill within the Stage 2A section of operational highway since open to traffic; and
- Assess the effectiveness of the presence of fauna fencing to prevent fauna being killed by vehicles while attempting to cross the WC2NH upgrade.

Details of the road kill mitigation measures implemented as part of WC2NH and being assessed are detailed in *Road Kill Monitoring Report WC2NH Stage 2A* (GeoLINK 2018a). This report provides the results of the Stage 2A Autumn (April) 2018 road kill monitoring event.

Methodology

Details of the Stage 2A site and road kill monitoring methodology are provided in GeoLINK (2018a). During the subject 2A Autumn (April) 2018 road kill monitoring event, the 13.3 km Stage 2A section of dual carriageway highway (26.6 km of roadway) was surveyed for four weekly monitoring events on 5, 12, 19 and 26 April 2018. The following monitoring methodology was adopted:

- A two-person team drove the length of Stage 2A in a vehicle to locate and identify fauna road mortalities, as a result of vehicle strike. The first pass of the survey area was undertaken within the first two hours of sunrise.
- The speed of travel averaged 60-70 km per hour, with both the driver and ecologist visually searching for fauna road kill along the highway alignment and within three metres from the fog line.
- A minimum of two passes of the survey area was completed to ensure that all records were accurately detected and could be safely recorded.

Urban and Regional Planning | Environmental Engineering | Civil Design | Environmental Impact Assessment | Ecological Surveys and Monitoring | Landscape Architecture | Urban Design |

Opportunistic road kill records would also be recorded if observed outside of the nominated weekly monitoring event.

For each road kill observed, the following attributes were recorded:

- Species of animal;
- Date of record;
- Global Positioning System (GPS) coordinates;
- Location of road kill record with in either the south or northbound carriageway;
- The presence of fauna fencing at/near to the road kill record;
- Distance to the nearest fauna fence if not installed adjacent to the road kill record;
- Photographic record of the animal; and
- Comments.

If the animal was identified as an *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) listed threatened species, the carcass was photographed and the following information recorded:

- Sex and age class (juvenile or adult).
- Presence of pouch young (for marsupials).
- Presence of flightless young (for flying-foxes or other bats).
- Distance to a fauna connectivity structure.
- Distance to drop down structure.
- If fauna fencing was installed, was there any damage to the fence in the vicinity.
- Weather conditions at the time of the monitoring (from the Bureau of Meteorology) – including temperature, rainfall in the last 24 hours, moon phase.
- For flying-foxes:
    - Distance to nearest camp
    - Distance to nearest canopy vegetation
    - Presence of flowering food trees in neighbouring median or roadside vegetation; plants identified to species and referenced with diet list.

Results

Number and species of Fauna Road Kills

The results of the Autumn (April) 2018 Stage 2A operational road kill monitoring are provided in **Appendix A**. A total of 12 fauna road mortalities were recorded during the four weekly monitoring events. Species diversity included five confirmed native species, three unidentifiable birds and one introduced mammal species. The road kill recordings included:

- Six (50 per cent) avifauna (birds) recordings comprising three Tawny Frogmouths (*Podargus strigoides*) and three unidentifiable birds.
- Two (16.5 per cent) native mammals recordings comprising a Black Flying Fox (*Pteropus alecto*) and a Swamp Wallaby (*Wallabia bicolor* – possible).
- One (8.5 per cent) introduced mammal recordings comprising a European Fox (*Vulpes vulpes*).
- Three (25 per cent) native reptile recordings comprising two Common Tree Snakes (*Dendrelaphis punctulatus*) and one Macleay River Turtle (*Emydura macquarii subsp.dharra*).

No *Biodiversity Conservation Act 2016* (BC Act) or EPBC Act listed threatened species road kills were recorded. No opportunistic road kill mortalities were recorded outside of the weekly monitoring events.

Figures 1.1 and **1.2** shows the number of fauna road kills recorded during each weekly monitoring event over the initial Summer 2017/18 (12 week) and subject Autumn 2018 (four week) monitoring events for WC2NH Stage 2A. The number of fauna mortality records peaked during week 2 of Stage 2A being operational with 20 road kill fauna records observed. Results indicate a general trend with the number of fauna road kill records declining over time. The mean weekly road kill rate has reduced from 7.8 road kills/ week (SD: 5.3) during the Summer 2017/12 monitoring event to three road kills/ week (SD: 1.4) during the Autumn (April) 2018 monitoring event (excludes opportunistic recordings)).

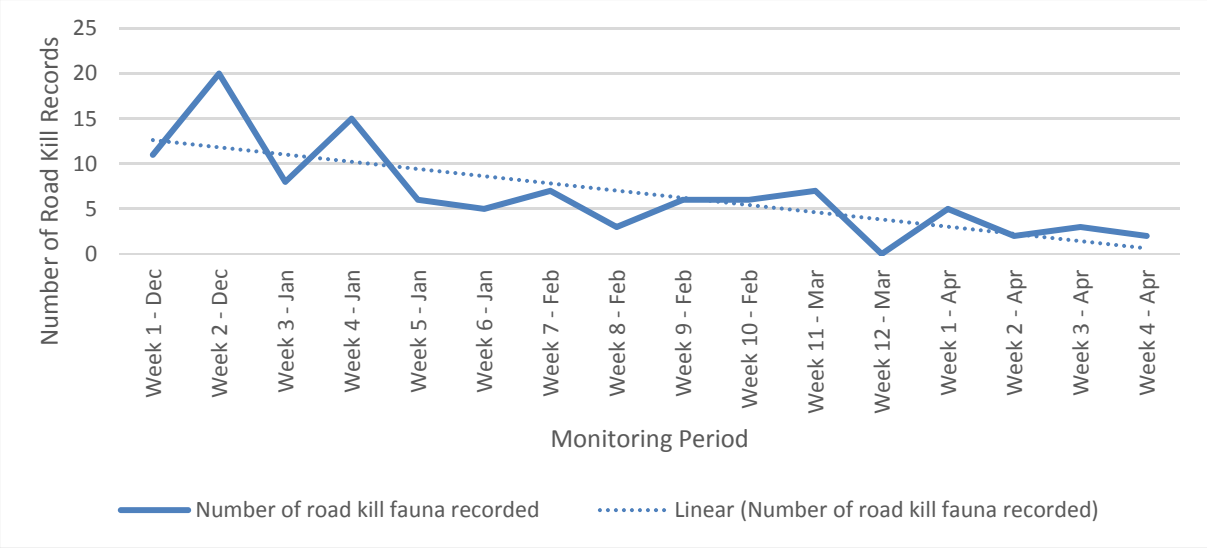


Figure 1-1 Number of fauna road kills recorded during each monitoring event and trend line for WC2NH Stage 2A

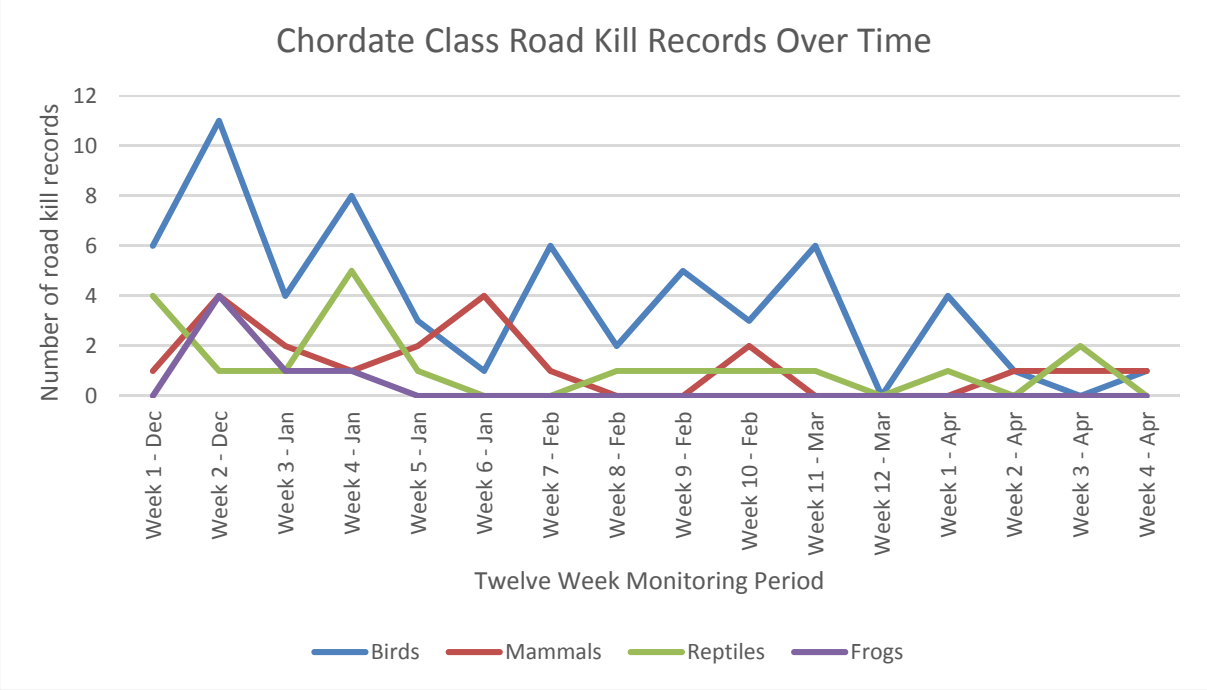


Figure 1-2 Number of road kill chordate class recorded over time for WC2NH Stage 2A

Distribution of Fauna Road Kill Records

Illustration 1.1 - 1.6 shows the location of the road kill records for the Autumn (April) 2018 monitoring event. One main concentration of road kills (four records) was recorded between chainage 49550 and 49900, and included two Common Tree Snakes, an unidentifiable bird and a European Fox. This overlaps with the Summer 2017/18 road kill identified concentration between chainages 49700 and 52000 throughout the Gumma Floodplain (GeoLINK 2018a).

Two road kill recordings (one Black Flying-fox and one Tawny Frogmouth) were recorded on the Nambucca River Bridge at chainages 52200 and 52400 respectively. No other concentrations of road kills were recorded.

Of the other two main road kill concentrations recorded during the Summer 2017/18 monitoring at chainages 48300-49000 and 52800-54900, only one road kill was recorded at these locations during the Autumn 2018 monitoring event. Specifically, a Swamp Wallaby (possible species identification) road kill was recorded at chainage 49200, which corresponds with the previously identified road kill concentration between chainages 48300 to 49000 (north from Lower Warrell Creek to the Macksville off-ramp at Bald Hill Road). This area has recorded the largest number of macropod road kills within the monitoring footprint to date.

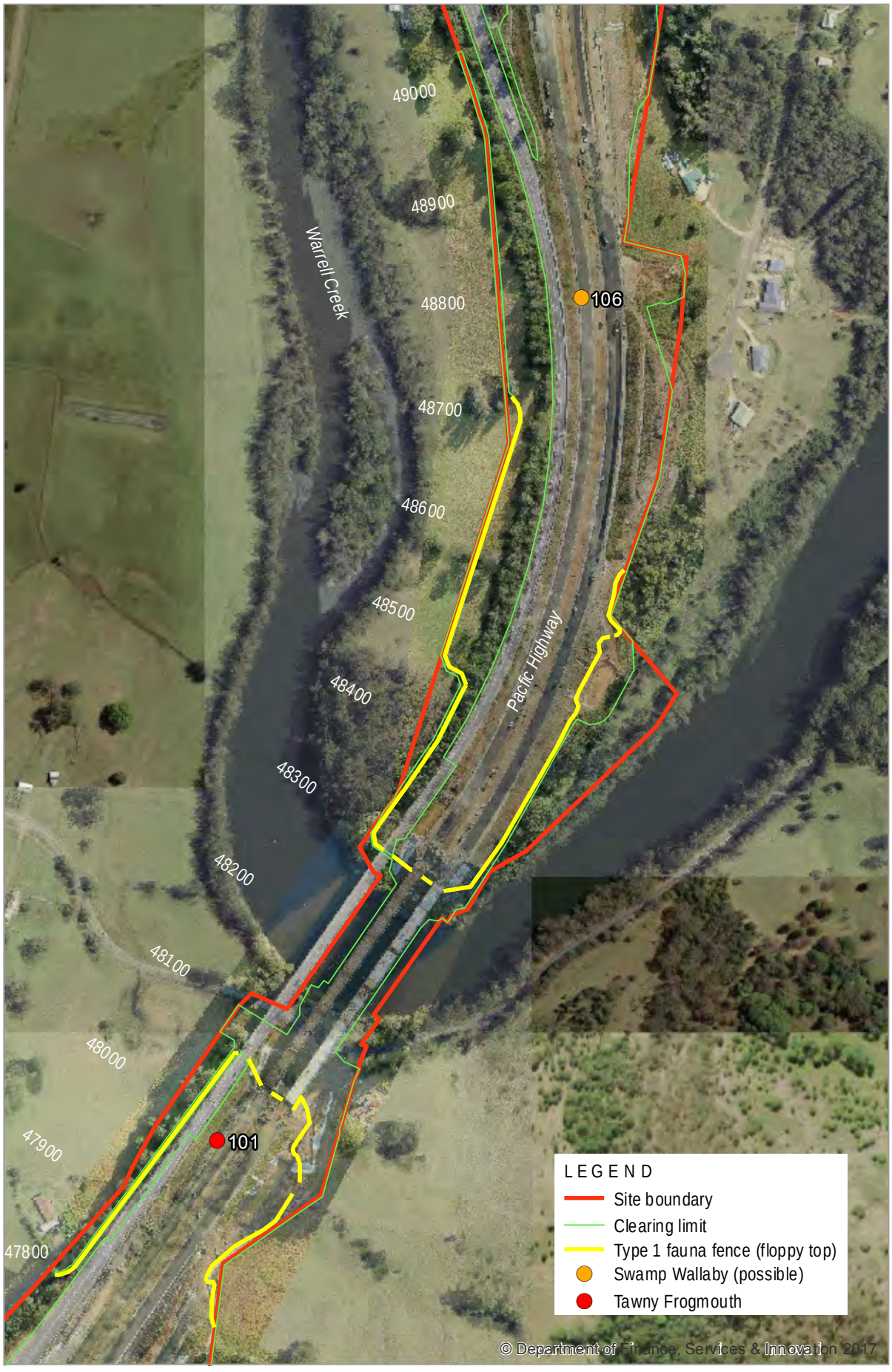
Of the 12 road kill recordings from the subject monitoring event:

- Six records (50 per cent) were located along the highway carriageway where fauna exclusion fence is present. Only one of these records comprised a species that the fencing may provide a barrier for (i.e. Macleay River Turtle).
- Six records (50 per cent) were located where fauna exclusion fencing is not present. Only two of these records comprised species that exclusion fencing may provide a barrier for (i.e. one European Fox and one Swamp Wallaby).
- Three records (25 per cent) were of species whose ability to enter the roadway is potentially inhibited by the exclusion fencing (i.e. one Macleay River Turtle, one European Fox and one Swamp Wallaby)
- Nine records (75 per cent) were of species whose ability to enter the roadway is not inhibited by the exclusion fencing (i.e. birds, flying-foxes {recorded outside of the Flying-fox exclusion fencing area} or snakes).

No flying-fox road kill records were made in the vicinity of the Type 4 fauna fencing (flying-fox fencing) between chainage 49700 and 50200. Flying-foxes were not recorded roosting in the adjacent swamp sclerophyll forest during the monitoring period (GeoLINK 2018b).

Information shown is for illustrative purposes only

Drawn by: RE Checked by: AB Reviewed by: JOL Date: 15/05/2018
Source of base data: Roads and Maritime Services and AFJV



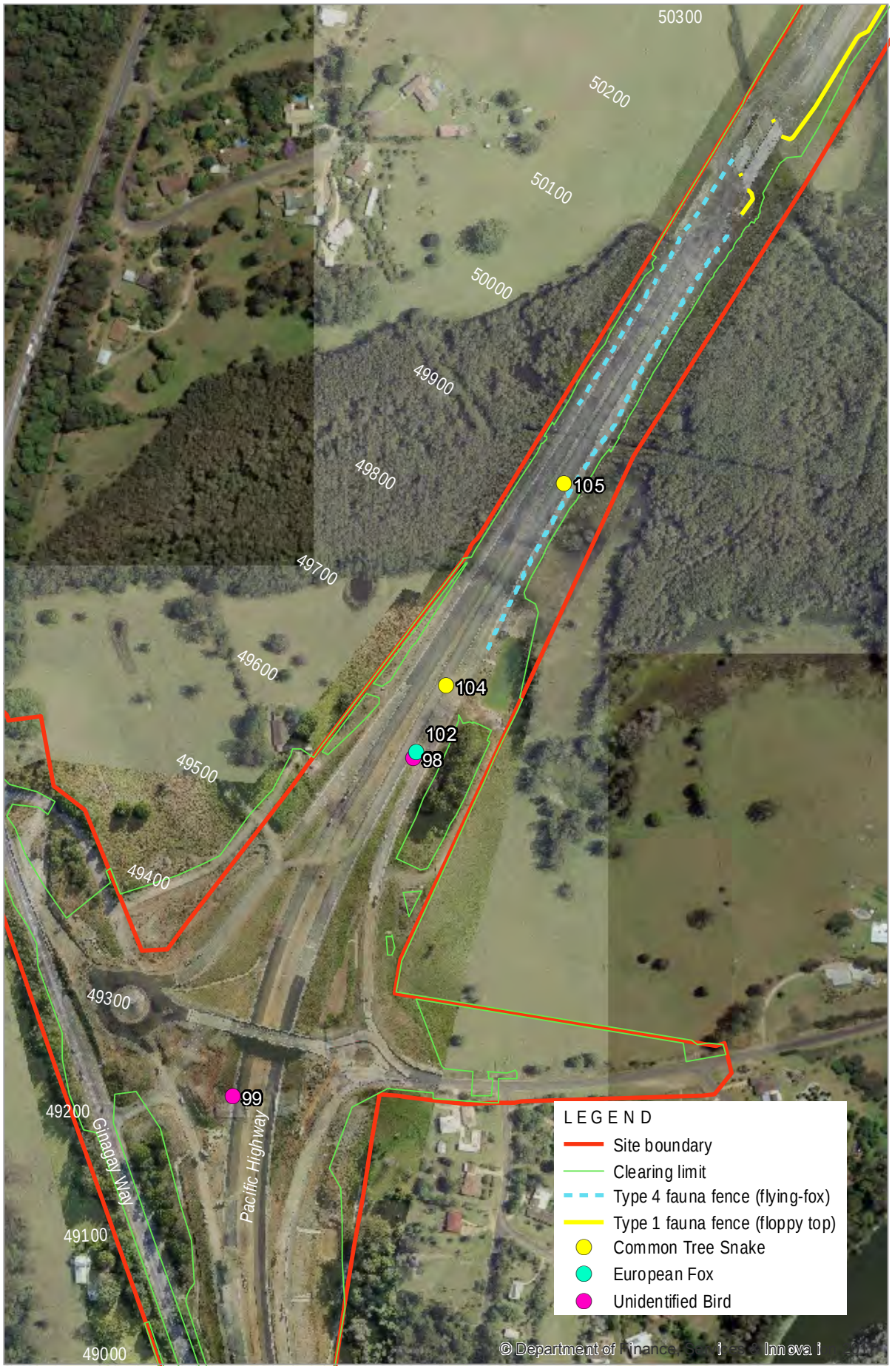
0 100

North

Road Kill Fauna Locations

Information shown is for illustrative purposes only

Drawn by: RE Checked by: AB Reviewed by: JOL Date: 15/05/2018
Source of base data: Roads and Maritime Services and AFJV



North

0 100

Road Kill Fauna Locations

Information shown is for illustrative purposes only

Drawn by: RE Checked by: AB Reviewed by: JOL Date: 15/05/2018
Source of base data: Roads and Maritime Services and AFJV

0 100

North

Road Kill Fauna Locations

Information shown is for illustrative purposes only

Drawn by: RE Checked by: AB Reviewed by: JOL Date: 15/05/2018
Source of base data: Roads and Maritime Services and AFJV

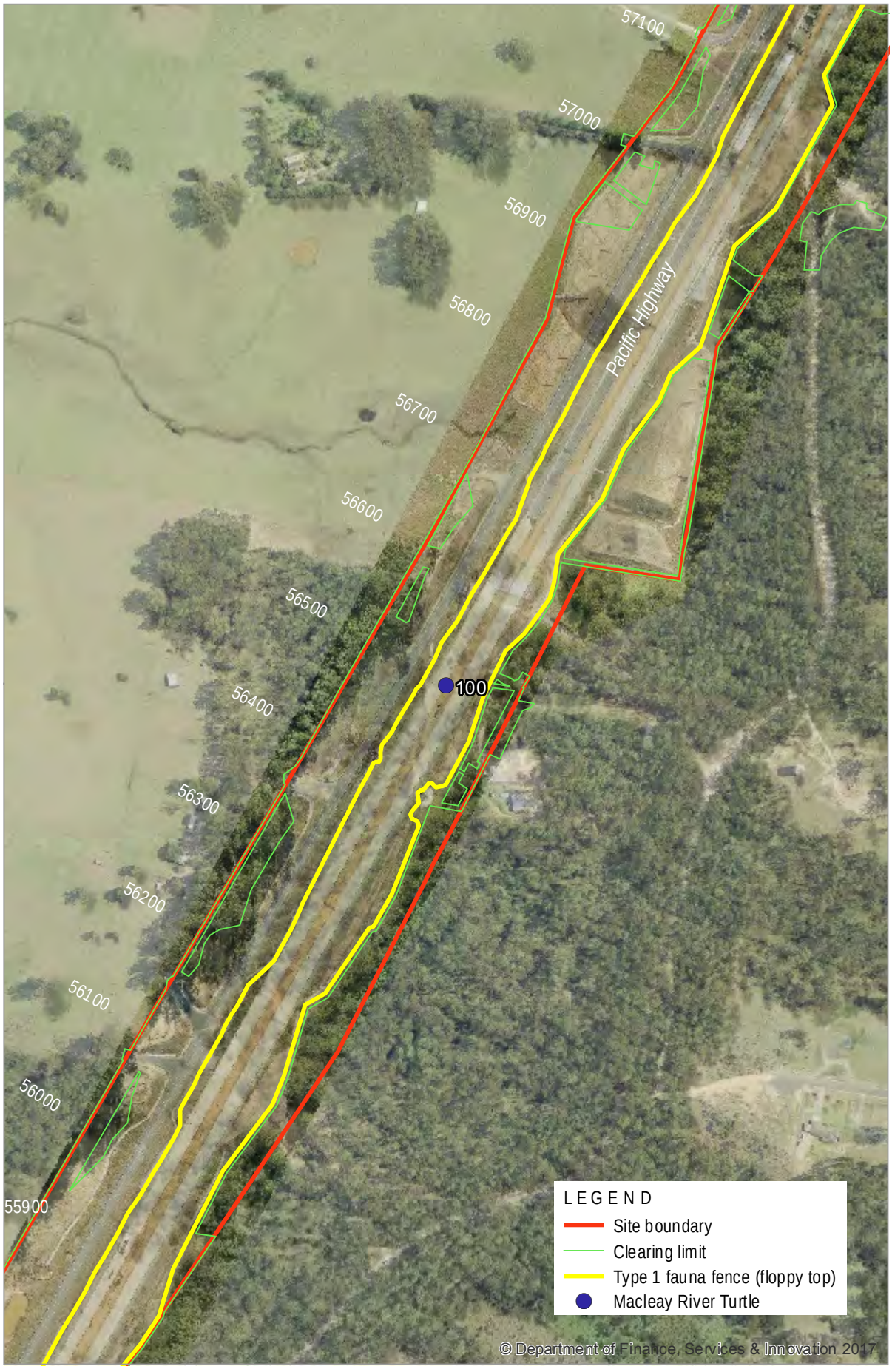
North

0 100

Road Kill Fauna Locations

Information shown is for illustrative purposes only

Drawn by: RE Checked by: AB Reviewed by: JOL Date: 15/05/2018
Source of base data: Roads and Maritime Services and AFJV



North

0 100

Road Kill Fauna Locations

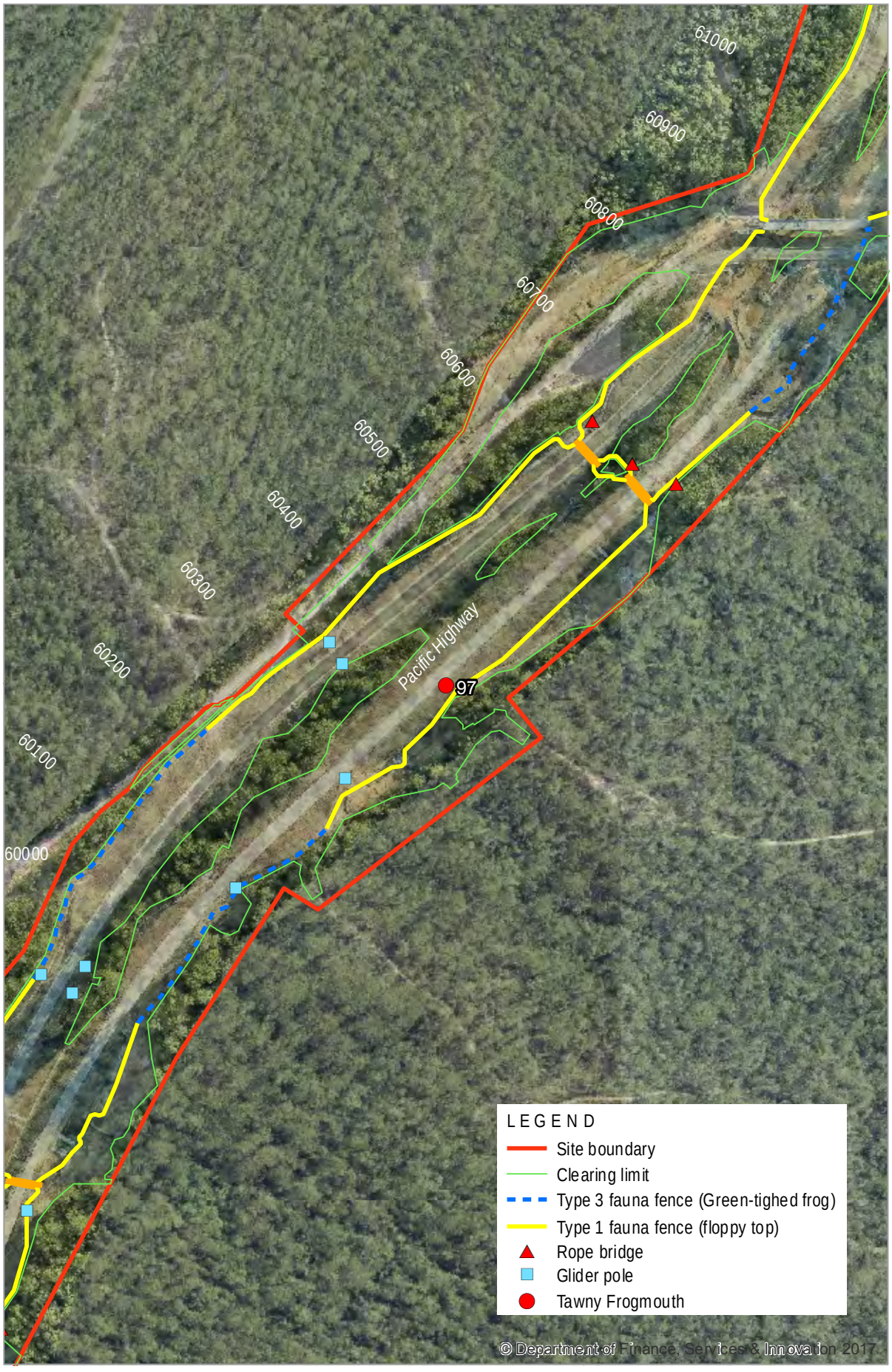
GeoLINK environmental management and design

Stage 2A Road Kill Monitoring Report - April 2018
2692-1105

Illustration 1.5

Information shown is for illustrative purposes only

Drawn by: RE Checked by: AB Reviewed by: JOL Date: 15/05/2018
Source of base data: Roads and Maritime Services and AFJV



North

0 100

Road Kill Fauna Locations

Discussion

In relation to threatened species:

- No BC Act or EPBC Act listed species road kills were recorded during the Autumn (April) 2018 monitoring event.
- No road kill recordings of target threatened species known to occur within habitat adjacent to the highway alignment that the fencing aims to protect were recorded. Such species include the Koala, Spotted-tailed Quoll, Grey Headed Flying-fox or Green-thighed Frog.

A reduction in the weekly rate of fauna road kills has been observed between Summer 2017/18 and Autumn 2018, with an overall decreasing trend in the number of road kills recorded over time being recorded. This may be attributed to:

- Reductions in roadside food resources for some species (e.g. applied seed mix for batter stabilisation).
- Some species habituating to the presence of the road and associated traffic.
- The seasonal changes in species behaviour.
- Potential local population declines (e.g. turtles potentially within the fencing).

Of the 12 road kill recordings, medium to large terrestrial native mammals comprise the main species group to which the fence design provides a barrier for. Recordings of these species was low (one record) over the reporting period. No arboreal mammal, amphibian or lizard road kills were recorded during April 2018 monitoring.

The majority of animals impacted by traffic continue to be bird species (six individuals or 50 per cent). Fauna exclusion fencing does not effectively mitigate against vehicle strike to birds due to their ability to fly over fauna fencing and into the road corridor. The reduction in records of Galah and Australian Wood Duck compared to the previous monitoring may be as a result of the hydrospray and hand application of seed for batter stabilisation having sprouted and reduced available suitable food resources for these species. Instead Tawny Frogmouths dominated the bird species count with three mortalities of this species recorded within the April 2018 monitoring event.

The lack of turtle records throughout the Gumma Floodplain area compared to the summer monitoring period may be due to the local turtle population which were fenced into the highway corridor being reduced as a result of vehicle strike impacts or season variations in activity (i.e. cooler temperatures starting to reduce the movements of turtles).

A potential emerging trend is Black-flying fox road kills on the Nambucca River Bridge, in the vicinity of the riparian zone. Three of the four Black-flying Fox road kill recordings to date are located at the bridge. Flying-foxes are known to use waterways and other landscape features as navigational tools and flight paths when moving across the landscape.

Please feel free to contact me if you require any additional information.

Yours sincerely
GeoLINK

Jessica O'Leary
Ecologist

PR	Description	Date issued	Issued By
2692-1103	First issue	21/05/2018	Jessica O'Leary

References

GeoLINK, (2018a). *Road Kill Monitoring Report – WC2NH (ref. 2692-1092)*. Unpublished report for Roads and Maritime Services, NSW.

GeoLINK, (2018). *Flying-fox Monitoring Report April 2018 (ref. 2692-1105)* for Warrell Creek to Nambucca Heads Pacific Highway Upgrade. Unpublished report for Roads and Maritime Services, NSW.

Appendix A

Stage 2A Road Kill Monitoring Results – Autumn (April) 2018

Table A1 Autumn (April) 2018 Stage 2A Road Kill Monitoring Results

Monitoring Week	Road Kill Fauna Reference	Species	Class of Chordate	Date	Easting	Northing	North or south bound lane	Location Description	Fauna fence installed adjacent Y/N	Distance to nearest fauna fence	Comments
Week 1	97	Tawny Frogmouth	Bird	05/04/2018	497010	6609846	Southbound		Yes	N/A	Nil
	98	Unidentifiable Bird	Bird	05/04/2018	492599	6600295	Southbound	Adjacent Bald Hill Road off ramp	No	100 m to the north	Badly damaged unidentifiable
	99	Unidentifiable Bird	Bird	05/04/2018	492437	6599992	Northbound	50 m south of Bald Hill Road overpass	No	>300 m to the southeast	Badly damaged unidentifiable
	100	Macleay River Turtle	Reptile	05/04/2018	495105	6606575	Northbound	Opposite Donnelly-bonnet residence	Yes	N/A	Nil
	101	Tawny Frogmouth	Bird	05/04/2018	492145	6598817	Northbound	Adjacent to southern abutment of Lower Warrell Creek	Yes	N/A	No access to capture photo
Week 2	102	Fox	Mammal*	12/04/2018	492601	6600300	Southbound	South of Bald Hill Road 250m	No		Very damaged skin and fur only
	103	Tawny Frogmouth	Bird	12/04/2018	493829	6602792	Northbound	On the NBR	No	N/A	Tawny Frogmouth identified by feathers and shape of beak

Monitoring Week	Road Kill Fauna Reference	Species	Class of Chordate	Date	Easting	Northing	North or south bound lane	Location Description	Fauna fence installed adjacent Y/N	Distance to nearest fauna fence	Comments
Week 3	104	Common Tree Snake	Reptile	19/04/2018	492628	6600360	Southbound	Approx. 300m north of Bald Hill Road overpass at the separation point of off ramp from highway	Yes	N/A	Nil
	105	Common Tree Snake	Reptile	19/04/2018	492733	6600540	Southbound	Approx. 350m north of Bald Hill Road overpass.	Yes	N/A	Nil
	106	Swamp Wallaby (possible)	Mammal	19/04/2018	492469	6599570	Northbound	Approx. 300m south of Bald Hill overpass	No	100 m to the south-west	Very damaged skin and fur remains
Week 4	107	Black Flying-fox	Mammal	26/04/2018	493755	6602630	Southbound	On Nambucca River Bridge	No	N/A	Appears to be juvenile not adult size
	108	Unidentifiable Bird	Bird	26/04/2018	493271	6601470	Northbound	Floodplain bridge 1 or 2 need to check this	Yes	N/A	Very degraded unidentified bird in centre median, no access.

Table A1 Autumn (April) 2018 Stage 2A Road Kill Monitoring Results

Species	Summer 2017/18 (Initial 12 Week Monitoring)													Autumn (April) 2018					Grand Total
	Opportunistic	Week 01	Week 02	Week 03	Week 04	Week 05	Week 06	Week 07	Week 08	Week 09	Week 10	Week 11	Week 12	TOTAL	Week 01	Week 02	Week 03	Week 04	TOTAL	
Australian Magpie		1	1					2		2		1		7						7
Australian Wood Duck		3	2	2	5	3		3				2		20						20
Black Flying-fox	1				1						1			3				1	1	4
Black Rat*			1											1						1
Blue Tongue Lizard					1									1						1
Carpet Python										1				1						1
Cat*							1							1						1
Common Tree Snake						1								1			2		2	3
Crested Pigeon				1			1							2						2
Eastern Long Neck Turtle		1												1						1
Eastern Water Dragon				1										1						1
European Fox*						1	1	1						3		1			1	4
Forest Kingfisher			1											1						1
Galah			4		1					1		1		7						7
Green Tree Frog			2											2						2
Hare*			1	1										2						2
Kookaburra										1		1		2						2
Kookaburra		1												1						1
Macleay River Turtle		1			3						1			5	1				1	6
Magpie Lark			1											1						1
Magpie Lark					1									1						1
Masked Owl				1										1						1
Northern Brown Bandicoot											1			1						1

Species	Summer 2017/18 (Initial 12 Week Monitoring)													Autumn (April) 2018					Grand Total
	Opportunistic	Week 01	Week 02	Week 03	Week 04	Week 05	Week 06	Week 07	Week 08	Week 09	Week 10	Week 11	Week 12	TOTAL	Week 01	Week 02	Week 03	Week 04	TOTAL	
Pacific Black Duck									1		1			2						2
Purple Swamphen			1					1			1			3						3
Rabbit*							1							1						1
Red Necked Wallaby		1												1						1
Red-bellied Black Snake												1		1						1
Striped Marsh Frog			2	1										3						3
Swamp Wallaby				1		1								2			1		1	3
Tawny Frogmouth											1			1	2	1			3	4
Unidentifiable bird		1	1		1				1	1		1		6	2			1	3	9
Unidentified Chelidae (Turtle) species		2	1		2				1					6						6
Unidentified Macropod	1		2											3						3
Unidentified Mammal							1							1						1
Grand Total	**2**	**11**	**20**	**8**	**15**	**6**	**5**	**7**	**3**	**6**	**6**	**7**	**0**	**96**	**5**	**2**	**3**	**2**	**12**	**108**

* denotes feral species.

Appendix 4 Road Kill Monitoring Report – Section 2A Winter (July) 2018 monitoring.

ABN 79 896 839 729
ACN 101 084 557

Return address:
PO Box 119
LENNOX HEAD
NSW 2478

LENNOX HEAD
T 02 6687 7666
F 02 6687 7782

COFFS HARBOUR
T 02 6651 7666

ARMIDALE
T 02 6772 0454

LISMORE
T 02 6621 6677

www.geolink.net.au

09 August 2018
Ref No.: 2692-1133

Roads and Maritime Services
124 Albert Drive
DONNELLYVILLE NSW 2447

Attention: Kris Hincks

Winter (July) 2018

GeoLINK was engaged by NSW Roads and Maritime Services to undertake Stage 2A operational phase road kill monitoring during winter (July) 2018 for the Warrell Creek to Nambucca Heads Pacific Highway upgrade project (WC2NH). This constitutes the third seasonal road kill monitoring event for the Stage 2A section.

The aim of the road kill monitoring program is to:

- Report on any animal road kill within the Stage 2A section of operational highway since being open to traffic; and
- Assess the effectiveness of the presence of fauna fencing to prevent fauna being killed by vehicles while attempting to cross the WC2NH upgrade.

Details of the road kill mitigation measures implemented as part of WC2NH upgrade being assessed are detailed in *Road Kill Monitoring Report WC2NH Stage 2A* (GeoLINK 2018a). This report provides the results of the Stage 2A winter (July) 2018 road kill monitoring event.

Methodology

Details of the Stage 2A site and road kill monitoring methodology are provided in GeoLINK 2018a. During the subject 2A winter (July) 2018 road kill monitoring event, the 13.3 km Stage 2A section of dual carriage highway (26.6 km of roadway) was surveyed weekly for four monitoring events on 5, 12, 19 and 26 July 2018. The following monitoring methodology was adopted:

- A two-person team drove the length of Stage 2A in a vehicle to locate and identify fauna road mortalities, as a result of vehicle strike. The first pass of the survey area was undertaken within the first two hours of sunrise.
- The speed of travel averaged 60-70 km per hour, with the ecologist visually searching for fauna road kill along the highway alignment and within three metres from the fog line.
- A minimum of two passes of the survey area was completed to ensure that all records were accurately detected and could be safely recorded.

Urban and Regional Planning | Environmental Engineering | Civil Design | Environmental Impact Assessment | Ecological Surveys and Monitoring | Landscape Architecture | Urban Design |

Opportunistic road kill records were also recorded if observed outside of the nominated weekly monitoring event.

For each road kill observed, the following attributes were recorded:

- Species of animal
- Date of record
- Global Positioning System (GPS) coordinates
- Location of road kill record; within either the south or northbound carriageway
- The presence of fauna fencing at/near the road kill record
- Distance to the nearest fauna fence if not installed adjacent to the road kill record
- Photographic record of the road kill
- Comments.

If the road kill was identified as an *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) listed species, the carcass was photographed, and the following information recorded:

- Sex and age class (juvenile or adult)
- Presence of pouch young (for marsupials)
- Presence of flightless young (for flying-foxes or other microbats)
- Distance to a fauna connectivity structure
- Distance to a drop-down structure
- If fauna fencing was installed, was there any damage to the fence in the vicinity
- Weather conditions at the time of the monitoring (from the Bureau of Meteorology) – including temperature, rainfall in the last 24 hours, moon phase
- For flying-foxes:
    - Distance to nearest camp
    - Distance to nearest canopy vegetation
    - Presence of flowering food trees in neighbouring median or roadside vegetation; plants identified to species and referenced with diet list.

Results

Number and Species of Fauna Road Kills

The results of the winter (July) 2018 Stage 2A operational road kill monitoring are provided in **Appendix A**. A total of 16 fauna road mortalities were recorded during the four weekly monitoring event. Species diversity included six confirmed native species, one unidentifiable bird and one introduced mammal species. The road kill recordings included:

- Fourteen (87.5 per cent) avifauna (birds) comprising two Tawny Frogmouths (*Podargus strigoides*), two Purple Swamphens (*Porphyrio porphyrio*), two Laughing Kookaburras (*Dacelo novaeguineae*), one Grey Butcherbird (*Cracticus torquatus*), six Barn Owls (*Tyto alba*) and one unidentifiable bird
- One (six per cent) native mammal comprising a macropod which was too badly decomposed to be identified to species level
- One (six per cent) introduced mammal comprising a European Fox (*Vulpes vulpes*).

No *Biodiversity Conservation Act 2016* (BC Act) or EPBC Act listed threatened species road kills were recorded. No road kill recordings of target threatened species (Koala, Spotted-tailed Quoll, Grey Headed Flying-fox or Green-thighed Frog) known to occur within habitat adjacent to the highway alignment that the fencing aims to protect were recorded.

One opportunistic road kill mortality, a Brahminy Kite (*Haliastur indus*) was also recorded outside of the weekly monitoring event.

Figures 1.1 and **1.2** show the number of fauna road kills recorded during each weekly monitoring event over the initial summer 2017/18 (12 weeks from December 2017 to March 2018), autumn 2018 (four weeks in April) and subject winter 2018 (four weeks in July) monitoring events for WC2NH Stage 2A. The number of fauna mortality records peaked during week 2 of Stage 2A being operational with 20 road kill records observed. Results indicate a general declining trend with the number of fauna road kill records decreasing over time. The mean weekly road kill rate has reduced from 7.8 road kills/ week (SD: 5.3) during the summer 2017/18 monitoring event to three road kills/ week (SD: 1.4) during the autumn (April) 2018 with a slight increase to four road kills/ week (SD: 1.4) during the winter (July) 2018 monitoring event (excludes opportunistic recordings)).

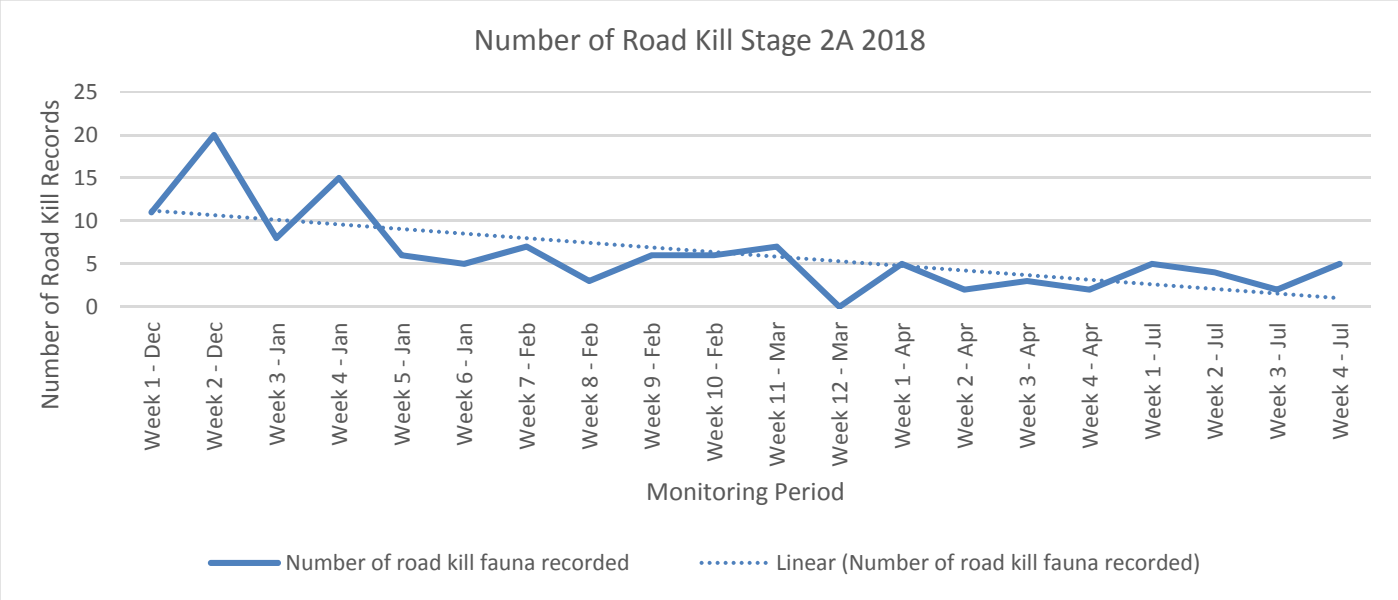


Figure 1.1 Number of road kills recorded during each monitoring event and trend line for WC2NH Stage 2A 2018.

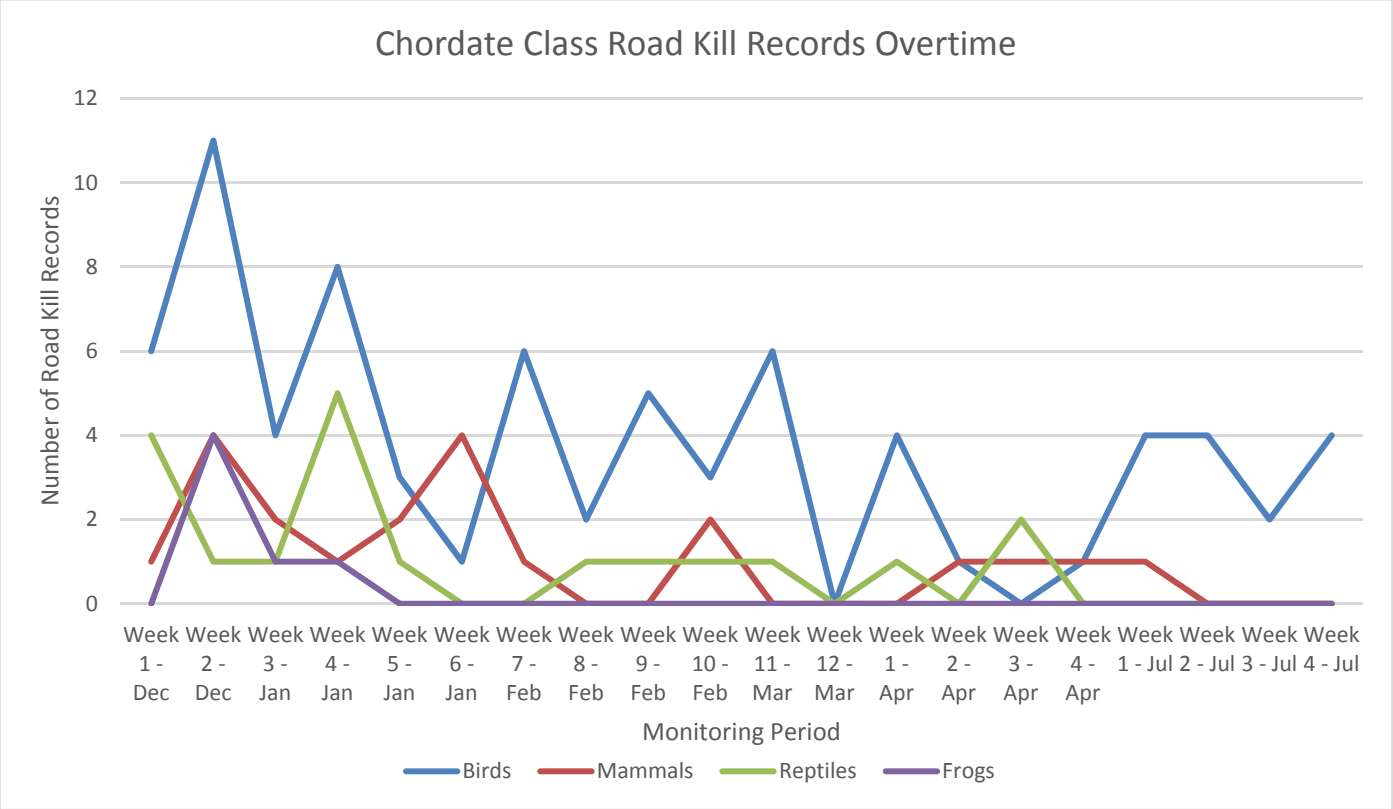


Figure 1.2 Number of road kill per chordate class recorded over time for WC2NH Stage 2A

Distribution of Fauna Road Kill Records

Illustrations 1.1 - 1.7 show the location of the road kill records for the winter (July) 2018 monitoring event. A small grouping of road kills was recorded over a 180 m section between chainages 53080 and 53260 and included one Grey Butcherbird (*Cracticus torquatus*), one Barn Owl (*Tyto alba*) and a possible juvenile Barn Owl. Two more road kills were observed to the north at chainages 53600 and 53830 respectively. This overlaps with the summer 2017/18 road kill identified concentration between chainages 52800 and 54900 from the northern abutment of the Nambucca River Bridge to the Mattick Road overpass (GeoLINK 2018a).

The remaining road kill records across Stage 2A were predominantly spaced at a minimum distance of 200 m apart across the monitoring footprint. This includes the six records between 50300 and 52000 which overlaps with the summer 2017/2018 road kill identified concentration between chainages 49700 and 52000.

Of the other main road kill concentration recorded during the summer 2017/18 monitoring at chainages 48300-49000, only one road kill, a Laughing Kookaburra, was recorded at this location during the winter 2018 monitoring event. No macropod records were recorded at this location which previously recorded the largest number of macropod road kills within the monitoring footprint to date.

One road kill recording (one Brahminy Kite) was recorded on the Nambucca River Bridge at chainage 52250.

Of the 16 road kill recordings from the subject monitoring event:

- Eight records (50 per cent) were located where fauna exclusion fence is present. Only one of these records comprised a species that the exclusion fencing may provide a barrier for (i.e. European Fox)
- Eight records (50 per cent) were located where fauna exclusion fencing is not present. Only one of these records comprised species that exclusion fencing may provide a barrier for (i.e. one macropod)
- Two records (12.5 per cent) were of species whose ability to enter the roadway is potentially inhibited by the exclusion fencing (i.e. one European Fox and one macropod)
- Fourteen records (87.5 per cent) were of species whose ability to enter the roadway is not inhibited by the exclusion fencing (i.e. birds).

A potential emerging trend of Black Flying-fox road kills on the Nambucca River Bridge, in the vicinity of the riparian zone was observed during April 2018 monitoring however no Flying-fox road kills records were observed at this location during the subject monitoring period. No flying-fox road kill records made in the vicinity of the Type 4 fauna fencing (flying-fox fencing) between chainage 49700 and 50200. Flying-foxes were not recorded roosting in the adjacent swamp sclerophyll forest during the monitoring period (GeoLINK 2018b).

Drawn by: RE Checked by: AB Reviewed by: JOL Date: 7/08/2018
Source of base data: Roads and Maritime Services and AFJV

Information shown is for illustrative purposes only

LEGEND

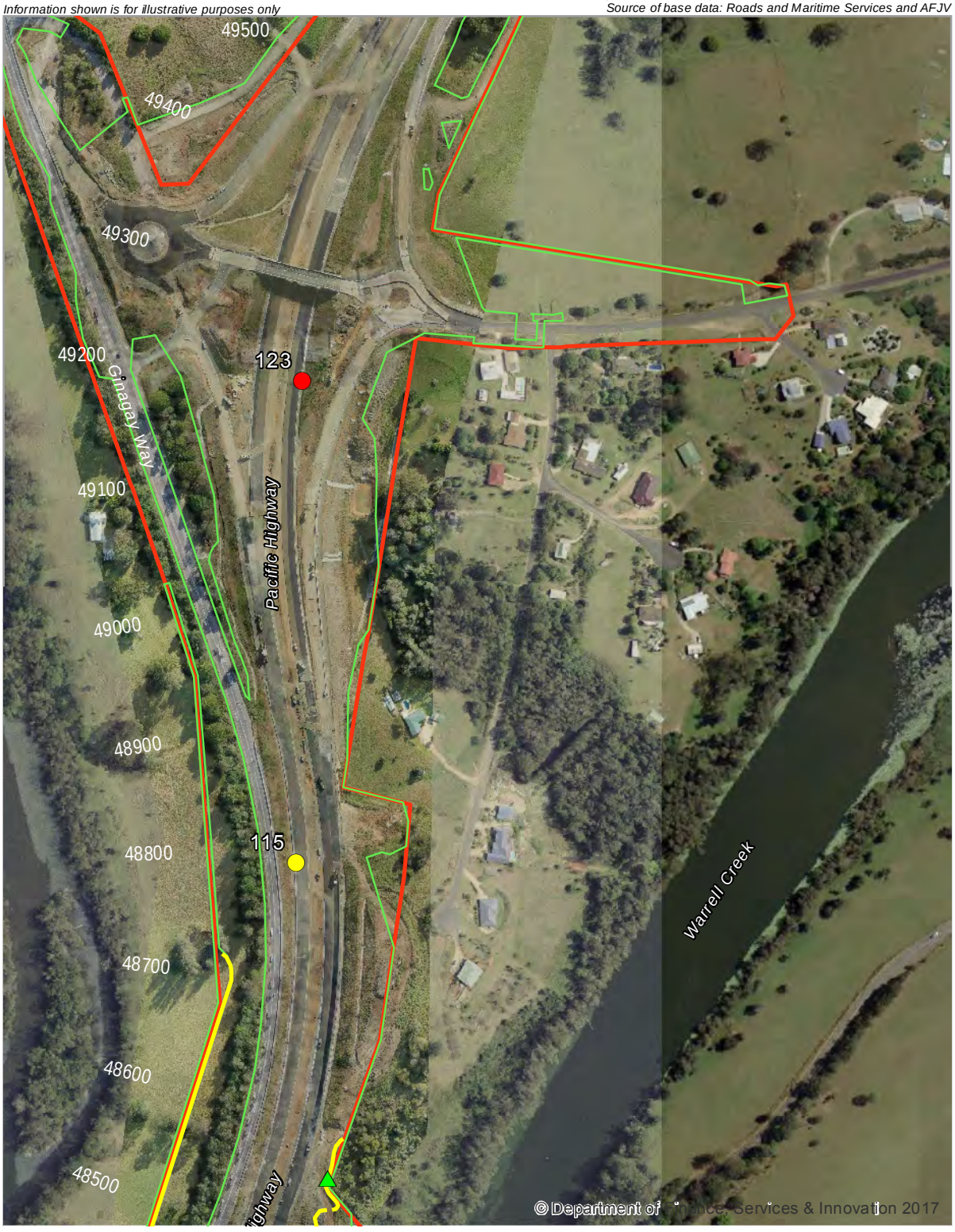
- Site boundary
- Clearing limit
- Fauna culvert
- Purple Swamphen

0 100

Road Kill Fauna Locations

Drawn by: RE Checked by: AB Reviewed by: JOL Date: 7/08/2018
Source of base data: Roads and Maritime Services and AFJV

Information shown is for illustrative purposes only



LEGEND

- Site boundary
- Clearing limit
- Fauna culvert
- Type 1 fauna fence (floppy top)
- Fauna drop down structure
- Barn Owl likely
- Laughing Kookaburra

0 100

Road Kill Fauna Locations

Drawn by: RE Checked by: AB Reviewed by: JOL Date: 7/08/2018
Source of base data: Roads and Maritime Services and AFJV

Information shown is for illustrative purposes only

LEGEND

- Site boundary
- Clearing limit
- Fauna culvert
- Type 4 fauna fence (flying-fox)
- Type 1 fauna fence (floppy top)
- Barn Owl likely
- Laughing Kookaburra
- Purple Swamphen
- Unidentified Bird

0 100

Road Kill Fauna Locations

Drawn by: RE Checked by: AB Reviewed by: JOL Date: 7/08/2018

Information shown is for illustrative purposes only

Source of base data: Roads and Maritime Services and AFJV

LEGEND

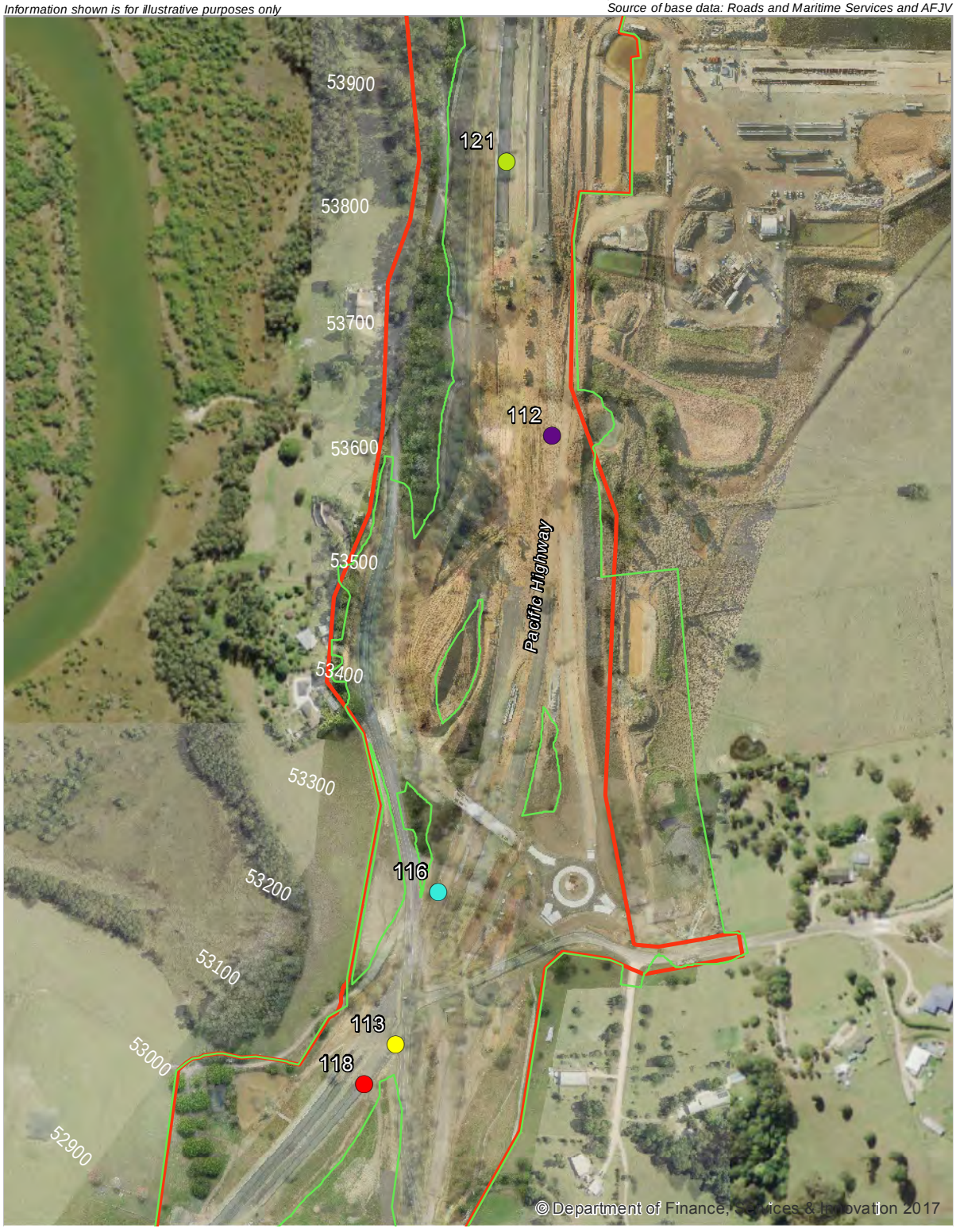
- Site boundary
- Clearing limit
- Fauna culvert
- Type 1 fauna fence (floppy top)
- Barn Owl likely
- Brahminy Kite
- European Fox

0 100

Road Kill Fauna Locations

Drawn by: RE Checked by: AB Reviewed by: JOL Date: 7/08/2018
Source of base data: Roads and Maritime Services and AFJV

Information shown is for illustrative purposes only



LEGEND

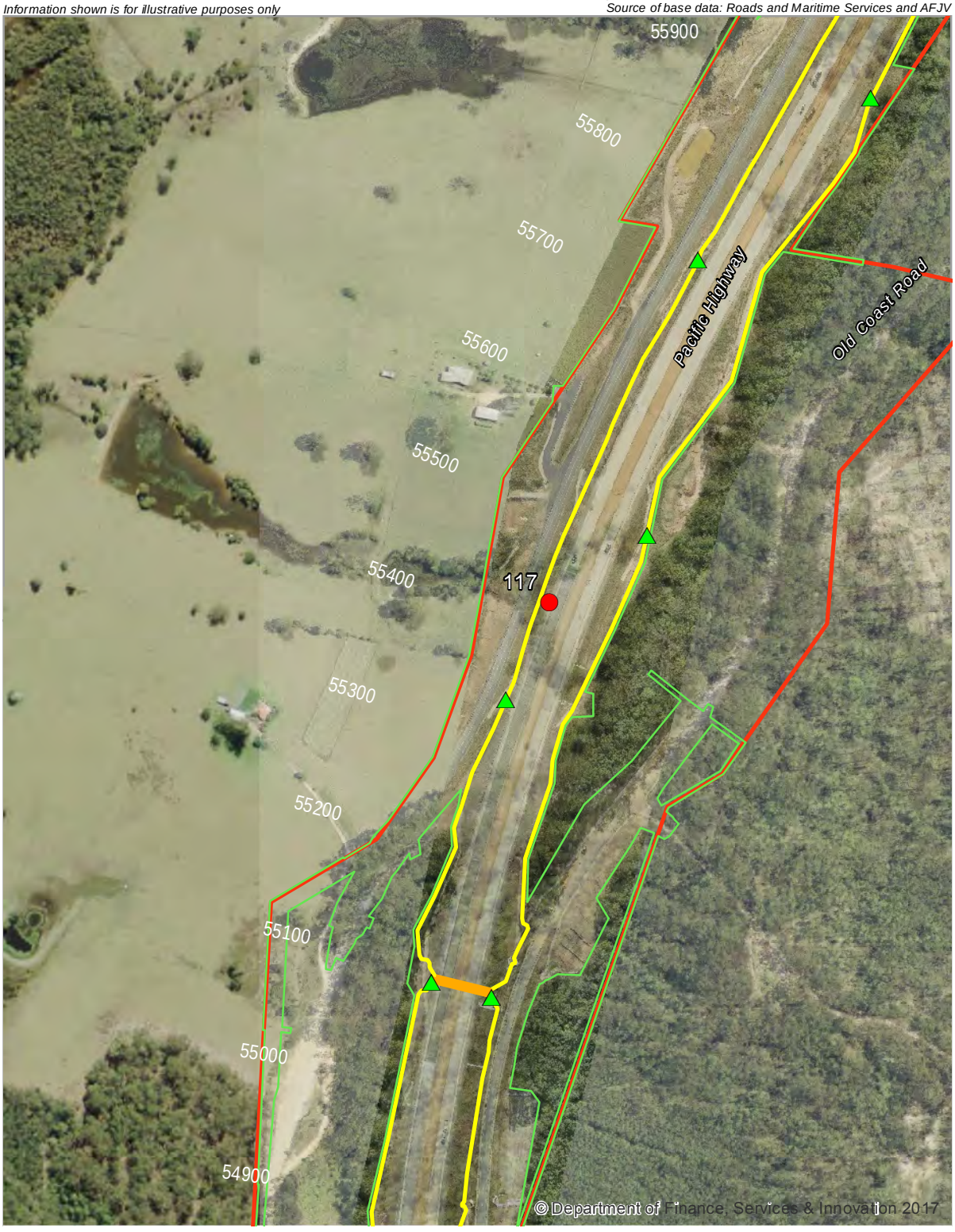
- Site boundary
- Clearing limit
- Fauna culvert
- Barn Owl
- Grey Butcherbird
- Possible juvenile Barn Owl
- Tawny Frogmouth
- Unidentified Macropod

0 100

Road Kill Fauna Locations

Drawn by: RE Checked by: AB Reviewed by: JOL Date: 7/08/2018
Source of base data: Roads and Maritime Services and AFJV

Information shown is for illustrative purposes only



LEGEND

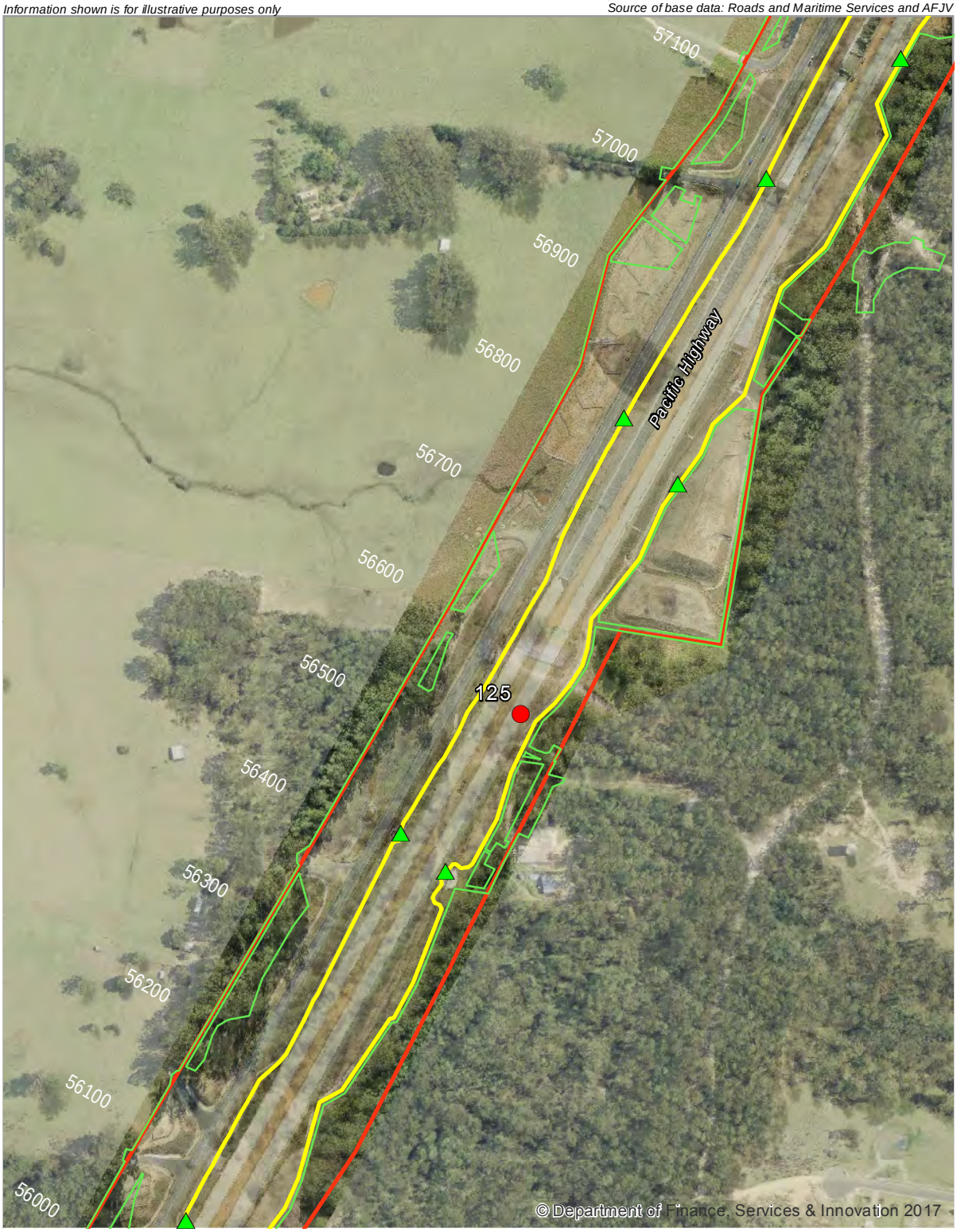
- Site boundary
- Clearing limit
- Fauna culvert
- Type 1 fauna fence (floppy top)
- Fauna drop down structure
- Barn Owl likely

0 100

Road Kill Fauna Locations

Drawn by: RE Checked by: AB Reviewed by: JOL Date: 7/08/2018
Source of base data: Roads and Maritime Services and AFJV

Information shown is for illustrative purposes only



LEGEND

- Site boundary
- Clearing limit
- Fauna culvert
- Type 1 fauna fence (floppy top)
- Fauna drop down structure
- Barn Owl

0 100

Road Kill Fauna Locations

Discussion

In relation to threatened species:

- No BC Act or EPBC Act listed species road kills were recorded during the winter (July) 2018 monitoring event.
- No road kill recordings of target threatened species (Koala, Spotted-tailed Quoll, Grey Headed Flying-fox or Green-thighed Frog) known to occur within habitat adjacent to the highway alignment that the fencing aims to protect were recorded.

A reduction in the weekly rate of fauna road kills has been observed between summer 2017/18 and autumn 2018 although a slight increase from autumn 2018 to winter 2018 monitoring was observed. An overall decreasing trend in the number of road kills recorded over time has been recorded. This may be attributed to:

- Reductions in roadside food resources for some species (e.g. applied seed mix for batter stabilisation)
- Some species habituating to the presence of the road and associated traffic
- Seasonal changes in species behaviour
- Potential local population declines.

Medium to large terrestrial native mammals comprise the main species group to which the fauna exclusion fence design provides a barrier for. Recordings of these species was low (two records; one native and one introduced species) over the reporting period. No arboreal mammal, amphibian or reptile road kills were recorded during July 2018 monitoring.

The majority of animals impacted by traffic continue to be bird species (14 individuals, 87.5 per cent). Fauna exclusion fencing does not effectively mitigate against vehicle strike to birds due to their ability to fly over fauna fencing and into the road corridor. The reduction in records of Galah and Australian Wood Duck compared to the summer 2017/18 monitoring event may be as a result of the hydrospray and hand application of seed for batter stabilisation having sprouted and reduced available suitable food resources for these species. Instead, Barn Owls dominated the bird species count with seven mortalities of this species recorded within the winter (July) 2018 monitoring event. One record was observed on 5 July, two records on 12 July and four records on 26 July. One Tawny Frogmouth road kill was recorded during July 2018, a decrease from three records during April 2018.

The increase of Barn Owl records may be attributable to a current or a recent breeding event which has increased the numbers of owls which are present and active locally. Barn Owls can breed year-round and raise successive broods if food resources are abundant, although typically two broods are raised in a year (Morcombe, 2004). It is not known if these Owls are from a local population or have dispersed from elsewhere in search of food resources during the winter period.

Please feel free to contact me if you require any additional information.

Yours sincerely
GeoLINK

Jessica O'Leary
Ecologist

UPR	Description	Date issued	Issued By
2692-1133	First issue	09/08/2018	Jessica O'Leary

References

GeoLINK, (2018a). *Road Kill Monitoring Report – WC2NH (ref. 2692-1092)*. Unpublished report for Roads and Maritime Services, NSW.

GeoLINK, (2018b). *Road Kill Monitoring Report Autumn (April) 2018 – WC2NH (ref. 2692-1092)*. Unpublished report for Roads and Maritime Services, NSW.

GeoLINK, (2018). *Flying-fox Monitoring Report July 2018 (ref. 2692-1135)* for Warrell Creek to Nambucca Heads Pacific Highway Upgrade. Unpublished report for Roads and Maritime Services, NSW.

Morcombe, M. (2004). *Field Guide to Birds of Australia*. Pascal Press, Australia.

Appendix A

Stage 2A Road Kill Monitoring Results – Winter (July) 2018

Table A1 Winter (July) 2018 Stage 2A Road Kill Monitoring Results

Monitoring Week	*No. of Records*	*Species Common Name*	*Species*	*Class of Chordate*	*Date*	*Easting*	*Northing*	*North or south bound lane*	*Location Description*	*Fauna fence installed adjacent Y/N*	*Distance to nearest fauna fence*	*Comments*
Opportunistic	109	Brahminy Kite	Brahminy Kite (Haliastur indus)	Bird	25/05/2018	493758	6602679	Northbound	Middle of Nambucca River Bridge	No	N/A for birds	Record provided by RMS could not get photo but distinctive description of solid rusty brown colur of body of bird of prey with solid white head.
Week 1	110	Purple Swamphen	Purple Swamphen	Bird	5/07/2018	492939	6600920	Northbound	100 m north of Gumma Floodplain Bridge 1	Yes	N/A for birds	n/a
	111	European Fox	European Fox	Mammal*	5/07/2018	493405	6601900	Center median	Centremedian 350m south of Nambucca River Bridge	Yes	within fauna fence	Badly amaged record
	112	Tawny Frogmouth	Tawny Frogmouth	Bird	5/07/2018	494433	6603863	Southbound	200 m north of Old Coast Road Overpass	No	N/A for birds	n/a
	113	Possible juvenile Barn Owl	Tawny Frogmouth	Bird	5/07/2018	494302	6603355	Southbound	300 m north of Nambucca River Bridge	No	N/A for birds	Very degraded wings only remain with possible rat scats deposit on and adjacent to the body.
	114	Purple Swamphen	Purple Swamphen	Bird	5/07/2018	490860	6596833	Southbound	250 m north of Rosewood Road Overpass	No	N/A for birds	n/a
Week 2	115	Laughing Kookaburra	Laughing Kookaburra	Bird	12/07/2018	492469	6599557	Northbound	1 km south Bald Hill Overpass	No	N/A for birds	n/a
	116	Grey Butcherbird	Grey Butcherbird (Cracticus torquatus)	Bird	12/07/2018	494338	6603482	Northbound	50 m south of Old Coast Road Overpass	No	N/A for birds	n/a
	117	Barn Owl	Barn Owl	Bird	12/07/2018	494595	6605636	Northbound	50 m south of	Yes	N/A for	Quite old carcass

Monitoring Week	No. of Records	Species Common Name	Species	Class of Chordate	Date	Easting	Northing	North or south bound lane	Location Description	Fauna fence installed adjacent Y/N	Distance to nearest fauna fence	Comments
		likely	(Tyto alba)						the Hartman property		birds	
	118	Barn Owl	Barn Owl (Tyto alba)	Bird	12/07/2018	494276	6603322	Southbound	Northern of the northern abutment of the Nambucca River Bridge	No	N/A for birds	n/a
Week 3	119	Laughing Kookaburra	Laughing Kookaburra	Bird	19/07/2018	493313	6601661		100 m north of Gumma Floodplain Bridge 2	Yes	N/A for birds	n/a
	120	Unidentified Bird	Unidentified Bird	Bird	19/07/2018	493093	6601122	Center median	300 m north of Gumma Floodplain Bridge 1	Yes	N/A for birds	Too badly dmaged to identify species.
Week 4	121	Unidentified Macropod	Unidentified Macropod	Mammal	26/07/2018	494395	6604091	Southbound	300 m north of Old Coast Road overpass	No	250 m	Very damaged fur and skin remains, species identification not possible.
	122	Barn Owl likely	Barn Owl likely	Bird	26/07/2018	493235	6601447	Northbound	20 m south of Gumma Floodplain Bridge 2	Yes	N/A for birds	n/a
	123	Barn Owl likely	Barn Owl likely	Bird	26/07/2018	492474	6599958	Southbound	50 m south of Bald Hill overpass	No	N/A for birds	n/a
	124	Barn Owl likely	Barn Owl likely	Bird	26/07/2018	493522	6602141	Southbound	Gumma Floodplain 400 m south of Nambucca River Bridge southern abutment	Yes	N/A for birds	n/a
	125	Barn Owl	Barn Owl	Bird	26/07/2018	495147	6606611	Southbound	100 m north of Bonnett-Donnelly property	Yes	N/A for birds	n/a

Table A1 **Autumn (April) 2018 Stage 2A Road Kill Monitoring Results**

Species	Summer 2017/18(Initial 12 weeks)													Autumn (April) 2018					Winter (July) 2018						Grand Total
	Opportunistic	Week 01	Week 02	Week 03	Week 04	Week 05	Week 06	Week 07	Week 08	Week 09	Week 10	Week 11	Total	Week 01	Week 02	Week 03	Week 04	Total	Opportunistic	Week 01	Week 02	Week 03	Week 04	Total	
Australian Magpie		1	1					2		2		1	7												
Australian Wood Duck		3	2	2	5	3		3				2	20												
Barn Owl																				1	2		4	7	7
Black Flying-fox	1				1						1		3				1	1							
Black Rat			1										1												
Blue Tongue Lizard					1								1												
Brahminy Kite																			1					1	1
Carpet Python										1			1												
Cat							1						1												
Common Tree Snake						1							1			2		2							
Crested Pigeon				1									2												
Eastern Long Neck Turtle		1											1											3	
Eastern Water Dragon				1		1							1											2	
European Fox						1	1	1					3		1			1		1				1	5
Forest Kingfisher			1										1												
Galah			4		1					1		1	7												
Green Tree Frog			2										2												
Grey Butcherbird																					1			1	1
Hare			1	1									2											7	
Kookaburra		1								1		1	3								1	1		2	5
Macleay River Turtle		1			3						1		5	1				1							
Magpie Lark			1										1											2	
Magpie Lark					1								1												
Masked Owl				1									1											3	
Northern Brown Bandicoot											1		1											1	
Pacific Black Duck									1		1		2											1	
Purple Swamphen			1					1			1		3							2				2	5
Rabbit							1						1											2	
Red Necked Wallaby		1											1												
Red-bellied Black Snake												1	1											1	
Striped Marsh Frog			2	1									3											1	
Swamp Wallaby				1		1							2			1		1						1	
Tawny Frogmouth											1		1	2	1			3		1				1	5
																								3	

Species	Summer 2017/18(Initial 12 weeks)													Autumn (April) 2018					Winter (July) 2018						Grand Total
	Opportunistic	Week 01	Week 02	Week 03	Week 04	Week 05	Week 06	Week 07	Week 08	Week 09	Week 10	Week 11	Total	Week 01	Week 02	Week 03	Week 04	Total	Opportunistic	Week 01	Week 02	Week 03	Week 04	Total	
Unidentifiable bird		1	1		1				1	1		1	6	2			1	3						1	10
Unidentified Chelidae (Turtle) species		2	1		2				1				6								1				
Unidentified Macropod	1		2										3										1	1	4
Unidentified Mammal							1						1											0	
Grand Total	**2**	**11**	**20**	**8**	**15**	**6**	**5**	**7**	**3**	**6**	**6**	**7**	**96**	**5**	**2**	**3**	**2**	**12**	**1**	**5**	**4**	**2**	**5**	**17**	**125**

1

Appendix 5 Stage 2B Initial 12 Week Monitoring Report.

Road Kill Monitoring Report – Initial 12 weeks

WC2NH Stage 2B

PO Box 119
Lennox Head NSW 2478
T 02 6687 7666

PO Box 1446
Coffs Harbour NSW 2450
T 02 6651 7666

PO Box 1267
Armidale NSW 2350
T 02 6772 0454

PO Box 229
Lismore NSW 2480
T 02 6621 6677

info@geolink.net.au

Prepared for: Roads and Maritime Services

© GeoLINK, 2018

UPR	*Description*	*Date Issued*	*Issued By*
2692-1142	First Issue	04/10/2018	Jessica O'Leary
2692-1149	Second Issue	05/10/2018	Jessica O'Leary

Table of Contents

1. Introduction 1

2. Methodology 9

2.1 Road Kill Monitoring 9

2.2 Analysis of Data 10

3. Results 11

3.1 Number and Species of Fauna Road Kills 11

3.2 Distribution of Fauna Road Kill Records 12

4. Discussion 14

4.1 Discussion 14

4.2 Comparison with Construction Road Kill Monitoring 14

4.3 Analysis of Data 14

4.4 Observations 15

5. Summary and Conclusion 16

Illustrations

Illustration 1-1 Road Kill Fauna Locations 2

Illustration 1-2 Road Kill Fauna Locations 3

Illustration 1-3 Road Kill Fauna Locations 4

Illustration 1-4 Road Kill Fauna Locations 5

Illustration 1-5 Road Kill Fauna Locations 6

Illustration 1-6 Road Kill Fauna Locations 7

Illustration 1-7 Road Kill Fauna Locations 8

Appendices

Appendix A Stage 2B Road Kill Monitoring Results

Executive Summary

GeoLINK was engaged by NSW Roads and Maritime Services to undertake weekly Road Kill Monitoring for the first 12 weeks of the operational phase of the Stage 2B section of the Warrell Creek to Nambucca Heads Pacific Highway Upgrade (WC2NH). A number of road kill mitigation measures were implemented for WC2NH with the aim to minimise vehicle collisions with native wildlife. The types of structures which were constructed to mitigate traffic impacts to fauna consist of:

- The installation of fauna fencing to exclude fauna from the road corridor or as a guide towards connectivity structures.
- Fauna Drop Down Structures (escape ramps) along the fauna fencing.
- Fauna connectivity structures, including fauna culvert underpasses, bridge underpasses, rope bridges and glider poles.

The aim of the monitoring program is to:

- Report on any animal road kill within the Stage 2B section of operational highway since open to traffic; and
- Assess the effectiveness of the presence of fauna fencing to prevent fauna being killed by vehicles while attempting to cross the WC2NH Pacific Highway Upgrade.

Road kill monitoring for Stage 2B of WC2NH was undertaken weekly (each Thursday) for the first 12 weeks after the opening of Stage 2B to traffic. The Stage 2B site covers 6.6 km of dual carriageway highway extending from Browns Crossing Road (Chainage 41700) in the south to Scott's Heads Road in the north (Chainage 48100). The survey area covered the north and southbound carriageways and has a combined length of 13.2 km of road

No BC or EPBC Act listed species were recorded during the monitoring period. No road kill recordings of target threatened species known to occur within habitat adjacent to the highway alignment that the fencing aims to protect were recorded. Such species include the Koala, Spotted-tailed Quoll or Giant Barred Frog.

Of the 27 road kill recordings, medium to large terrestrial native mammals comprise the main species group to which the fence design provides a barrier for. Recordings of these species were moderate (44.5 per cent of records) over the reporting period.

Two road kill hotspots were identified across Stage 2B including the Rosewood Creek to Rosewood Tributary and to a lesser degree to the north of Rosewood Road overpass.

No Giant Barred Frog road kill records were made in the vicinity of the Type 2 fauna fencing (Giant Barred Frog fencing) between chainage 42550 and 43400.

Results indicate a general trend with the number of fauna road kill records increasing slightly over time. Week 5 of the 12 weeks of monitoring was the only monitoring event where no fauna mortalities were recorded.

Statistical analysis to determine the effectiveness of the fauna fencing does not contain strong statistical power due to the small results data pool, particularly of relevant fauna groups (i.e. medium to large sized terrestrial mammals). The results of future monitoring should be consolidated to develop a larger data set to allow for future statistical analysis.

A recommendation to review the fauna fence and drop down structure configuration within the Rosewood Creek to Rosewood Tributary area has been suggested should the trend of mammal road kill records at this location continue.

1. Introduction

GeoLINK was engaged by NSW Roads and Maritime Services to undertake weekly Road Kill Monitoring for the first 12 weeks of the operational phase of the Stage 2B section of the Warrell Creek to Nambucca Heads Pacific Highway Upgrade (WC2NH). A number of road kill mitigation measures were implemented for WC2NH with the aim to minimise vehicle collisions with native wildlife. The types of structures which were constructed to mitigate traffic impacts to fauna consist of:

- Fauna fencing to exclude fauna from the road corridor and guide fauna towards connectivity structures.
- Fauna Drop Down Structures (escape ramps) along the fauna fencing.
- Fauna connectivity structures, including fauna culvert underpasses, bridge underpasses, vegetated widened medians, rope bridges and glider poles.

Several fauna fence designs were installed to target threatened species including:

- **Type 1** - Chainmesh fence 1.8 m tall with floppy top feature which is designed to exclude a range of native mammal species such as macropods, possums, Spotted-tail Quoll (*Dasyurus maculatus*) and Koala (*Phascolarctos cinereus*). A total of 1.16 km of this fence type occurs at the site, located on one side of the highway only.
- **Type 2** – Comprises Type 1 fence as described above, with Giant Barred Frog (GBF) (*Mixophyes iteratus*) exclusion at the bottom. The GBF exclusion comprises small gauge mesh fence with sheet metal return angled away from the highway. A total of 1.74 km of Type 2 fauna fence occurs at the site, located on both sides of the highway for a stretch of approximately 520 m and one side of the highway for a stretch of approximately 350 m. Approximately 870 km of highway is covered by Type 2 fauna fencing.

The locations of fauna fences and design types are presented within **Illustration 1-1 to Illustration** 1-7.

The aim of the monitoring program is to:

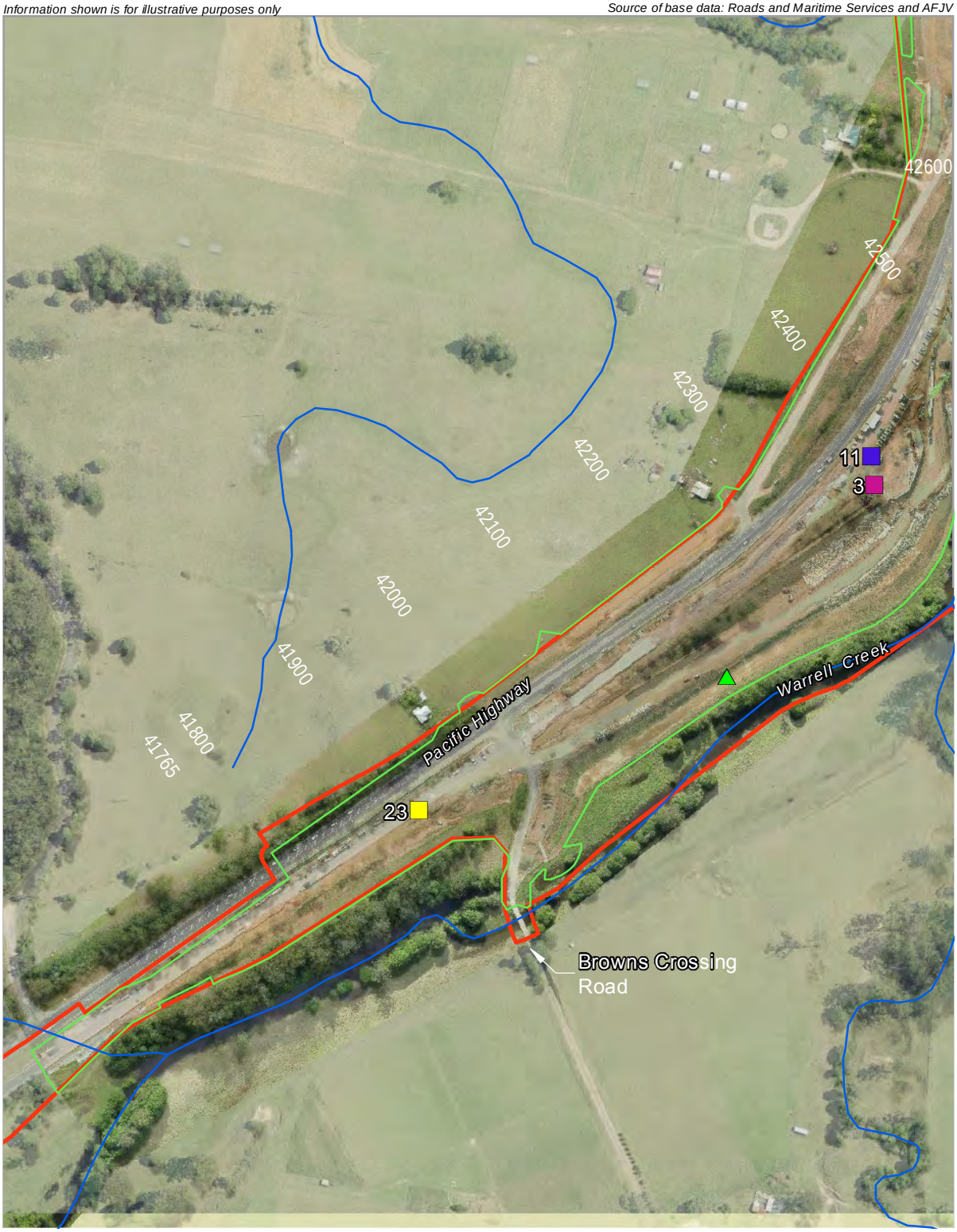
- Report on any animal road kill within the Stage 2B section of operational highway since open to traffic; and
- Assess the effectiveness of the presence of fauna fencing to prevent fauna being killed by vehicles while attempting to cross the WC2NH Upgrade.

This report provides the results of the first 12 weeks of road kill monitoring since Stage 2B became operational to traffic on 29 June 2018.

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 4/10/2018

Information shown is for illustrative purposes only

Source of base data: Roads and Maritime Services and AFJV



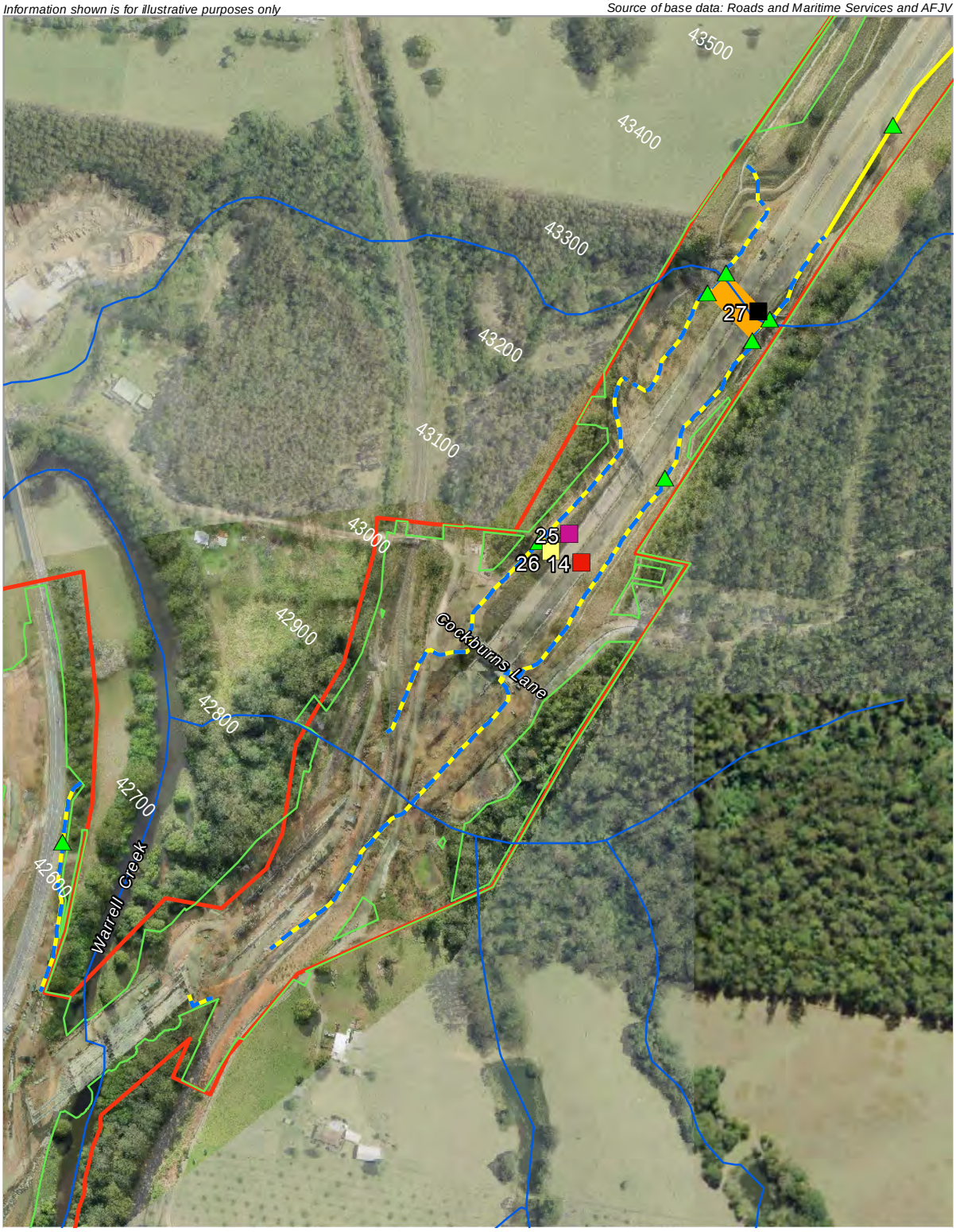
LEGEND

- Site boundary
- Clearing limit
- Fauna culvert
- Watercourse
- Fauna drop down structure
- Australian Magpie
- Australian White Ibis
- Common Brushtail Possum

0 100

Road Kill Fauna Locations

Information shown is for illustrative purposes only



LEGEND

- Site boundary
- Clearing limit
- Fauna culvert
- Watercourse
- Type 1 fauna fence (floppy top)
- Type 2 fauna fence (Giant Barred Frog)
- Fauna drop down structure
- Barn Owl
- Common Brushtail Possum
- Short-beaked Echidna
- Tawny Frogmouth

0 100

Road Kill Fauna Locations

Information shown is for illustrative purposes only

LEGEND

- Site boundary
- Clearing limit
- Fauna culvert
- Watercourse
- Type 1 fauna fence (floppy top)
- Fauna drop down structure
- Barn Owl
- Common Brushtail Possum (likely)
- European Fox
- Northern Brown Bandicoot
- Red-necked Wallaby
- Unidentified Macropod

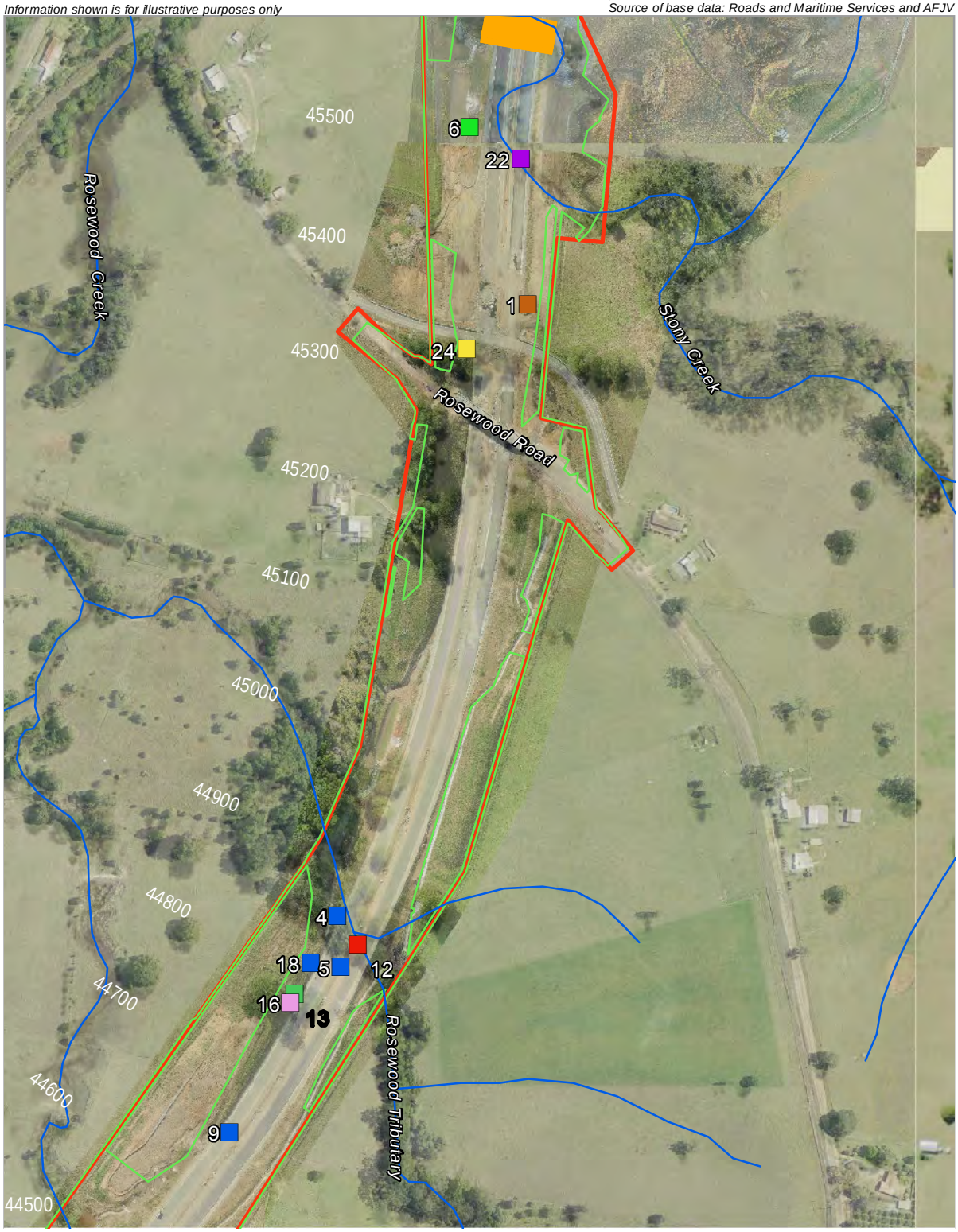
0 100

Road Kill Fauna Locations

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 4/10/2018

Information shown is for illustrative purposes only

Source of base data: Roads and Maritime Services and AFJV



LEGEND

- Site boundary
- Clearing limit
- Fauna culvert
- Watercourse

- Australian Wood Duck
- Barn Owl
- Blue or Pink Tongue Sink
- Northern Brown Bandicoot
- Pacific Black Duck
- Purple Swamphen
- Red-necked Wallaby
- Unidentified Macropod

0 100

Road Kill Fauna Locations

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 4/10/2018
Source of base data: Roads and Maritime Services and AFJV

LEGEND

- Site boundary
- Clearing limit
- Fauna culvert
- Watercourse
- Barn Owl
- Red-necked Wallaby
- Magpie-lark

0 100

Road Kill Fauna Locations

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 4/10/2018

Information shown is for illustrative purposes only

Source of base data: Roads and Maritime Services and AFJV

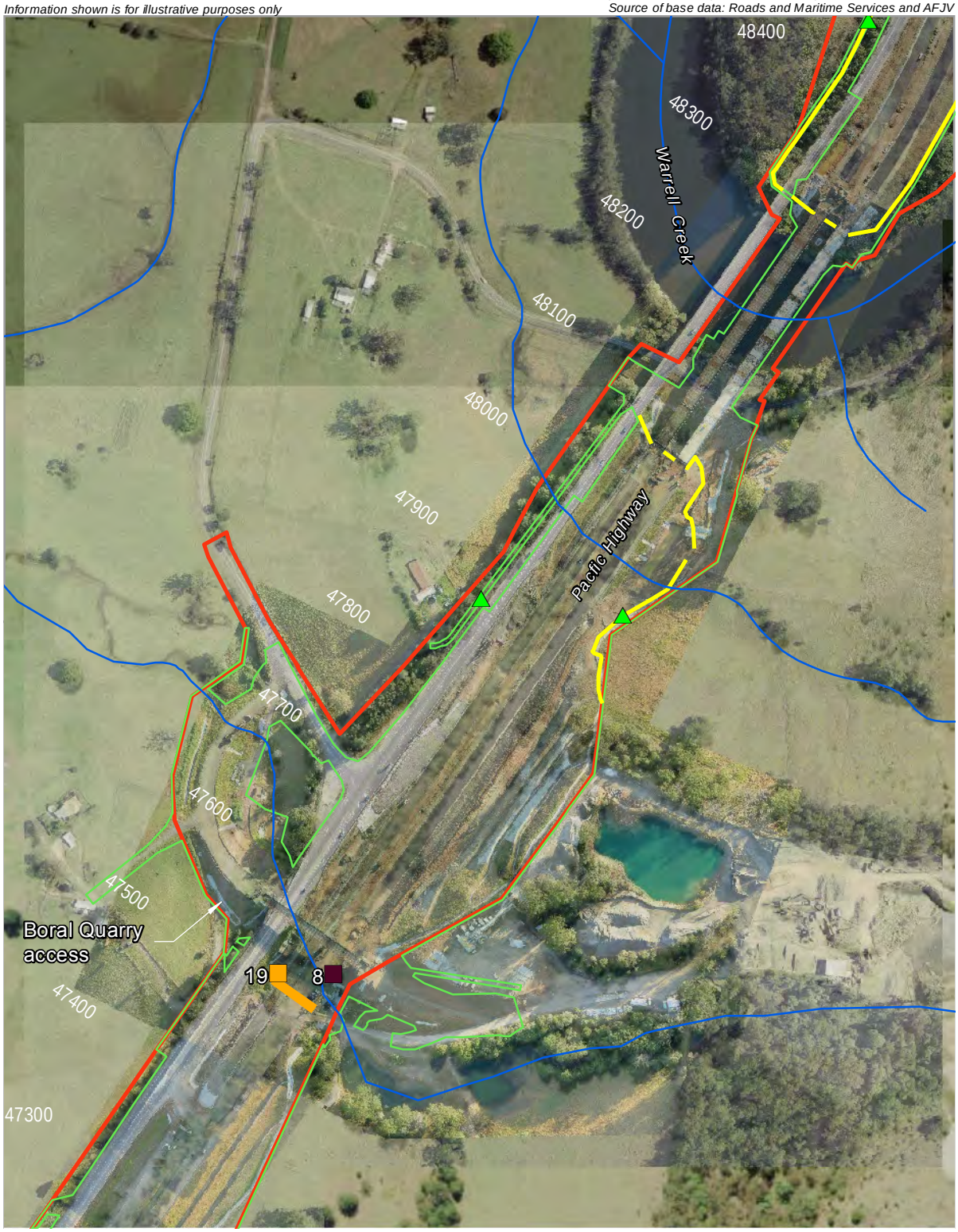
LEGEND

- Site boundary
- Clearing limit
- Fauna culvert
- Watercourse
- Barn Owl
- Red-necked Wallaby
- Feral Pigeon
- Magpie-lark
- Southern Boobook

0 100

Road Kill Fauna Locations

Information shown is for illustrative purposes only



LEGEND

- Site boundary
- Clearing limit
- Fauna culvert
- Watercourse
- Type 1 fauna fence (floppy top)
- Fauna drop down structure
- Feral Pigeon
- Southern Boobook

0 100

Road Kill Fauna Locations

2. Methodology

2.1 Road Kill Monitoring

Road kill monitoring for Stage 2B of WC2NH was undertaken weekly (each Thursday) for the first 12 weeks after the opening of Stage 2B to traffic. The Stage 2B site covers 6.6 km of dual carriageway highway extending from Browns Crossing Road (Chainage 41700) in the south to Scott's Heads Road in the north (Chainage 48100). The survey area covered the north and southbound carriageways and has a combined length of 13.2 km of road (refer to **Illustration 1-1 to Illustration** 1-7). In total, 1.9 km (29 per cent) of the 6.6 km of dual carriageway contains fauna exclusion fencing (Type 1 or 2) on one or both sides of the highway. Of this, Type 2 fauna exclusion fencing (with GBF exclusion) covers 870 m (13 per cent) of the highway.

The 12 weekly monitoring events commenced on 5 July 2018 and ended on 20 September 2018. No opportunistic road kill records were observed outside of the nominated weekly (Thursday) monitoring events for Stage 2B. The following monitoring methodology was adopted:

- A two-person team drove the length of Stage 2B in a vehicle to locate and identify fauna road mortalities, as a result of vehicle strike.
- The speed of travel averaged 60-70 km per hour, with both the ecologist visually searching for fauna road kill along the highway alignment and within three metres from the fog line.
- A minimum of two passes of the survey area was completed to ensure that all records were accurately detected and could be safely recorded. The first pass of the survey area was undertaken within the first two hours of sunrise. Occasionally a third pass was undertaken to collect data not recorded during the first two pass due to inaccessibility or no place to safely collect data at the time of observation.

For each road kill observed, the following attributes were recorded:

- Species of animal.
- Date of record.
- Global Positioning System (GPS) coordinates.
- Location of road kill record within either the south or northbound carriageway.
- The presence of fauna fencing at/near to the road kill record.
- Distance to the nearest fauna fence if not installed adjacent to the road kill record.
- Photographic record of the animal.
- Comments.

If the animal was identified as an *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) listed threatened species, the carcass was photographed, and the following information recorded:

- Sex and age class (juvenile or adult).
- Presence of pouch young (for marsupials).
- Presence of flightless young (for flying-foxes or other bats).
- Distance to a fauna connectivity structure.
- Distance to drop down structure.
- If fauna fencing was installed, was there any damage to the fence in the vicinity.
- Weather conditions at the time of the monitoring (from the Bureau of Meteorology) – including temperature, rainfall in the last 24 hours, moon phase.

- For flying-foxes:
    - Distance to nearest camp
    - Distance to nearest canopy vegetation
    - Presence of flowering food trees in neighbouring median or roadside vegetation; plants identified to species and referenced with diet list.

2.2 Analysis of Data

Mammals are the main targets of exclusion fencing; therefore, mammal data was analysed to determine whether there was any difference in the number of road kill between fenced and unfenced section of the site. Count data was available for the analysis. Each road kill was nominated as being either within or outside a fauna fenced area. The within fencing category applied regardless of whether the fencing was on one or both sides of the highway at the road kill site. Insufficient data was available to test whether time, since fence installation, affected the number of road kill (e.g. using a Kruskall-Wallis analysis). No frog road kill recordings were made; therefore an analysis of the effectiveness of the Type 2 fauna exclusion fencing (with GBF exclusion) in relation to frogs was not undertaken.

The G-test has been shown to be superior to the Chi-squared test for comparing frequency data where the expected proportions were not derived from the data. The G-test is a non-parametric log-likelihood test that conforms to a Chi-squared distribution. It tests the null hypothesis that the observed and expected frequencies do not differ (Dytham 2003). A G-test was applied to frequency data by pooling monitoring periods for both fenced and non-fenced areas. Expected proportions were taken from the proportion of total highway length (6.6 km) that was fenced (29 per cent) versus unfenced (71 per cent). A two-tailed G-test was conducted by programming the G-test into an Excel spreadsheet.

3. Results

3.1 Number and Species of Fauna Road Kills

The results of the road kill surveys during the first 12 weeks of Stage 2B being operational are provided in **Appendix A**. A total of 27 fauna road mortalities were recorded. Species diversity included 16 native species and two introduced species. The road kill recordings included:

- Twelve (44.5 per cent) native avifauna (birds) comprising nine confirmed species/species groups.
- One (3.7 per cent) introduced avifauna species; a Feral Pigeon (*Columba livia*).
- Twelve (44.5 per cent) native mammal comprising a minimum of six confirmed species/species groups including:
    - Seven macropods (including Red-necked Wallaby {*Macropus rufogriseus*} and one unidentifiable macropod species)
    - Three Common Brushtail Possum (*Trichosurus vulpecula*)
    - One Northern Brown Bandicoot (*Isoodon macrourus*)
    - One Echidna (*Tachyglossus aculeatus*).
- One (3.7 per cent) introduced mammal species; a European Fox (*Vulpes vulpes*).
- One (3.7 per cent) native reptile; a Blue or Pink Tongue Sink (*Tiliqua sp.*) that was too badly damaged to identify to species level.

No opportunistic road kill mortalities were recorded outside of the weekly monitoring events for Stage 2B and no frog road kill recordings were made.

Figures 3.1 and **3.2** show the number of fauna road kills recorded each monitoring event over the 12-week monitoring period. The number of fauna mortality records peaked during week 7 of Stage 2B being operational with five road kill fauna records observed. Results indicate a general trend with the number of fauna road kill records increasing slightly over time. Week 5 of the 12 weeks of monitoring was the only monitoring event where no fauna mortalities were recorded.

No road kill recordings of BC or EPBC Act listed threatened species occurred during the monitoring.

Plate 1.1 Barn Owl road kill recorded 16 August 2018

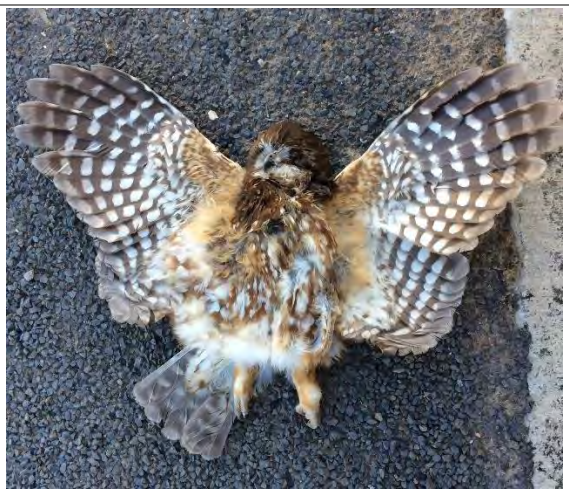


Plate 1.2 Southern Boobook road kill recorded 30 August 2018

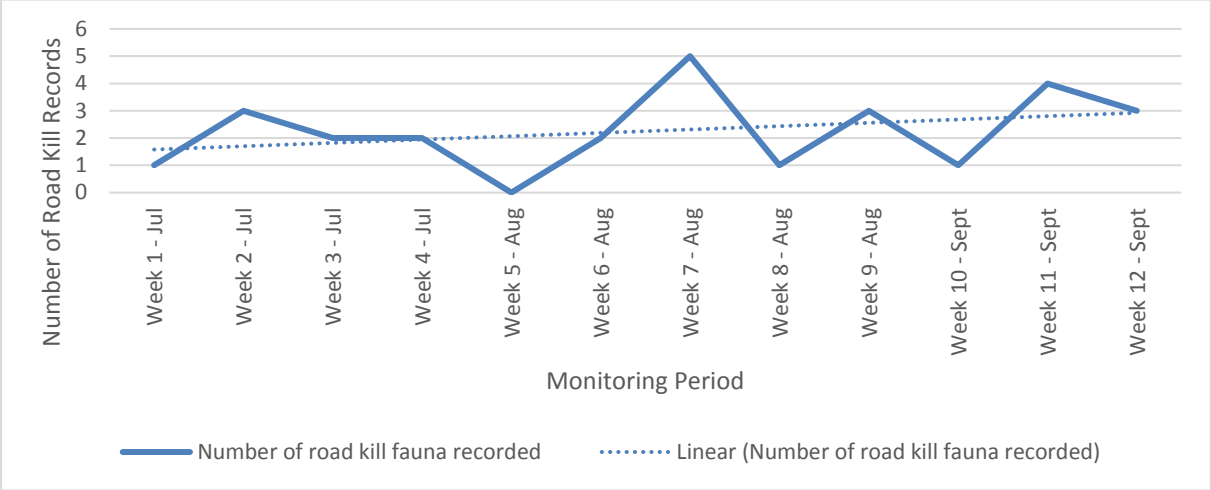


Figure 3-1 Number of fauna road kills recorded during each monitoring event and trend line

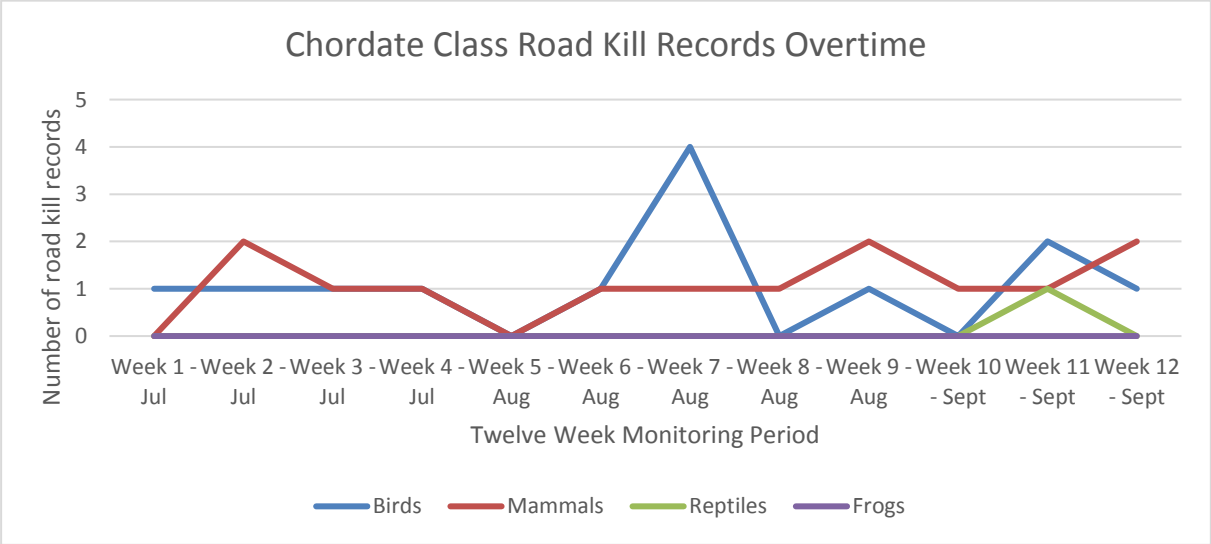


Figure 3-2 Number of road kill chordate class recorded over time

3.2 Distribution of Fauna Road Kill Records

Illustration 1-1 to Illustration 1-7 show the location of the road kill records. Two main concentrations of road kill records were observed:

- Chainages 44100 to 44860 from south of Rosewood Creek to just north of Rosewood Tributary (not fenced). The majority of records were mammal species both native and introduced. Two Barn Owl records were observed within this grouping.
- Chainages 45300 to 45500 north of Rosewood Road overpass (not fenced). The majority of records were bird species with one reptile record.

Two additional small concentrations (three records) were noted at chainages:

- 43050 to 43100 north of Cockburns Lane overpass (fauna fence adjacent).
- 46650 to 46700 approximately 300 m south of Williamson Creek (not fenced).

Of the 27 road kill fauna records, five records (18.5 per cent) were located along the highway carriageway where fauna exclusion fence is installed. Thirteen of the 27 records (50 per cent) were birds which are not prevented from entering the road corridor by fauna exclusion fencing due to their ability to fly. Twenty-two (81.5 per cent) of road kill records were located where no fauna exclusion fencing was installed, of which 11 records (41 per cent) were birds.

No Giant Barred frogs were observed within the vicinity of the Type 2 exclusion fencing between chainages 42550 and 43400.

A concentration of Red-necked Wallaby road kill records were observed within the Rosewood Creek and Tributary area where no fauna exclusion fencing was installed between chainages 44100 to 44860. With the exception of one Red-necked Wallaby record was observed with approximately 120 m from the beginning of the fauna exclusion fencing at Chainage 44120.

4. Discussion

4.1 Discussion

No BC or EPBC Act listed species were recorded during the monitoring period. No road kill recordings of target threatened species known to occur within habitat adjacent to the highway alignment, that the fencing aims to protect, were recorded. Such species include the Koala, Spotted-tailed Quoll or Giant Barred Frog.

Of the 27 road kill recordings, medium to large terrestrial native mammals comprise the main species group to which the fence design provides a barrier for. Recordings of these species were moderate (12 of 27 records) over the reporting period.

The majority of animals impacted by traffic have been bird species (12 individuals or 45.5 per cent). Fauna exclusion fencing does not effectively mitigate against vehicle strike to birds due to their ability to fly over fauna fencing and into the road corridor. Although some areas of the newly finished batters received the recent application of hydroseed and hand seed, birds which are attracted to the grain and seeds within the mix have not been recorded in similar numbers to what was observed within the initial 12 monitoring of Stage 2A (GeoLINK, 2018) which recorded a substantial number of road kill Ducks and Galah.

Medium to large mammals were predominantly recorded within the Rosewood Creek and Rosewood Tributary areas. Of the 10 mammals recorded within this concentration five of the records were Red-necked Wallabies and one unidentified macropod. A local population of Red-necked Wallaby have been observed with this location and adjacent to the site while the highway upgrade was under construction.

A recommendation has been suggested (refer to **Section 4.4**) with the aim to further reduce fauna road kills associated with Stage 2B of the highway upgrade.

4.2 Comparison with Construction Road Kill Monitoring

The road kill monitoring during February 2015 and June 2018 (42 months) undertaken during construction between Chainages 41000 and 48100 (Stage 2B equivalent) by the WC2NH contractor recorded 40 road kill mortalities. One EPBC Act listed road kill was recorded. It is not possible to make a meaningful comparison between this construction monitoring data and the subject operational monitoring data due to:

- Differences in survey methodologies, data collected and personnel skill levels.
- Construction monitoring targeting different locations (i.e. subject sections of WC2NH follows a different alignment to the old Pacific Highway).

Notwithstanding, when pooling the 40 construction phase roadkill monitoring results where chainages were recorded into one kilometre segments, the data anecdotally shows roadkill 'hotspots' at:

- Chainage 41001-42000 (Upper Warrell Creek locality): six roadkill recordings
- Chainage 44001-45000 (Rosewood Creek locality): eight roadkill recordings
- Chainage 47001-48000 (south of Lower Warrell Creek locality): six roadkill recordings
- Chainage 48001-49000 (north of Lower Warrell Creek locality): eight roadkill recordings.

4.3 Analysis of Data

As limited data was available, native and non-native non-flying mammals were pooled to increase sample size. The data shown in **Table 4.1** was available for analysis.

Table 4.1 Summary of Road Kill Data Used in the Analyses

Survey Date	*No. Mammal Road Kill (Fauna Fence)*	*No. Mammal Road Kill (No Fauna Fence)*
5/07/2018	0	0
12/07/2018	0	2
19/07/2018	0	1
26/07/2018	0	1
2/08/2018	0	0
9/08/2018	0	1
16/08/2018	0	1
23/08/2018	0	1
30/08/2018	1	1
6/09/2018	0	1
13/09/2018	0	0
20/09/2018	2	0
Sum	3	9

The G-test comparing fenced versus unfenced road kill frequencies produced x^2 = 1.573, p = 0.21. There was no evidence that fencing affected the number of road kill along the highway alignment. However, this does not necessarily mean that there was no difference between fence and non-fenced areas. Limited road kill data was available for analysis and the test results could simply be an artefact of low statistical power. This could be remedied if more data was able to be collected, or to use additional data from other highway monitoring sites in a meta-analysis. To demonstrate that there is truly no difference in the data, the burden of proof is reversed and an equivalence test using the null hypothesis that there is a difference due to fencing would be required. Equivalence tests use two one-tailed tests to determine whether the data fall within specific bounds that are assumed to indicate that there is no true difference (Quertemont 2011).

4.4 Observations

The following observation is provided to further augment road kill mitigations along Stage 2B of WC2NH or to incorporate into future road kill mitigation strategies:

- Should the trend of mammal (particularly Macropod) road kill records continue from the Rosewood Creek to Rosewood Tributary area, a review of the fauna fence and fauna drop down structure configuration is suggested. The design could be improved by extending the Type 1 fauna fence on both the eastern and western sides of the alignment from chainages 44300 to 45100 and incorporating additional fauna drop down structures around culvert headwalls and within 100 m from the end of the fauna fence.

5. Summary and Conclusion

No BC or EPBC Act listed species were recorded during the monitoring period. No road kill recordings of target threatened species known to occur within habitat adjacent to the highway alignment that the fencing aims to protect were recorded. Such species include the Koala, Spotted-tailed Quoll or Giant Barred Frog.

Of the 27 road kill recordings, medium to large terrestrial native mammals comprise the main species group to which the fence design provides a barrier for. Recordings of these species were moderate (44.5 per cent of records) over the reporting period.

Two road kill hotspots were identified across Stage 2B including the Rosewood Creek to Rosewood Tributary and to a lesser degree to the north of Rosewood Road overpass.

No Giant Barred Frog road kill records were made in the vicinity of the Type 2 fauna fencing (Giant Barred Frog fencing) between chainage 42550 and 43400.

Results indicate a general trend with the number of fauna road kill records increasing slightly over time. Week 5 of the 12 weeks of monitoring was the only monitoring event where no fauna mortalities were recorded.

Statistical analysis to determine the effectiveness of the fauna fencing does not contain strong statistical power due to the small results data pool, particularly of relevant fauna groups (i.e. medium to large sized terrestrial mammals). The results of future monitoring should be consolidated to develop a larger data set to allow for future statistical analysis.

A recommendation to review the fauna fence and drop down structure configuration within the Rosewood Creek to Rosewood Tributary area has been suggested should the trend of mammal road kill records at this location continue.

References

Dytham, C. (2003). *Choosing and Using Statistics: A Biologist's Guide, Second Edition*. Blackwell Publishing, Oxford.

GeoLINK, (2018). Stage 2A Road Kill Monitoring Report *(ref. 2692-1092)* for Warrell Creek to Nambucca Heads Pacific Highway Upgrade. Unpublished report for Roads and Maritime Services, NSW.

Quertemont, E. (2011). How to statistically show the absence of an effect. *Psychologica Belgica* **51-2**: 109-127.

Copyright and Usage

©GeoLINK, 2018

This document, including associated illustrations and drawings, was prepared for the exclusive use of Roads and Maritime Services to report compliance with WC2NH Project ecological monitoring requirements. It is not to be used for any other purpose or by any other person, corporation or organisation without the prior consent of GeoLINK. GeoLINK accepts no responsibility for any loss or damage suffered howsoever arising to any person or corporation who may use or rely on this document for a purpose other than that described above. This document, including associated illustrations and drawings, may not be reproduced, stored, or transmitted in any form without the prior consent of GeoLINK. This includes extracts of texts or parts of illustrations and drawings.

The information provided on illustrations is for illustrative and communication purposes only. Illustrations are typically a compilation of data supplied by others and created by GeoLINK. Illustrations have been prepared in good faith, but their accuracy and completeness are not guaranteed. There may be errors or omissions in the information presented. In particular, illustrations cannot be relied upon to determine the locations of infrastructure, property boundaries, zone boundaries, etc. To locate these items accurately, advice needs to be obtained from a surveyor or other suitably-qualified professional.

Appendix A

Stage 2B Road Kill Monitoring Results

Monitoring Week	No. of Records	Species	Class of Chordate	Date	Easting	Northing	Carriageway (northbound or southbound)	Location Description	Fauna Fence Present (yes/no)	Distance to Nearest Fauna Fence	Comments	Image No.	Stage 2B
Week 1	1	Pacific Black Duck (*Anas superciliosa*)	Bird	5/07/2018	490859	6596643	Southbound	100 m north of Rosewood Road overpass	No	n/a for birds	Nil	7544	Stage 2B
Week 2	2	Magpie-lark (*Grallina cyanoleuca*)	Bird	12/07/2018	491394	6597726	Southbound	400 m south of Williamsons (Crouches) Creek Bridge	No	n/a for birds	Nil	n/a	Stage 2B
	3	Common Brushtail Possum (*Trichosurus vulpecula*)	Mammal	12/07/2018	489166	6594172	Southbound	On Upper Warrel Creek Bridge	No	~120 m to the north	Badly damaged Brushtail Possum.	7703	Stage 2B
	4	Red-necked Wallaby (*Macropus rufogriseus*)	Mammal	12/07/2018	490701	6596134	Northbound	Rosewood Tributary Culvert	No	~ 500 m to the south	Nil	7686	Stage 2B
Week 3	5	Red-necked Wallaby (*Macropus rufogriseus*)	Mammal	19/07/2018	490703	6596092	Centre median	Rosewood Tributary Culvert	No	~ 500 m to the south	Nil	2052	Stage 2B
	6	Australian Wood Duck (*Chenonetta jubata*)	Bird	19/07/2018	490811	6596790	Northbound	200 m north of Rosewood Road	No	n/a for birds	Nil	2055	Stage 2B
Week 4	7	Red-necked Wallaby (*Macropus rufogriseus*)	Mammal	26/07/2018	491383	6597723	Centre median	400 m south of Williamsons (Crouches) Creek Bridge	No	>500 m to nearest fauna fence	Nil	999	Stage 2B
	8	Feral Pigeon (*Columba livia*)	Bird	26/07/2018	491919	6598424	Southbound	Beneath Boral Quarry access bridge (near Scotts Head Road turnoff)	No	n/a for birds	Nil	n/a	Stage 2B

Monitoring Week	No. of Records	Species	Class of Chordate	Date	Easting	Northing	Carriageway (northbound or southbound)	Location Description	Fauna Fence Present (yes/no)	Distance to Nearest Fauna Fence	Comments	Image No.	Stage 2B
Week 5	-	No road kill records detected during week 5 monitoring event		2/08/2018	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Week 6	9	Red-necked Wallaby (*Macropus rufogriseus*)	Mammal	9/08/2018	490611	6595955	Northbound	600 m south of Rosewood Road overpass	No	~350 m to the south	Nil	2060-2063	Stage 2B
	10	Barn Owl (*Tyto alba*)	Bird	9/08/2018	491346	6597734	Northbound	400 m south of Williamsons (Crouches) Creek Bridge	No	>500 m to nearest fauna fence	Nil	2064-2072	Stage 2B
Week 7	11	Australian White Ibis (*Threskiornis molucca*)	Bird	16/08/2018	489163	6594196	Northbound	On Upper Warrell Creek Bridge	No	~120 m to the north	Nil	2100	Stage 2B
	12	Barn Owl (*Tyto alba*)	Bird	16/08/2018	490718	6596110	Centre median	Rosewood Tributary Culvert	No	n/a for birds	Centre median access not possible.	2099	Stage 2B
	13	Unidentifiable Macropod	Mammal	16/08/2018	490665	6596070	Northbound	Rosewood Tributary Culvert	No	~ 500 m to the south	Very badly damaged Macropod record. Possible Red-necked Wallaby.	2096	Stage 2B
	14	Barn Owl (*Tyto alba*)	Bird	16/08/2018	489687	6594685	Southbound	100m north of Cockburns Lane overpass	Yes	n/a for birds	Nil	2094-2095	Stage 2B
	15	Barn Owl (*Tyto alba*)	Bird	16/08/2018	490538	6595828	Centre median	Rosewood Creek Culvert	No	n/a for birds	Nil	2088-2093	Stage 2B

Monitoring Week	No. of Records	Species	Class of Chordate	Date	Easting	Northing	Carriageway (northbound or southbound)	Location Description	Fauna Fence Present (yes/no)	Distance to Nearest Fauna Fence	Comments	Image No.	Stage 2B
Week 8	16	Northern Brown Bandicoot (*Isoodon macrourus*)	Mammal	23/08/2018	490662	6596062	Northbound	Rosewood Tributary Culvert	No	~ 500 m to the south	Nil	001-002	Stage 2B
Week 9	17	Red-necked Wallaby (*Macropus rufogriseus*)	Mammal	30/08/2018	490294	6595537	Southbound	300 m south of Rosewood Creek Culvert	Yes	Fence adjacent	Very dry damaged record.	n/a	Stage 2B
	18	Red-necked Wallaby (*Macropus rufogriseus*)	Mammal	30/08/2018	490679	6596095	Northbound	Rosewood Tributary Culvert	No	~ 500 m to the south	Very damaged dry record.	2063-2064	Stage 2B
	19	Southern Boobook (*Ninox novaeseelandiae*)	Bird	30/08/2018	491873	6598425	Northbound	South side of Boral Quarry access overpass	No	n/a for birds	Clear Boobook record.	2065-2067	Stage 2B
Week 10	20	Common Brushtail Possum (*Trichosurus vulpecula*)	Mammal	6/09/2018	490486	6595769	Southbound	Rosewood Creek Culvert	No	~150m to the south	Fur and claw only very damaged size consistent with Brushtail Possum.	2104-2105	Stage 2B
Week 11	21	European Fox (*Vulpes vulpes*)	Introduced Mammal	13/09/2018	490432	6595713	Southbound	100 m south of Rosewood Creek Culvert	No	~80m to the south	Appears to be female fox with the tail missing from the body.	001	Stage 2B
	22	Purple Swamphen (*Porphyrio porphyrio*)	Bird	13/09/2018	490853	6596764	Southbound	200m north of Rosewood Road overpass	No	n/a for birds	Nil	003	Stage 2B
	23	Australian Magpie (*Cracticus tibicen*)	Bird	13/09/2018	488787	6593901	Southbound	50m south of Browns Crossing Road	No	n/a for birds	Nil	004	Stage 2B

Monitoring Week	No. of Records	Species	Class of Chordate	Date	Easting	Northing	Carriageway (northbound or southbound)	Location Description	Fauna Fence Present (yes/no)	Distance to Nearest Fauna Fence	Comments	Image No.	Stage 2B
	24	Blue or Pink Tongue Sink (*Tiliqua sp.*)	Reptile	13/09/2018	490808	6596606	Northbound	50m north of Rosebank Road overpass	No	>500 m to nearest fauna fence	Very damaged could not be identified to species level.	005	Stage 2B
Week 12	25	Common Brushtail Possum (*Trichosurus vulpecula*)	Mammal	20/09/2018	489677	6594708	Centre median	Butchers Creek Culvert	Yes	Fence adjacent	Damaged record, beak visible to distinguish species.	n/a	Stage 2B
	26	Short-beaked Echidna (*Tachyglossus aculeatus*)	Mammal	20/09/2018	489662	6594694	Northbound	100m north of Cockburns Lane overpass	Yes	Fence adjacent	Female Echidna	8405-8410	Stage 2B
	27	Tawny Frogmouth (*Podargus strigoides*)	Bird	20/09/2018	489835	6594894	Northbound	100 m north Cockburns Lane overpass	Yes	n/a for birds	Very damaged record, likely Brushtail Possum.	8403-8404	Stage 2B

Appendix 6 Annual report 2018 inc. Spring (October) 2018 Monitoring Report.

Pacific Highway Upgrade Warrell Creek to Nambucca Heads:

operational phase roadkill monitoring - annual report 2018

Sandpiper Ecological

1/94 Main Street

Alstonville

Final Report

27 November 2018

Document Review

Date	Version	Status	Sent to	Represent	Delivered Format	Dispatched By
24/11/18	A	Draft	S. Hardiman	RMS	MSW	D. Rohweder

Document Distribution

Date	Version	Status	Sent to	Represent	Delivered Format	Dispatched By
27/11/18	1	Final	S. Hardiman & K. Hincks	RMS	PDF (Web compatible)	D. Rohweder

Project team:

Dr D. Rohweder (project management, survey report writing)

Mr N. Priest (project management, field survey)

Mr M. Jenkins (field survey)

Mr G. McDonald (field survey)

Mr O. Taylor (field survey)

Report prepared for:

Roads and Maritime Services NSW

© Sandpiper Ecological Surveys 2018
ABN: 82 084 096 828

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

Cover Photo: Roadkilled barn owl.

Disclaimer:
This report has been prepared in accordance with the scope of services described in the contract or agreement between Sandpiper Ecological Surveys (ABN 82 084 096 828) and Pacific Complete. The report relies upon data, surveys and measurement obtained at the times and locations specified herein. The report has been prepared solely for Pacific Complete and Sandpiper Ecological Surveys accepts no responsibility for its use by other parties. Sandpiper Ecological Surveys accepts no responsibility or liability for changes in context, meaning, conclusions or omissions caused by cutting, pasting or editing the report.

Table of contents

1. Introduction 1
1.1 Background 1
1.2 Study area 2
2. Methodology 3
2.1 Roadkill surveys 3
2.2 Data summary and analysis 3
2.2.1 Statistical analysis 3
3. Results 4
3.1 October 2018 sample 4
3.1.1 Weather conditions 4
3.1.2 Species richness and abundance 5
3.1.3 Opportunistic roadkill information 8
3.1.4 Distribution of roadkill 8
3.2 Annual results 2018 19
3.2.1 Statistical analysis 19
3.2.2 Species richness and abundance 19
3.2.3 Distribution of roadkill 21
4. Discussion 21
4.1 October 2018 21
4.2 Seasonal variation and species composition 21
4.3 Fenced vs unfenced 22
5. Recommendations 23
6. References 23
Appendix A – Field Survey Data 1

List of tables

Table 1: Fauna groups included in comparison of fenced and unfenced sections of alignment. 4

Table 2: Weather conditions in the 24hrs preceding each sample event. Data obtained from Envirodata weather station at the southern compound. 5

Table 3: Species of vertebrate recorded during roadkill surveys during the operational phase of the WC2NH upgrade. 5

Table 4: Results of G-test on roadkills in fenced and unfenced sections of the alignment. 19

Table 3: Visual assessment of health of koalas recorded during spotlight and diurnal surveys.. 9

List of figures

Figure 1: Location of the WC2NH upgrade corridor. 2

Figure 2: Number of roadkills recorded in each sample week during the October 2018 (Spring) sample period. 7

Figure 3: Number of roadkilled fauna from four vertebrate classes during each sample week in October 2018. 8

Figure 4: Location of roadkilled fauna recorded in October 2018 and stage 2A monitoring. 9

Figure 5: Location of roadkilled fauna recorded in October 2018 and stage 2A monitoring. 11

Figure 6: Location of roadkilled fauna recorded in October 2018 and stage 2A monitoring. 11

Figure 7: Location of roadkilled fauna recorded in October 2018 and stage 2A monitoring. 12

Figure 8: Location of roadkilled fauna recorded in October 2018 and stage 2A monitoring. 13

Figure 9: Location of roadkilled fauna recorded in October 2018 and stage 2A monitoring. 14

Figure 10: Location of roadkilled fauna recorded in October 2018 and stage 2A monitoring. 15

Figure 11: Location of roadkilled fauna recorded in October 2018 and stage 2A monitoring. 16

Figure 12: Location of roadkilled fauna recorded in October 2018 and stage 2A monitoring. 17

Figure 13: Location of roadkilled fauna recorded in October 2018 and stage 2A monitoring. 18

Figure 14: Number of roadkill recorded each week expressed as a total (Left axis) and number/km sampled (right axis). 20

Figure 15: Average number of roadkills and number/sample/km for each season in 2018. 20

1. Introduction

1.1 Background

In 2015, Roads and Maritime Services (RMS) NSW, in conjunction with Acciona Ferrovial Joint Venture (AFJV), commenced the upgrade of the Pacific Highway between Warrell Creek and Nambucca Heads (WC2NH). The WC2NH project was opened to traffic in two stages: stage 2a - 13.5km section from Lower Warrell Creek Bridge to Nambucca Heads opened on 18 December 2017; and stage 2b 6.25km section from the southern end of the project to the Lower Warrell Creek bridge opened in late June 2018.

The upgrade included a number of roadkill mitigation measures to minimise vehicle collisions with native wildlife. The types of structures constructed to mitigate roadkill included:

- Fauna fencing to exclude fauna from the road corridor and to guide fauna towards connectivity structures.
- Fauna Drop Down Structures (escape ramps) along the fauna fencing.
- Fauna connectivity structures, including culverts, bridges, ropebridges and glide poles.

Several fauna fence designs were installed to target threatened species including:

- **Type 1** - Chainmesh fence 1.8 m tall with floppy top feature which is designed to exclude a range of native mammal species such as macropods, possums, spotted-tail Quoll (*Dasyurus maculatus*) and koala (*Phascolarctos cinereus*). 18.03 km of this fence type occurs at the site.
- **Type 3** - Small gauge mesh fence with sheet metal return angled away from the highway (combined with fauna floppy top fence) which is designed to exclude green-thighed frog (*Litoria brevipalmata*) from the road corridor. 1.32 km of type 3 fauna fence occurs at the site, overlapping with the type 1 fencing.
- **Type 4** - Chainmesh fence 4 m tall through the Macksville Flying-fox camp Paperbark Swamp Forest community designed to discourage grey-headed flying-fox (*Pteropus poliocephalus*) from flying within range of passing traffic when exiting or entering the roost. 1km of type 4 fence occurs at the site.

Sandpiper Ecological Surveys (SES) has been contracted by RMS to deliver the WC2NH operational ecological and water quality monitoring program, which includes seasonal roadkill surveys over the entire upgrade length.

Monitoring of roadkilled fauna is a requirement of the approved WC2NH koala, spotted-tailed quoll and grey-headed flying-fox management plans and the Ecological Monitoring Program (RMS 2018a). Priority species for roadkill surveys are grey-headed flying-fox, koala, spotted-tailed quoll, and giant barred frog (*Mixophyes iteratus*). Monitoring is required for the first five years of operation, and includes weekly surveys for the first 12 weeks of operation and four surveys (at weekly intervals) each season thereafter. Seasonal surveys are scheduled for October, January, April, and July. Due to the staged opening of the project, monitoring of stage 2a commenced in December 2017 with monitoring of stage 2b commencing in July 2018. The 12-week monitoring period for stage 2b ended on 30 September 2018 and Sandpiper Ecological commenced monitoring in October 2018. Previous roadkill monitoring was conducted by Geolink (2018a, b, c, d).

The aim of monitoring is to:

- report on any vertebrate roadkill following opening to traffic; and
- assess the effectiveness of the presence of fauna fencing to prevent fauna being killed by vehicles while attempting to cross the WC2NH Upgrade.

The following report details the methods used to monitor roadkilled fauna in spring (October) 2018 and compares roadkill data from fenced verses unfenced sections of the alignment. Monitoring in October 2018 covered the entire alignment.

1.2 Study area

The WC2NH project covers a total length of 19.75km and extends from Warrell Creek in the south to Nambucca Heads in the North (Figure 1).

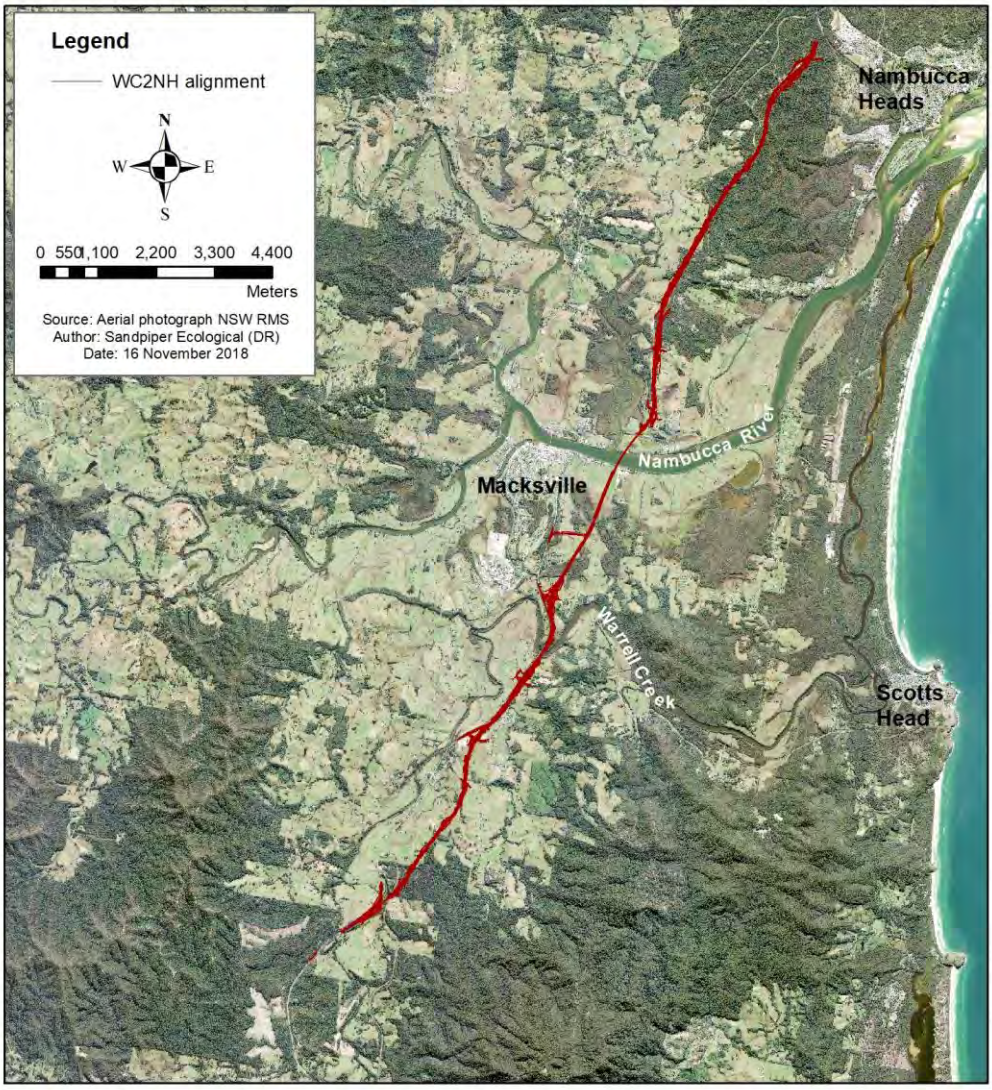


Figure 1: Location of the WC2NH alignment.

2. Methodology

2.1 Roadkill surveys

Roadkill surveys were conducted by a two-person team from a vehicle driven at 60-70km/hr in the left lane with amber (flashing) and hazard lights on. The team consisted of a driver and ecologist with experience identifying road-killed fauna. All surveys commenced within two hours of sunrise and where possible, were completed within three hours of sunrise, with an interval of 6-7 days between samples. During each survey both the driver and ecologist scanned the road surface and road shoulder for fauna. When roadkilled fauna were detected the vehicle was pulled onto the shoulder/parking bay and the subject animal was visually inspected by the ecologist. Fauna that could not be identified immediately were photographed and images sent to colleagues. Carcasses were removed from the road surface when safe to do so.

Data collected on each roadkill included:

- Geographic coordinate
- Presence/absence of fauna furniture
- Species/fauna group
- Date of survey
- Roadkill location – north or southbound carriageway

Data collected for threatened species listed on the *Environment Protection and Biodiversity Conservation Act* (1999) included, where possible: sex and age (juvenile/adult); presence of pouch young; presence of flightless young (flying-foxes); distance to a fauna connectivity structure (determined from GIS); distance to a drop-down structure (determined from GIS); damage to fauna fencing; weather conditions; if the animal was a flying-fox – distance to nearest camp, distance to nearest canopy vegetation, and presence of flowering food trees in median or roadside vegetation.

Distance to connectivity structure, and distance to drop-down was determined via GIS. All other data were uploaded to an Ipad onsite.

2.2 Data summary and analysis

Data from the October 2018 survey were uploaded to Microsoft excel. The October data were compared with results from the previous 12 week sample (see Geolink 2018d) to identify any duplicates. Using a combination of species and geographic location nine overlapping records were identified and removed from the October dataset. Graphs have been produced showing the total number of roadkills in October and the number of roadkills in different fauna groups each week of the survey. The location of roadkills has been overlaid on the WC2NH alignment to show their distribution. The number of roadkills for each species recorded during roadkill surveys over all monitoring periods was summarized by combining the October data with data from previous surveys (e.g. Geolink 2018a, b, c, d).

2.2.1 Statistical analysis

The primary aim of statistical analysis is to determine if there is a statistical difference in the frequency of roadkills between fenced and unfenced sections of the alignment. A secondary aim is to

determine if the frequency of roadkill varies through time in fenced and unfenced sections of the alignment.

Roadkill data were summarised by removing species/groups that would not (under normal circumstances) be stopped by exclusion fence from accessing the road alignment e.g. birds. Species/groups of fauna likely to be stopped by exclusion fence and therefore included in the analysis are listed in Table 1. Introduced species were included in the analysis to bolster sample size. Freshwater turtles were included as exclusion fence with a ground return should stop this group. Small lace monitors could move through exclusion fence, however, individuals of that size are rarely recorded in open habitats.

The location of each roadkill in relation to exclusion fence was determined from previous reports, and for October 2018, by overlaying roadkill records on a plan of exclusion fence extent using ArcGIS. If exclusion fence occurred on one side only the record was classified as "No fence". Sections of the alignment with a single fence may be included as a separate category in future analysis as sample size increases.

Table 1: Fauna groups included in comparison of fenced and unfenced sections of alignment.

Group	Species included
Macropods	Red-necked wallaby, swamp wallaby & eastern grey kangaroo
Bandicoots	Long-nosed & northern brown bandicoots
Possum	Brushtail & ringtail possums
Canid	Fox & dog
Feline	Cat
Leporidae	Hare & rabbits
Freshwater turtles	Long-necked, saw-shelled and Macleay river turtles
Goanna	Lace monitor

Data were pooled across all samples and divided into "fenced" and "unfenced". Expected proportions were based on the proportion of highway with fence on both sides ("fenced") and proportion with a single fence, or no fence ("no fence"). The proportion of fenced verses unfenced was 0.55 to 0.45. Data were analysed using a two-tailed G-test as per the equation of McDonald (2013), and a Kruskal-Wallis test in Systat 13.

3. Results

3.1 October 2018 sample

3.1.1 Weather conditions

Weather conditions in the 24hrs preceding each sample were conducive to fauna movement and retention of carcasses on the road surface (Table 1). Light showers occurred on two of the sample days but conditions were still suitable for roadkill surveys.

Table 2: Weather conditions in the 24hrs preceding each sample event. Data obtained from Envirodata weather station at the southern compound.

Date	Average Relative Humidity (%)	Total Rainfall (mm)	Maximum Temperature (^{0}C)	Average Wind Speed (KPH)	Visibility during survey	Rain during survey
4/10/18	81	0	25	5	Good	Nil
10/10/18	82	0	27	4	Good	Light
17/10/18	85	10	22	8	Good	Light
24/10/18	78	0	27	5	Good	Nil

3.1.2 Species richness and abundance

Forty-seven (47) roadkilled fauna were recorded during the October 2018 sample period. This included 19 native species, four introduced species, and seven fauna groups (Table A1, Appendix A). Birds were the most diverse group represented in roadkill with 12 species (including 2 introduced species) recorded. Six species of mammal (including 2 introduced species), five species of reptile, and possibly two species of frog were recorded (Table 3).

Eastern long-necked turtle (*Chelodina longicollis*) was the most frequently recorded species with six records, followed by barn owl (*Tyto javanica*) with three records (Appendix A). Unidentified mammals accounted for three records and frogs for three records. A possible eastern grass owl (*T. longimembris*), which is listed on the *Biodiversity Conservation Act 2017,* was recorded on the Gumma Floodplain between lower Warrell Creek and the Nambucca River. No target species were recorded during the October 2018 roadkill surveys.

Of the 47 roadkill records 18 (or 38%) were individuals expected to be blocked by exclusion fence. The remaining 29 records included birds, snakes, lizards, and frogs that readily move through or over exclusion fence.

Table 3: Species of vertebrate recorded during roadkill surveys during the operational phase of the WC2NH upgrade.

Species	Summer 17/18	Autumn 2018	Winter 2018	Spring 2018	Total
Australian magpie	6	1		1	8
Australian white ibis			1		1
Australian wood duck	20			2	22
Barn owl			11	3	14
Black flying-fox	2	1			3
Black rat	1				1
Blue tongue lizard	1			2	3
Cattle egret				1	1
Carpet python	1			2	3
Cat	1				1
Common-brushtail possum			1	2	3
Common tree snake	1	2			3

Species	Summer 17/18	Autumn 2018	Winter 2018	Spring 2018	Total
Crested pigeon	2				2
Domestic goose				1	1
Eastern grey kangaroo				3	3
Eastern long-neck turtle	1			6	7
Eastern water dragon	1			1	2
European fox	3	1	1	2	7
Forest kingfisher	1				1
Galah	7				7
Green tree frog	2				2
Grey butcherbird			1		1
Grass owl				1	1
Hare	2			1	3
Laughing kookaburra	3		2	1	6
Macleay river turtle	5	1			6
Magpie-lark	2		1		3
Masked owl	1				1
Northern brown bandicoot	1		1		2
Pacific black duck	2		1		3
Pied currawong				1	1
Purple swamphen	3		2	2	7
Rabbit	1				1
Red-necked wallaby	1		6		7
Red-bellied black snake	1				1
Rock pigeon			1	1	2
Short-beaked echidna				3	3
Southern boobook			1	1	2
Striped marsh frog	3				3
Swamp wallaby	2	1		1	4
Tawny frogmouth	1	3	1	2	7
Wattled bat				1	1
Whistling kite				1	1
Yellow-faced whipsnake				1	1
Macropod spp	3		2	1	6
Medium bird				1	1
Medium mammal				2	2
Large mammal				1	1
Medium frog				3	3
Large frog				1	1
Unidentifiable bird	5	4	1		10

Species	Summer 17/18	Autumn 2018	Winter 2018	Spring 2018	Total
Unidentified Chelidae (Turtle) species	6				6
Unidentified Mammal	1			3	4
Total	93	14	34	55	196

The number of roadkill recorded each week varied during the sample period. A trend of decreasing roadkill abundance was recorded over the first three sample weeks but roadkill abundance increased sharply in week four (Figure 2). Fifteen roadkilled fauna were recorded in week one, with 21 recorded in week four. Weeks one and four of the sample period coincided with the new and full moon respectively.

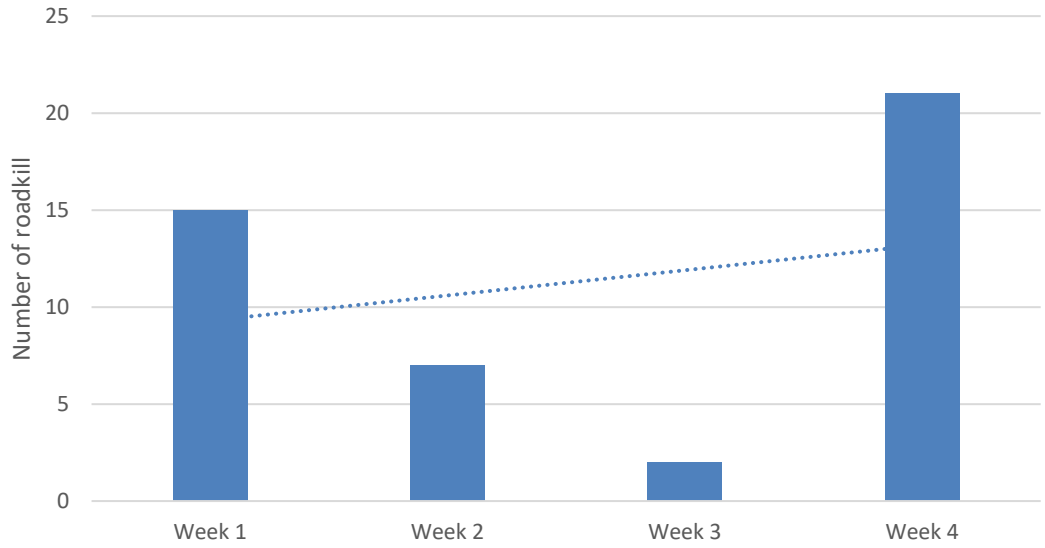


Figure 2: Number of roadkills recorded in each sample week during the October 2018 (Spring) sample period.

The abundance of roadkilled fauna in the four vertebrate groups varied during the sample period (Figure 3). The number of roadkilled mammals went from five in week one to none in week three and seven in week four. Likewise, the number of roadkilled birds decreased from four in week one to one in week three before rising to eight in week four. A similar trend was evident for reptiles, although the increase in week four was less distinct. Frogs were recorded in week four only (Figure 3).

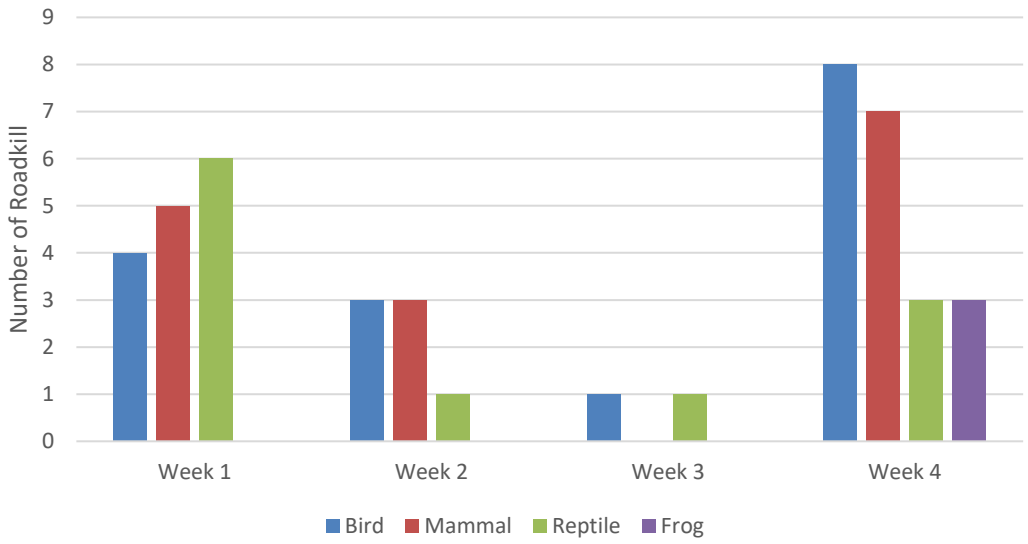


Figure 3: Number of roadkilled fauna from four vertebrate classes during each sample week in October 2018.

3.1.3 Opportunistic roadkill information

No opportunistic roadkill records were obtained during the reporting period.

3.1.4 Distribution of roadkill

In October 2018 roadkilled fauna was recorded over the entire WC2NH alignment (Figure 4-13), although the majority of records (62%) were recorded in stage 2B, between the southern end and lower Warrell Creek. Eighty-four percent (or 38 specimens) of roadkill was recorded between the Nambucca River and southern end of the project. Within that area, 53% of roadkill occurred between the southern end and Albert Drive (Figures 4 & 5). Seven roadkilled fauna were recorded in the 1.5km section of alignment south of Albert Drive (Figure 5). That section traverses predominantly cleared land with three drainage lines and does not contain fauna exclusion fence. The section of alignment north of Albert Drive traverses similar habitat and contained four roadkills (Figure 6). A cluster of long-necked turtle records occurred along the Gumma floodplain (Figure 7). That section contained Type 4 exclusion fence. The eastern grass owl was also recorded in that area.

Comparison with stage 2A monitoring indicates a substantial reduction in roadkill in October 2018 on the floodplain south of the Nambucca River and the 2.5km section north of the Nambucca River (Figures 8 & 9). Three records of frogs occurred immediately north of upper Warrell Creek where Type 2 (giant barred frog) fence occurs.

In October 2018, 25 roadkills were recorded in areas with exclusion fence, and 20 were recorded in areas without exclusion fence (Figures 4-13). Eleven records (or 44%) in sections with fence were species that should have been blocked by the fence (i.e. medium and large mammals & reptiles). In contrast, 30% of roadkills in sections without fence were of species that should have been blocked by the fence. Whilst these figures suggest that fauna are finding their way through or around exclusion fence they do not show how many individuals are being blocked by the fence.

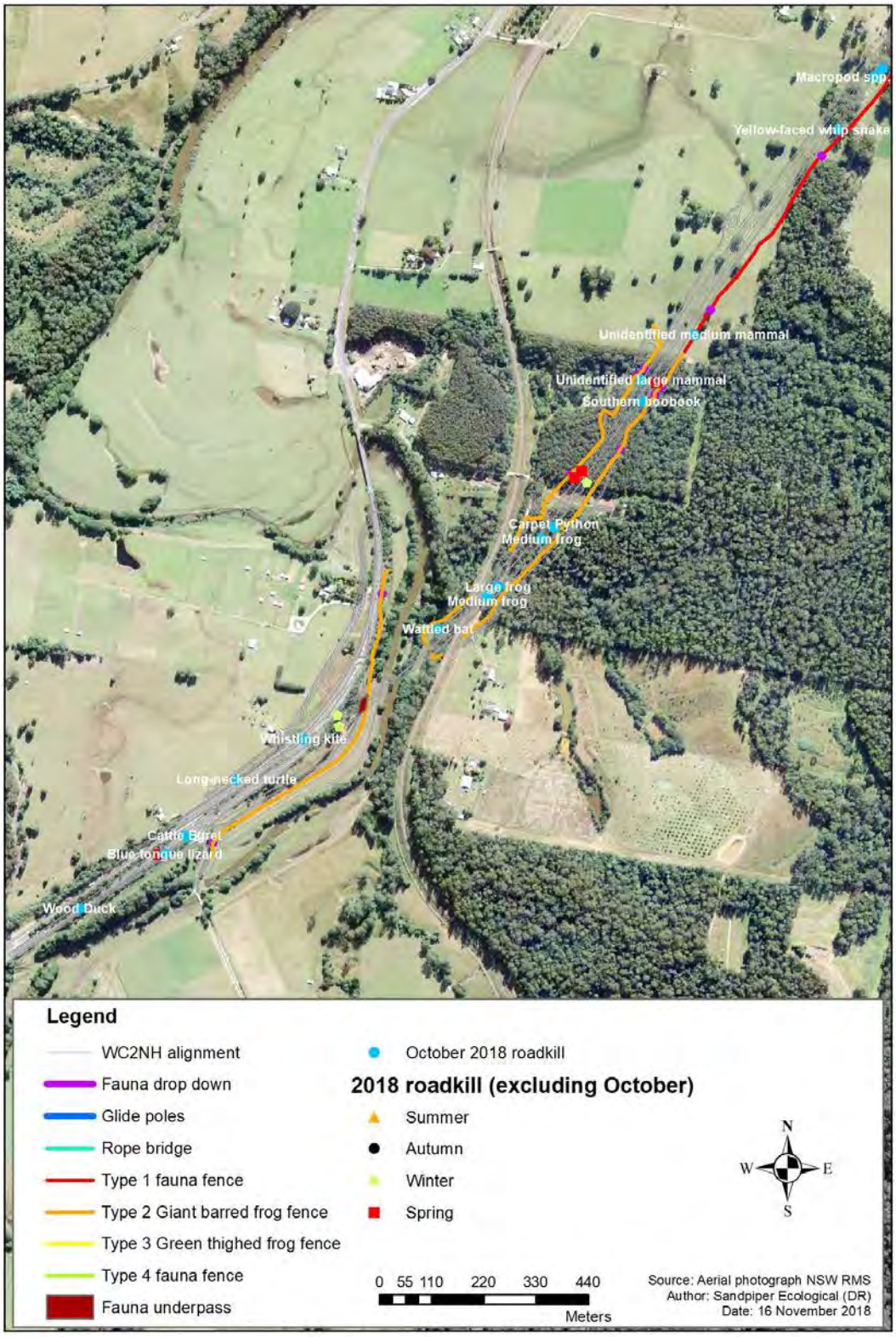


Figure 4: Location of roadkilled fauna recorded in October 2018 and stage 2A monitoring.

Figure 5: Location of roadkilled fauna recorded in October 2018 and stage 2A monitoring.

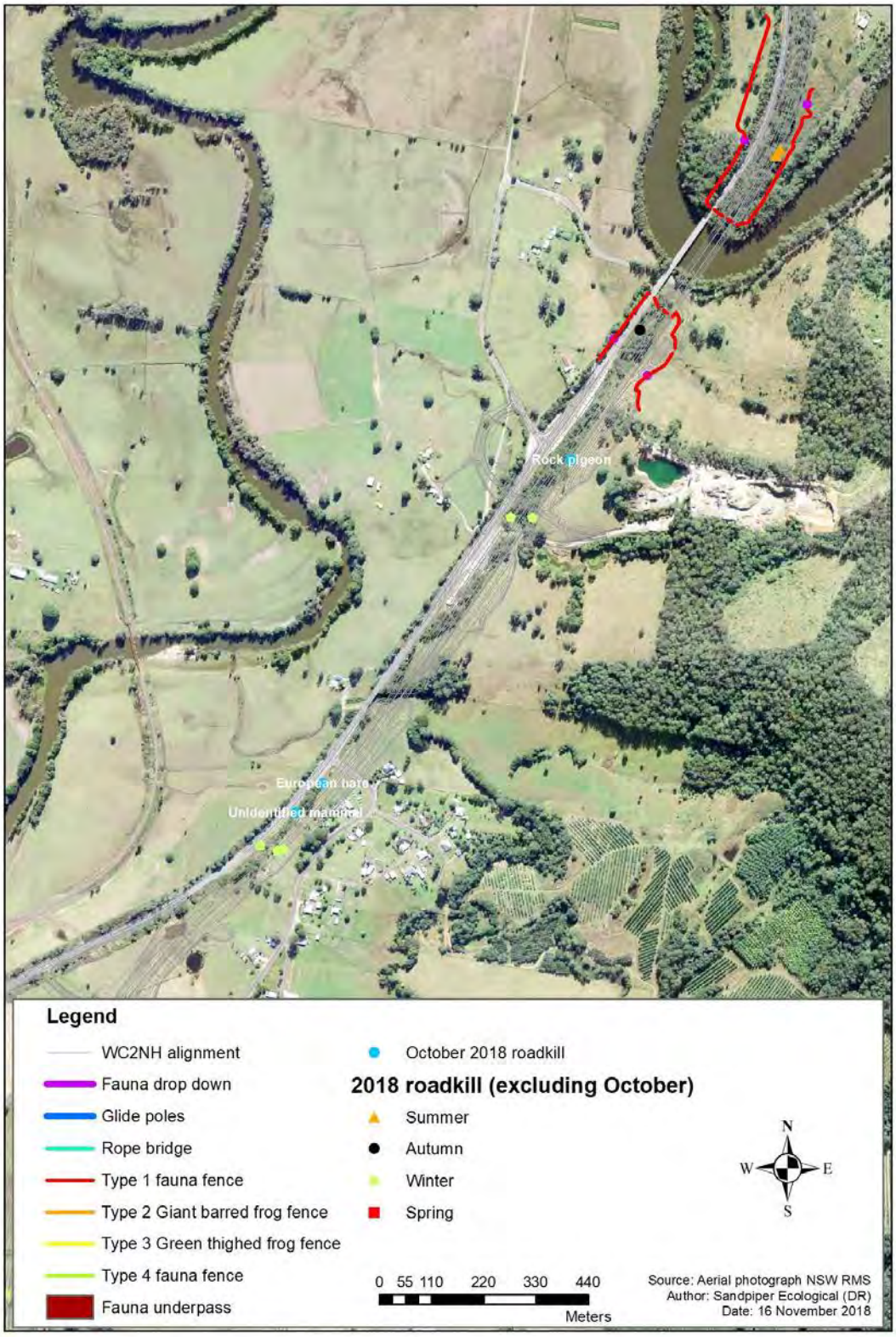


Figure 6: Location of roadkilled fauna recorded in October 2018 and stage 2A monitoring.

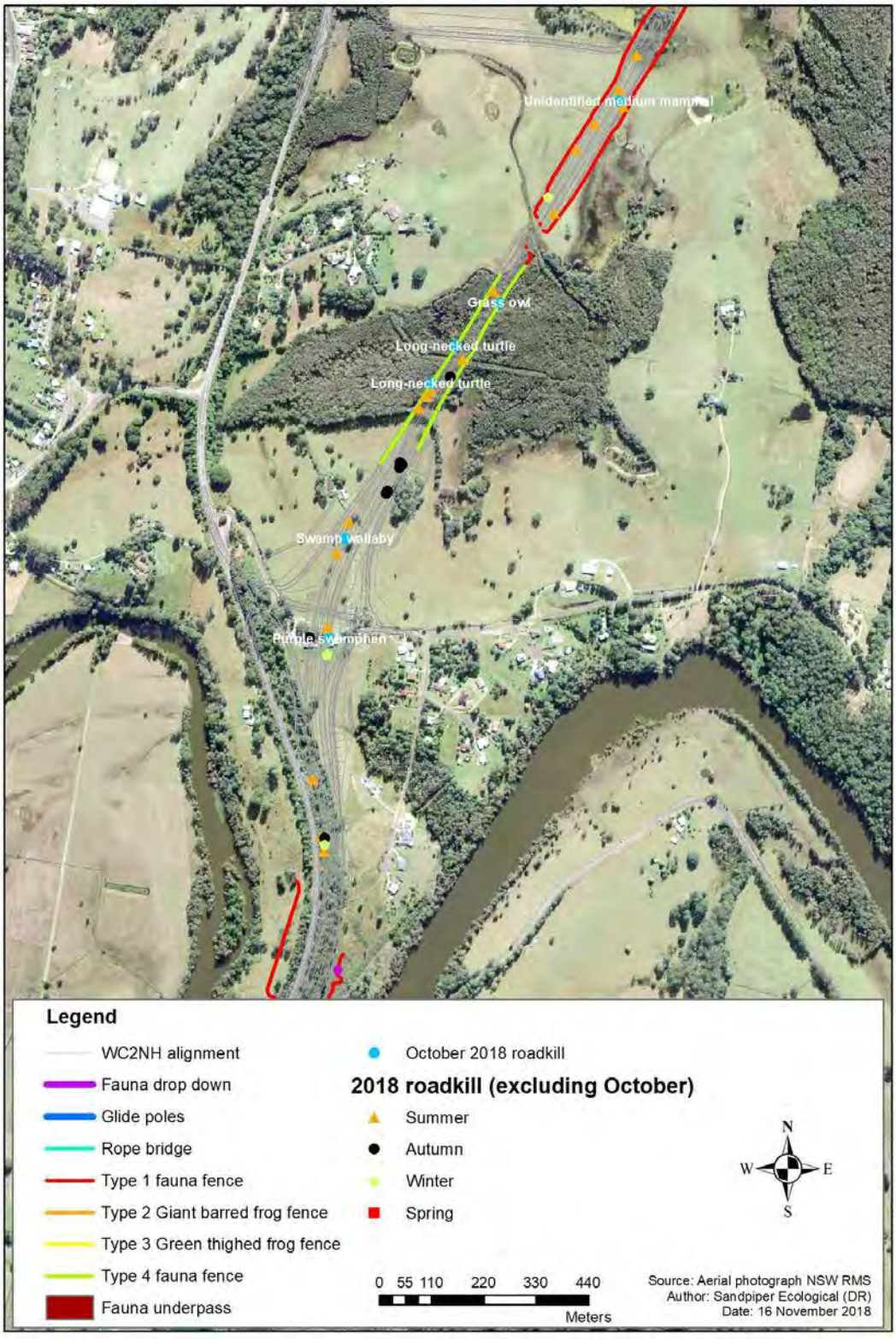


Figure 7: Location of roadkilled fauna recorded in October 2018 and stage 2A monitoring.

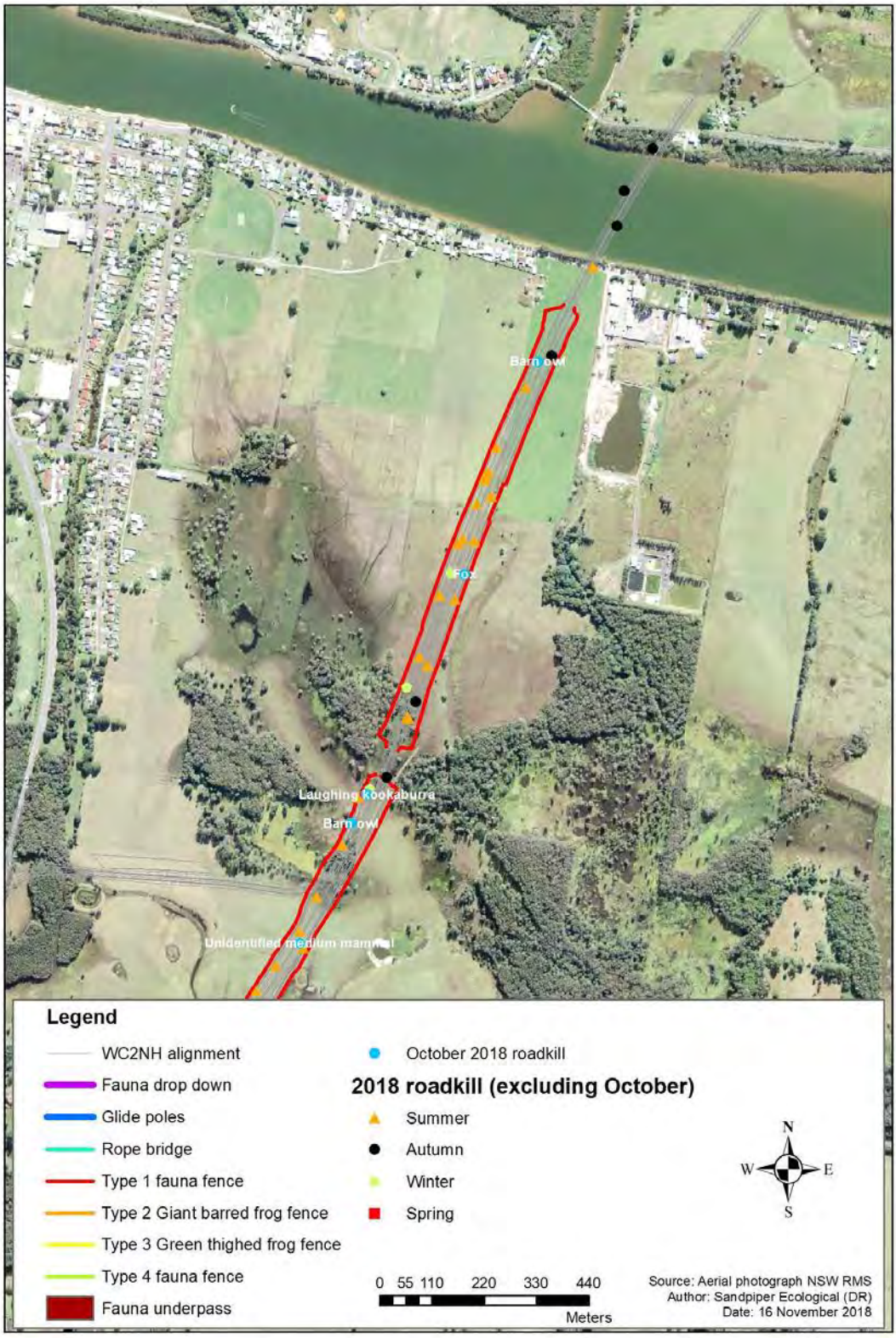


Figure 8: Location of roadkilled fauna recorded in October 2018 and stage 2A monitoring.

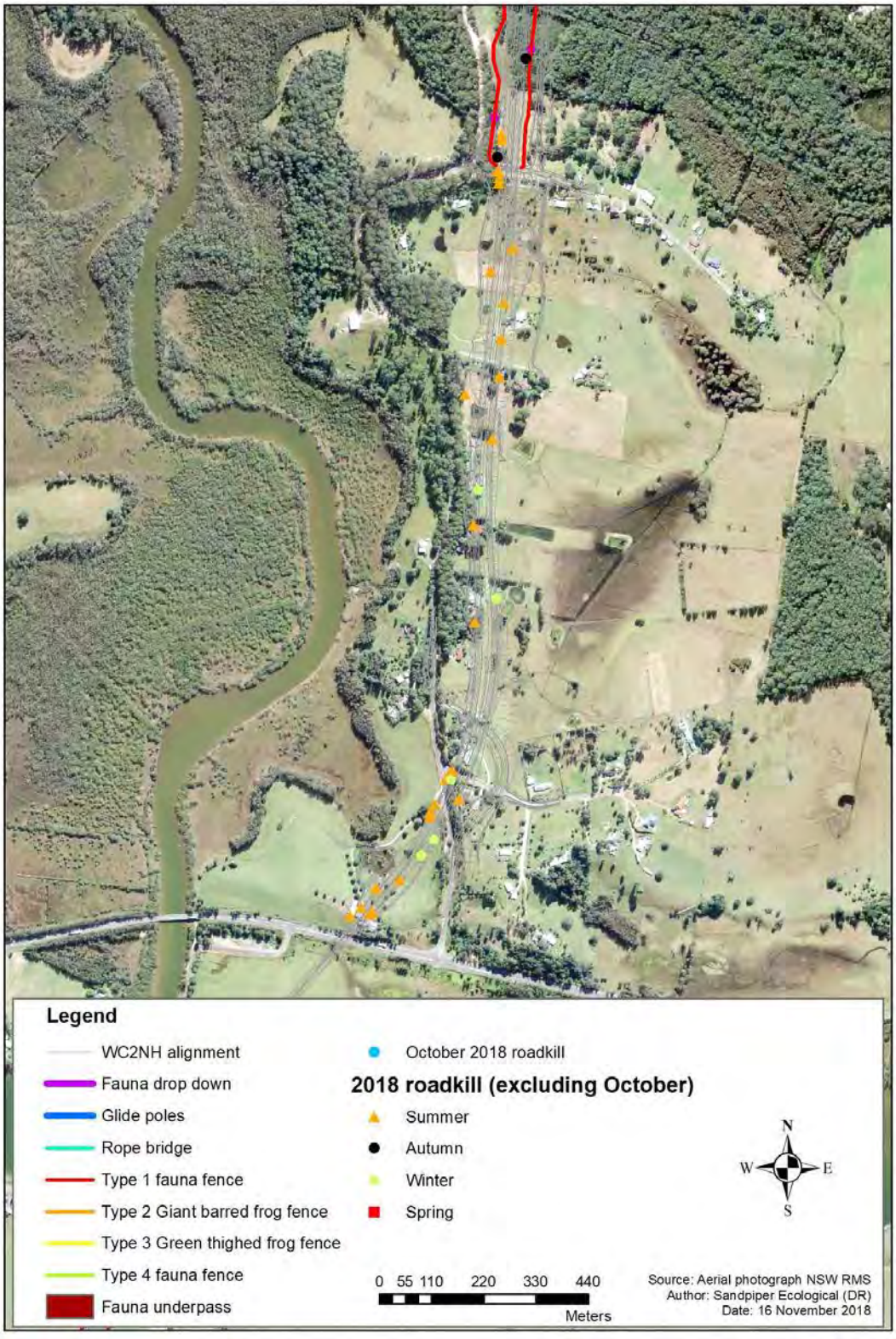


Figure 9: Location of roadkilled fauna recorded in October 2018 and stage 2A monitoring.

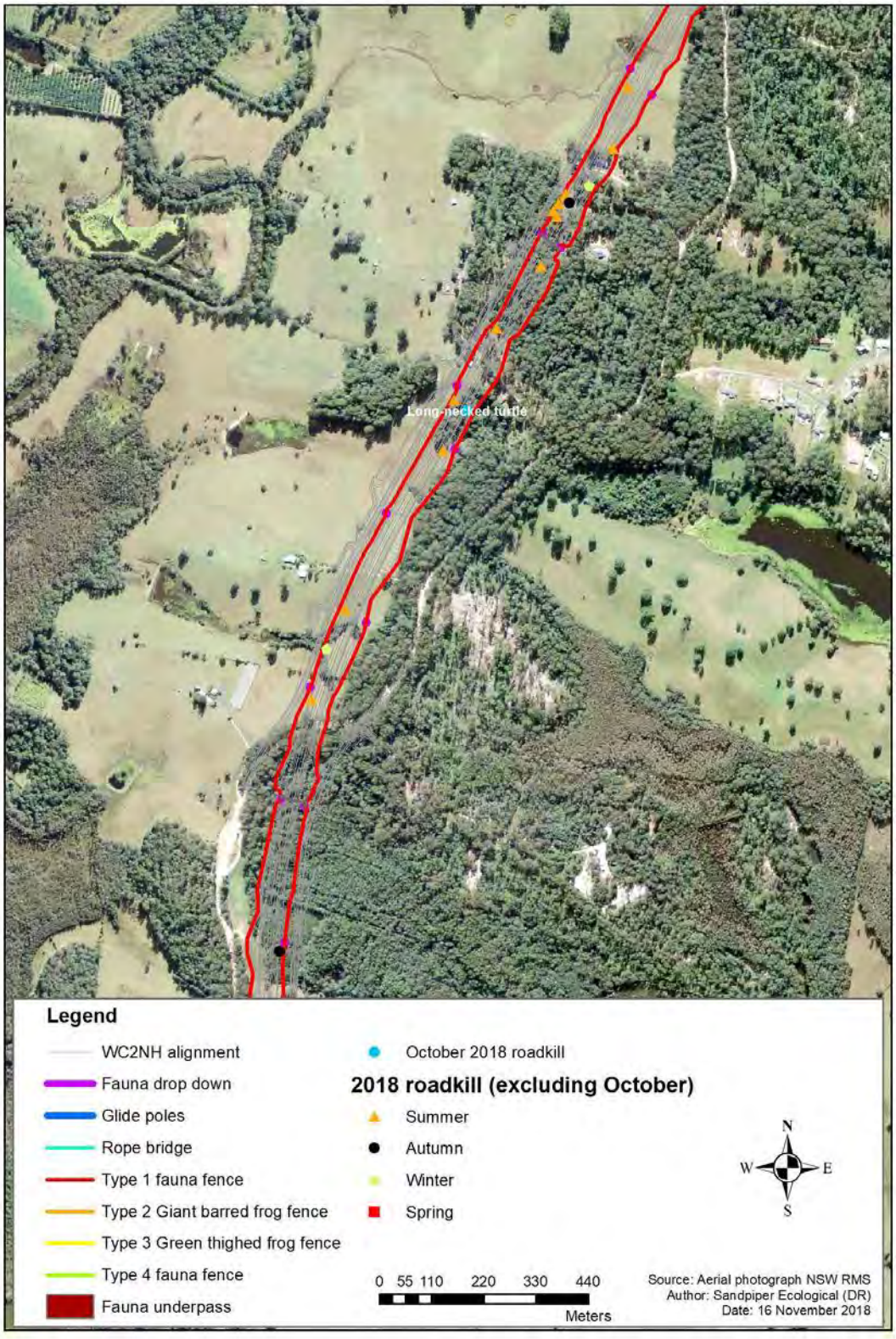


Figure 10: Location of roadkilled fauna recorded in October 2018 and stage 2A monitoring.

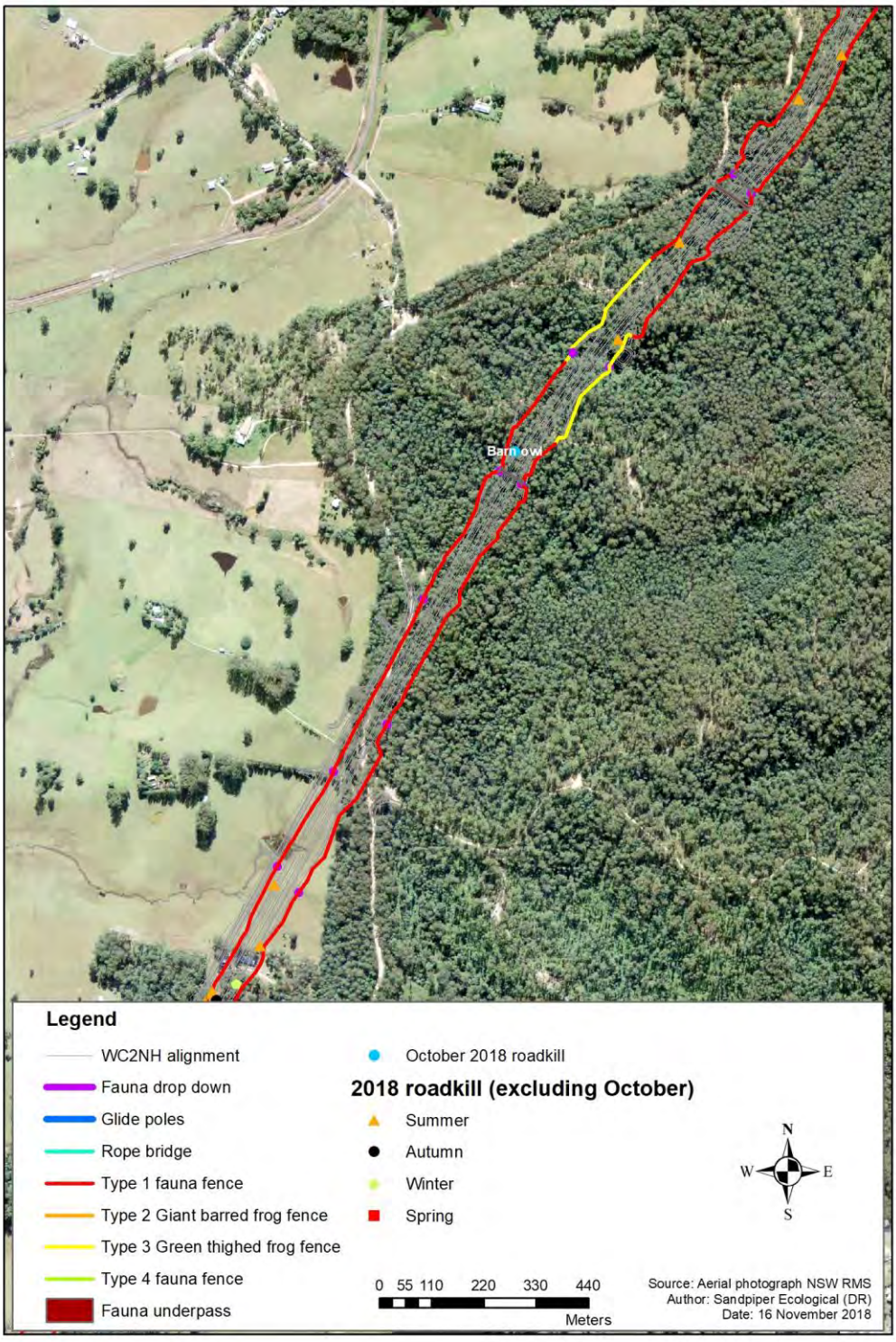


Figure 11: Location of roadkilled fauna recorded in October 2018 and stage 2A monitoring.

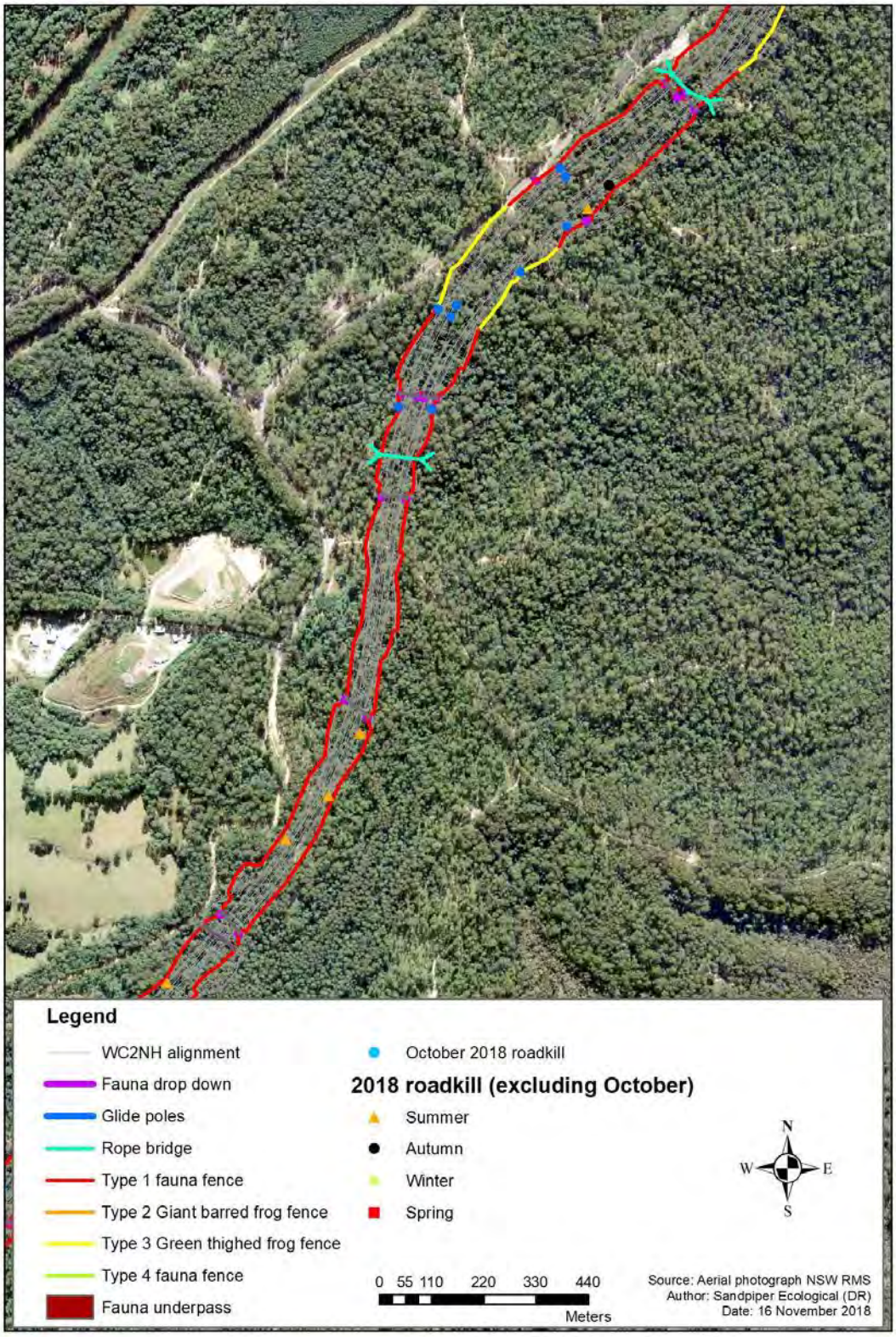


Figure 12: Location of roadkilled fauna recorded in October 2018 and stage 2A monitoring.

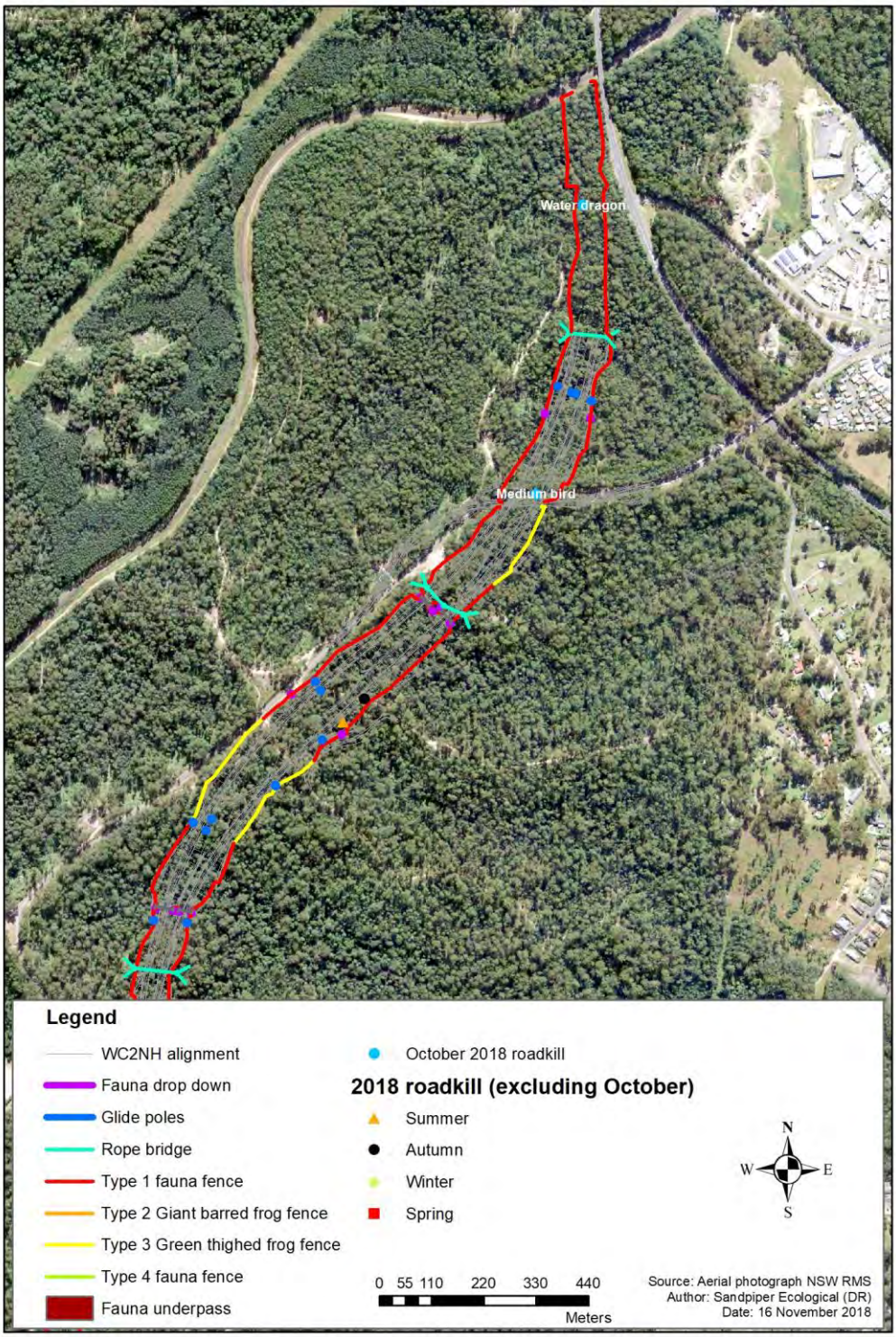


Figure 13: Location of roadkilled fauna recorded in October 2018 and stage 2A monitoring.

3.2 Annual results 2018

3.2.1 Statistical analysis

The G-test was run on three sets of data, all species (from Table 1), no reptiles, and no introduced species (Table 4). No statistically significant difference in number of roadkill was recorded for all species or no introduced species. A statistically significance difference in number of roadkill between fenced and unfenced sections of the alignment was recorded if reptiles were removed from the analysis (P=0.042), with a higher proportion of roadkill in unfenced sections of the alignment. The Kruskill-Wallis test did not record a statistically significant difference between fenced and unfenced sections of the alignment (n=34, df=1, P=0.334).

Table 4: Results of G-test on roadkills in fenced and unfenced sections of the alignment.

Group	Category	No. roadkill	Expected proportion	Expected N°.	Df	G statistic	P (2 tail)
All species	Fence	32	0.55	34.1	1	0.29	0.593
	No fence	30	0.45	27.9			
No reptiles	Fence	17	0.55	23.65	1	4.14	0.042
	No fence	26	0.45	19.35			
No introduced	Fence	25	0.55	28.05	1	0.73	0.392
	No fence	26	0.45	22.95			

3.2.2 Species richness and abundance

A total of 42 species have been recorded during roadkill surveys in 2018 (Table 3). This is comprised of 36 native species and six introduced species. The highest diversity of roadkill was recorded in summer (30 species), followed by spring (23 species), winter (7 species) and autumn (6 species). Nine additional fauna groups were identified (Table 3). The most commonly recorded species were Australian wood duck (22 records), barn owl (14 records), freshwater turtles (19 records), Australian magpie (8 records), and galah, fox, purple swamphen, red-necked wallaby and tawny frogmouth with seven records each. Laughing kookaburra, and Macropod spp each had six records (Table 3).

A total of 196 individuals were recorded across the 36 roadkill samples (Table A2, Appendix A). Birds were the most commonly recorded group with 105 records, followed by mammals (52 records), reptiles (32 records) and frogs (7 records). Roadkill abundance has fluctuated between sample weeks (Figure 14). The number of roadkill/km sampled was strongly correlated with the total number of roadkill recorded (Pearson correlation co-efficient 0.89) but the relationship weakened during the spring survey (weeks 33-36) when the entire alignment was sampled. The trendline suggests a slight temporal decrease in number of roadkill over the sample period (Figure 14).

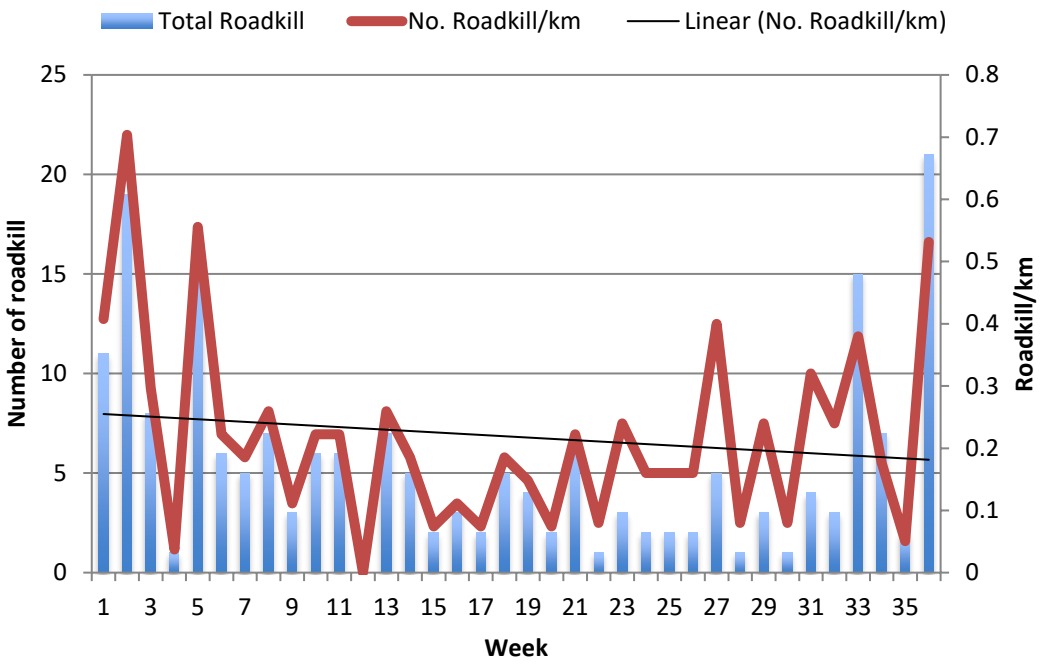


Figure 14: Number of roadkill recorded each week expressed as a total (Left axis) and number/km sampled (right axis).

Roadkill abundance has fluctuated substantially between seasons with notable peaks in summer and spring and decreases in autumn and winter (Figure 15).

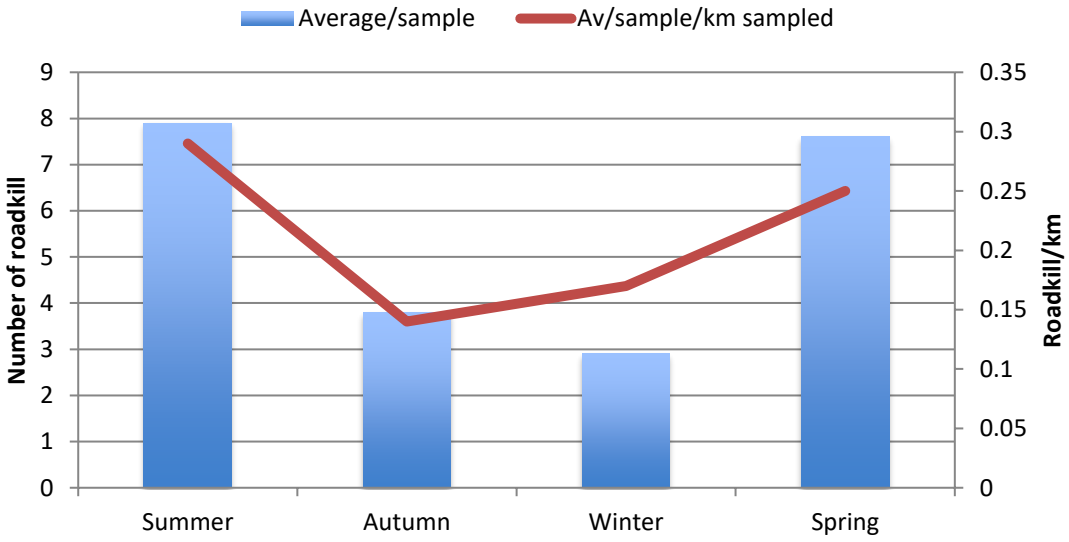


Figure 15: Average number of roadkills and number/sample/km for each season in 2018.

3.2.3 Distribution of roadkill

Roadkilled fauna have been recorded over the entire study area (Figures 4-13). Notable roadkill hotspots include:

- South end of project to Albert Drive (approx. 41 records – Figs 4&5)
- Gumma floodplain (approx. 62 records – Figs 7&8)
- Nambucca River to Mattick Road (31 records – Fig 9).

There are substantially fewer records through Nambucca State Forest where Type 1 exclusion fence occurs on both sides of the highway.

4. Discussion

4.1 October 2018

Monitoring of roadkill over the entire WC2NH alignment in October 2018 indicates that a substantial number of fauna continue to be killed by vehicles 12 weeks after the entire alignment was open to traffic. Monitoring identified a distinct clustering of roadkill in Stage 2B (i.e. between the southern end and lower Warrell Creek) with substantially fewer records in Stage 2A which was opened to traffic in December 2017 (Geolink 2018a). This difference may be indicative of fauna habituation to live traffic or the attrition of individuals that occupied habitat around the upgrade corridor during construction. A similar trend may become apparent in stage 2B over time. The absence of a notable temporal trend of decreasing roadkill, as recorded for stage 2A monitoring (see Geolink 2018a), may be due to the small sample size, or the influence of other variables such as lunar phase (Mizuta 2014; Grant *et al.* 2013). Indeed, the inclusion of lunar phase in future analysis may assist in identifying patterns in the frequency of roadkill.

A similar diversity and species composition of roadkill was recorded in October 2018 and Stage 2A monitoring, which occurred in summer/autumn 2017/18 (Geolink 2018a). The frequency of occurrence of different fauna groups (birds, mammals, reptiles & frogs) differed between the two samples, with a greater proportion of mammals recorded in October and fewer reptiles and birds. This difference could be due to season or the inclusion of different habitats in Stage 2B. Roadkill hotspots identified in October include the Gumma Floodplain, and from the southern end to Albert Drive. Geolink (2018a) also identified the Gumma Floodplain as a roadkill hotspot. Birds and reptiles comprised the majority of roadkills in both locations.

4.2 Seasonal variation and species composition

Monitoring identified a strong seasonal effect on roadkill frequency with peaks recorded in spring and summer. The observed pattern is not surprising as fauna tend to be more mobile during the spring / summer period when most species breed and disperse. Geolink (2018a) also highlighted the possible influence of grass seeding close to the highway at the time of opening to traffic on galah and wood duck roadkill.

Birds were more than twice as likely to be struck by vehicles as mammals, and the only threatened species recorded as roadkill were both birds (masked owl and grass owl), which highlights how susceptible that group is to vehicle strike. The occurrence of birds in roadkill is predicted to reduce overtime as individuals habituate to the highway. Nonetheless, the results provide further evidence of

the substantial impact that roads have on bird populations (Loss *et al.* 2014). The high occurrence of barn owls in winter and spring 2018 is consistent with opportunistic observations on the Pacific Highway throughout northern NSW over the same period (N. Priest pers obs). The result is attributed to drought conditions in western NSW forcing more owls into coastal areas.

4.3 Fenced vs unfenced

Analysis of roadkill data showed no statistically significant difference in the frequency of roadkill between fenced and unfenced sections of the alignment for target species (refer Table 1). This result suggests that fauna are being killed at the same frequency regardless of whether exclusion fence is present or not. The significantly higher frequency of roadkill in unfenced areas when reptiles were removed from the analysis indicates that reptiles, particularly freshwater turtles, contributed substantially to roadkill in fenced sections of the alignment. Turtle records were distributed across most of the alignment, with a noticeable cluster on the Gumma Floodplain, and north of the Nambucca River. Geolink (2018a) attributed the high incidence of roadkilled turtles during Stage 2A monitoring to individuals trapped on the roadside of the exclusion fence following fence construction. Whilst this suggestion is plausible further monitoring is required to determine if the frequency of turtle roadkill decreases with time. Roadkilled turtles were recorded in areas with both Type 1 and Type 4 exclusion fence and the frequency of roadkills was similar in Spring (1.5 individuals/week) and Summer/autumn (1.2 roadkills/week). Freshwater turtles, particularly eastern long-necked turtles, often move between wetlands in spring making them more susceptible to vehicle strike.

Freshwater turtles should be blocked by exclusion fence where there is a ground return. The incidence of turtle roadkill may be due to the absence of a ground return on the Type 4 fence across the flying-fox habitat section of the Gumma Floodplain, and/or use of open drains to get beneath the fence. Whilst efforts have been made to make open drains impenetrable to fauna, some gaps may exist.

Despite the equivalent incidence of target species roadkill in fenced and unfenced areas the results do not show how many individuals the exclusion fence stops from entering the alignment. Exclusion fence corresponds with vegetated areas that have a higher abundance of fauna. Without exclusion fence roadkill would be substantially higher in these areas (de Carvalho *et al.* 2014). In addition, general observation suggests that there is typically a spike in roadkill immediately after a highway is opened to traffic and a temporal decline in roadkill frequency is anticipated. The low incidence of fauna mortality in Stage 2A in October may be indicative of such a decrease. The low incidence of target species mortality through the Nambucca State Forest section shows that the exclusion fence is having a positive effect on roadkill frequency.

At this stage of monitoring no modifications to exclusion fence design or extent is recommended. Further monitoring is required to confirm the presence of roadkill hotspots and the overall frequency of roadkill within the WC2NH alignment.

Most of the species recorded near drop-down structures were non-target species (i.e. birds) and at this stage of monitoring there is no obvious correlation between drop-down structures and target species roadkill. As sample size increases correlations between drop-downs and target species should be explored.

5. Recommendations

1. Continue seasonal roadkill surveys during year two of the operational phase using the same methods applied in year one.
2. Continue to monitor the distribution of freshwater turtle roadkills in relation to habitat inside the exclusion fence.
3. Explore correlations between drop-downs and the distribution of target species in the year two annual report.

6. References

Geolink (2018a). *Roadkill monitoring report: WC2NH Stage 2A*. Report prepared for NSW Roads and Maritime Services.

Geolink (2018b). *Roadkill monitoring summary report: autumn (April) 2018*. Letter report prepared for NSW Roads and Maritime Services.

Geolink (2018c). *Roadkill monitoring summary report: winter (July) 2018*. Letter report prepared for NSW Roads and Maritime Services.

Geolink (2018d). *Roadkill monitoring report - initial 12 weeks WC2NH Stage 2B*. Report prepared for NSW Roads and Maritime Services.

Grant, R., Halliday, T. & Chadwick, E. (2013). Amphibians' response to the lunar synodic cycle – a review of current knowledge, recommendations, and implications for conservation. *Behavioural Ecology:* **24,** 53-62.

De Carvalho, N. C., Bordignon, M. O. & Shapiro, J. T. (2014). Fast and furious: a look at the death of animals on the highway MS-080, southwestern Brazil. *Iheringia, Ser. Zool:* **104,**

Loss, S. R., Will, T., & Marra, P. P. (2014). Estimation of bird-vehicle collision mortality on U.S. roads. *The Journal of Wildlife Management:* https://doi.org/10.1002/jwmg.721

McDonald, J. H. (2014). *Handbook of biological statistics*. Sparky House Publishing, Baltimore, Maryland.

Mizuta, T. (2014). Moonlight-related mortality: lunar conditions and roadkill occurrence in the Amami woodcock *Scolopax mira. The Wilson Journal of Ornithology:* **126, 544-552.**

RMS (2018). *Warrell Creek to Nambucca Heads Stage 2 Ecological Monitoring Program*. Report prepared by NSW Roads and Maritime Services.

Appendix A – Field Survey Data

Table A1: October 2018 roadkill results. NB = northbound; SB = southbound

Date	Observers	Start time	End time	Carriage way	Species	Species blocked by fauna fence	Sex & age class	Presence of pouch or back young	RK general location	Easting	Northing	Cleared off Rd (Y/N)	Fauna fence P/A & proximity	Fence condition
5/10/2018	GM, OT	700	1000	SB	Fox	Yes	Adult	No	700m sth of bridge	493434	6601897	N	Floppy, 20m	Good
5/10/2018	GM, OT	700	1000	SB	Grass owl (probable)	No	Adult		700m nth bald hill rd	492836	6600697	N	3m cyclone fence	Good
5/10/2018	GM, OT	700	1000	SB	Purple swamp hen (possible)	No	Adult		50m sth bald hill rd	492479	6599990	N	Concrete barrier fence part of on ramp	Good
5/10/2018	GM, OT	700	1000	SB	Eastern grey kangaroo x 2	Yes	Adult	No	300m nth rosewood creek	490709	6596073	N	Absent	
5/10/2018	GM, OT	700	1000	SB	Short-beaked echidna	Yes	Adult			490310	6595555	N	Floppy top	Good
5/10/2018	GM, OT	700	1000	SB	Unidentified mammal	Yes				490294	6595539	N	Floppy top	Good
5/10/2018	GM, OT	700	1000	SB	Carpet Python	No	Adult		Under cockburn lane	489618	6594590	N	Floppy top	Good
5/10/2018	GM, OT	700	1000	SB	Tawny frogmouth	No	Adult		Near rosewood creek	490580	6595923	Y	Absent	
5/10/2018	GM, OT	700	1000	NB	Carpet Python	No	Adult		Near rosewood creek	490611	6595969	N	Absent	
5/10/2018	GM, OT	700	1000	NB	Long-necked turtle	Yes	Juv		550m nth bald hill rd	492745	6600606	Y	3m cyclone fence	Good
5/10/2018	GM, OT	700	1000	NB	Long-necked turtle	Yes	Adult		530m nth bald hill rd	492693	6600527	Y	3m cyclone fence	Good
5/10/2018	GM, OT	700	1000	NB	Long-necked turtle	Yes	Adult		520m nth bal hill rd	492745	6600606	Y	3m cyclone fence	Good
5/10/2018	GM, OT	700	1000	NB	Unidentified mammal	Yes			510 nth bald hill rd	492745	6600606	N	3m cyclone fence	Good
5/10/2018	GM, OT	700	1000	NB	Barn owl	No	Adult		100m sth Nambucca river flood plain bridge 2	493196	6601373	Y	Floppy top	Good
5/10/2018	GM, OT	700	1000	NB	Water dragon	No	Adult		250 sth of railway	497470	6610885	Y	Floppy top	Good
11/10/18	DR, OT	745	925	SB	Short-beaked echidna	Yes	Adult		480m Sth of rosewood rd (SB)	490539	6595826	Y	Absent	
11/10/18	DR, OT	745	925	SB	Macropod spp.	Yes	Adult			490292	6595538	Y	Absent	
11/10/18	DR, OT	745	925	SB	Southern boobook (possible)	No	Unknown			488903	6594854	N	Floppy top	Good
11/10/18	DR, OT	745	925	SB	Blue tongue lizard	No	Adult		Browns crossing	488799	6593902	NA	Absent	

Date	Observers	Start time	End time	Carriage way	Species	Species blocked by fauna fence	Sex & age class	Presence of pouch or back young	RK general location	Easting	Northing	Cleared off Rd (Y/N)	Fauna fence P/A & proximity	Fence condition
11/10/18	DR, OT	745	925	SB	Goose /duck	No	Adult		Browns crossing	488850	6593939	N	Just south of floppy top	
11/10/18	DR, OT	745	925	NB	Whistling kite (possible)	No	Adult		Browns crossing	489092	6594144	N	Floppy top on east side	
11/10/18	DR, OT	745	925	NB	Unidentified mammal	Yes	Unknown		500m Sth macksville nterchange	491421	6597802	Y	Absent	
18/10/18	GM/OT	710	900	NB	Long-necked turtle	No	Adult		50m north rosewood road	490807	6596594	Y	Absent	
18/10/18	GM/OT	710	900	NB	Laughing kookaburra	No	Adult		40m sth Nambuc river floodplain bridge 2	493229	6601434	Y	Floppy top	Good
25/10/18	NP/MJ	730	950	SB	Medium bird	No	Adult		Under Old Coast Rd Bridge	497371	6610277	N	Floppy top	Good
25/10/18	NP/MJ	730	950	SB	Medium mammal	Yes			700m north macksville interchanfe	493088	6601121	N	Floppy top	Good
25/10/18	NP/MJ	730	950	SB	Long-necked turtle	Yes			1km north of Mattick Rd	494890	6606136	Y	Floppy top	Good
25/10/18	NP/MJ	730	950	SB	Rock pigeon (possible)	No	Adult		200m north of overpass?	492000	6598545	Y	Absent	
25/10/18	NP/MJ	730	950	SB	Yellow-faced whip snake	No	Adult		1km north of Cockburns Lane	490215	6595426	Y	Floppy top	Good
25/10/18	NP/MJ	730	950	SB	Medium frog x 2	No			20m s Cockburns Lane	489592	6594565	Y	Floppy top	Good
25/10/18	NP/MJ	730	950	SB	Medium mammal	Yes			500m north Cockburns Lane	489913	6594995	N	Floppy top	Good
25/10/18	NP/MJ	730	950	SB	Large frog	No	Adult		40m north rail bridge	489501	6594465	N	Floppy top	Good
25/10/18	NP/MJ	730	950	SB	Medium frog	No	Adult		20m north Rail brudge	489478	6594444	N	Floppy top	Good
25/10/18	NP/MJ	730	950	SB	Cattle Egret (poss)	No	Adult		100m south of UWC	488841	6593941	N	Floppy top on east side	
25/10/18	NP/MJ	730	950	SB	Wood Duck x 2	No	Adult		500m south of UwC	488620	6593787	N	Absent	
25/10/18	NP/MJ	730	950	SB	Pied Currawong	No	Adult		700m south of UWC	488345	6593614	N	Absent	
25/10/18	NP/MJ	730	950	NB	Long-necked turtle	Yes	Adult		400m south of UWC	488950	6594059	N	Floppy top on east side	
25/10/18	NP/MJ	730	950	NB	Wattled bat (*Chalinolobus* spp.)	No	Adult		50m south of rail bridge	489374	6594376	N	Floppy top	Good
25/10/18	NP/MJ	730	950	NB	Large mammal	Yes			200m n off rail bridge	489801	6594900	N	Floppy top	Good
25/10/18	NP/MJ	730	950	NB	Eastern grey kangaroo	Yes	Adult		Rosewood Creek	490647	6596010	N	Absent	
25/10/18	NP/MJ	730	950	NB	Medium bird	No	Adult		50m north Rosewood Rd	490806	6596631	N	Absent	
25/10/18	NP/MJ	730	950	NB	European hare	Yes			500m south of Scott's	491478	6597864	N	Absent	

Date	Observers	Start time	End time	Carriage way	Species	Species blocked by fauna fence	Sex & age class	Presence of pouch or back young	RK general location	Easting	Northing	Cleared off Rd (Y/N)	Fauna fence P/A & proximity	Fence condition
									Head turn off					
25/10/18	NP/MJ	730	950	NB	Swamp wallaby	Yes	Adult		100m north of Bald Hill Rd	492512	6600200	N	Absent	
25/10/18	NP/MJ	730	950	NB	Barn owl (prob)	No			100m s of Nambucca bridge	493588	6602344	N	Floppy top	Good
25/10/18	NP/MJ	730	950	NB	Barn owl	No				495733	6607729	N	Floppy top	Good

Appendix 7 Road Kill Monitoring Report – Summer (January) 2019 monitoring.

Pacific Highway Upgrade

Warrell Creek to Nambucca Heads: operational phase roadkill monitoring – Summer (January) Report 2019.

Sandpiper Ecological

1/94 Main Street Alstonville

Sandpipereco.com

Final Report (Version 2)

15 February 2019

Document Review

Date	Version	Status	Sent to	Represent	Delivered Format	Dispatched By
8/2/19	A	Draft	D. Rohweder	SES	MSW	N. Priest
10/2/19	1	Draft	S. Hardiman/K. Hincks	Roads and Maritime	MSW	D. Rohweder

Document Distribution

Date	Version	Status	Sent to	Represent	Delivered Format	Dispatched By
15/2/19	2	Final	S. Hardiman	Roads and Maritime	MSW	D. Rohweder

Project team:

Dr D. Rohweder (project management, field survey, reporting)
Mr N. Priest (field survey, reporting)
Mr L. Andrews (field survey)

Report prepared for:

Roads and Maritime Services NSW

© Sandpiper Ecological Surveys 2019
ABN: 82 084 096 828

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

Cover Photo: Road-killed northern brown bandicoot detected during January 2019 surveys.

Disclaimer:
This report has been prepared in accordance with the scope of services described in the contract or agreement between Sandpiper Ecological Surveys (ABN 82 084 096 828) and NSW Roads and Maritime Services. The report relies upon data, surveys and measurement obtained at the times and locations specified herein. The report has been prepared solely for Pacific Complete and Sandpiper Ecological Surveys accepts no responsibility for its use by other parties. Sandpiper Ecological Surveys accepts no responsibility or liability for changes in context, meaning, conclusions or omissions caused by cutting, pasting or editing the report.

Table of contents

1. Introduction 1
1.1 Background 1
1.2 Study area 2
2. Methods 3
2.1 Roadkill surveys 3
2.2 Data summary and analysis 3
3. Results 4
3.1 Weather conditions 4
3.2 Species richness and abundance 4
3.1.3 Opportunistic roadkill information 7
3.1.4 Distribution of roadkill 7
4. Discussion 18
4.1 January 2019 18
4.2 Seasonal variation and species composition 18
4.3 Flying-fox impacts 19
5. Recommendations 19
6. References 20
Appendix A – Field Survey Data 1

List of tables

Table 1: Weather conditions in the 24hrs preceding each sample event. Data obtained from Envirodata weather station at the southern compound. 4

Table 2: Species of vertebrate recorded during roadkill surveys during the operational phase of the WC2NH upgrade. * denotes threatened species. 4

List of figures

Figure 1: Location of the WC2NH alignment. 2

Figure 2: Number of road-kills recorded in each sample week during the January 2019 (summer) sample period. 6

Figure 3: Number of road-killed fauna from four vertebrate classes during each sample week in January 2019 7

Figure 4: Location of road-killed fauna in January 2019 8

Figure 5: Location of road-killed fauna in January 2019 9

Figure 6: Location of road-killed fauna in January 2019 10

Figure 7: Location of road-killed fauna in January 2019 11

Figure 8: Location of road-killed fauna in January 2019 12

Figure 9: Location of road-killed fauna in January 2019 13

Figure 10: Location of road-killed fauna in January 2019 14

Figure 11: Location of road-killed fauna in January 2019 15

Figure 12: Location of road-killed fauna in January 2019 16

Figure 13: Location of road-killed fauna in January 2019 17

1. Introduction

1.1 Background

In 2015, Roads and Maritime Services (Roads and Maritime) NSW, in conjunction with Acciona Ferrovial Joint Venture (AFJV), commenced the upgrade of the Pacific Highway between Warrell Creek and Nambucca Heads (WC2NH). The WC2NH project was opened to traffic in two stages: stage 2a - 13.5km section from Lower Warrell Creek Bridge to Nambucca Heads opened on 18 December 2017; and stage 2b - 6.25km section from the southern end of the project to the Lower Warrell Creek bridge opened in late June 2018.

The upgrade included a number of roadkill mitigation measures to minimise vehicle collisions with native wildlife. The types of structures constructed to mitigate roadkill included:

- Fauna fencing to exclude fauna from the road corridor and to guide fauna towards connectivity structures.
- Fauna Drop-down Structures (escape ramps) along the fauna fencing.
- Fauna connectivity structures, including underpasses, bridges, rope bridges and glide poles.

Several fauna fence designs were installed to target threatened species including:

- **Type 1** - Chainmesh fence 1.8 m tall with floppy top feature which is designed to exclude a range of native mammal species such as macropods, possums, spotted-tail Quoll (*Dasyurus maculatus*) and koala (*Phascolarctos cinereus*). 18.03 km of this fence type occurs at the site.
- **Type 3** - Small gauge mesh fence with sheet metal return angled away from the highway (combined with fauna floppy top fence) which is designed to exclude green-thighed frog (*Litoria brevipalmata*) from the road corridor. 1.32 km of type 3 fauna fence occurs at the site, overlapping with the type 1 fencing.
- **Type 4** - Chainmesh fence 4 m tall through the Macksville Flying-fox camp Paperbark Swamp Forest community designed to discourage grey-headed flying-fox (*Pteropus poliocephalus*) from flying within range of passing traffic when exiting or entering the roost. 1km of type 4 fence occurs at the site.

Sandpiper Ecological Surveys (SES) has been engaged by Roads and Maritime to deliver the WC2NH operational ecological and water quality monitoring program, which includes seasonal roadkill surveys over the entire upgrade length.

Monitoring of road-killed fauna is a requirement of the approved WC2NH koala (*Phascolarctus cinereus*), spotted-tailed quoll (*Dasyurus maculatus*) and grey-headed flying-fox (*Pteropus poliocephalus*) management plans and the Ecological Monitoring Program (Roads and Maritime 2018a). Priority species for roadkill surveys are grey-headed flying-fox, koala, spotted-tailed quoll, and giant barred frog (*Mixophyes iteratus*). Monitoring is required for the first five years of operation and includes weekly surveys for the first 12 weeks of operation and four surveys (at weekly intervals) each season thereafter. Due to the staged opening of the project, monitoring of stage 2a commenced in December 2017 with monitoring of stage 2b commencing in July 2018. The 12-week monitoring period for stage 2b ended on 30 September 2018 and Sandpiper Ecological commenced seasonal monitoring in October 2018. The results of monitoring in 2018 were analysed and discussed by

Sandpiper Ecological (2018). The following report covers the January (summer) monitoring event and covered the entire WC2NH alignment. Remaining seasonal monitoring events in 2019 are scheduled for April (autumn), July (winter) and October (spring). Previous roadkill monitoring was conducted by Geolink (2018a, b, c, d).

The aim of monitoring is to:

- report on any vertebrate roadkill following opening to traffic; and
- assess the effectiveness of the presence of fauna fencing to prevent fauna being killed by vehicles while attempting to cross the WC2NH Upgrade.

1.2 Study area

The WC2NH project covers a total length of 19.75km and extends from Warrell Creek in the south to Nambucca Heads in the North (Figure 1).

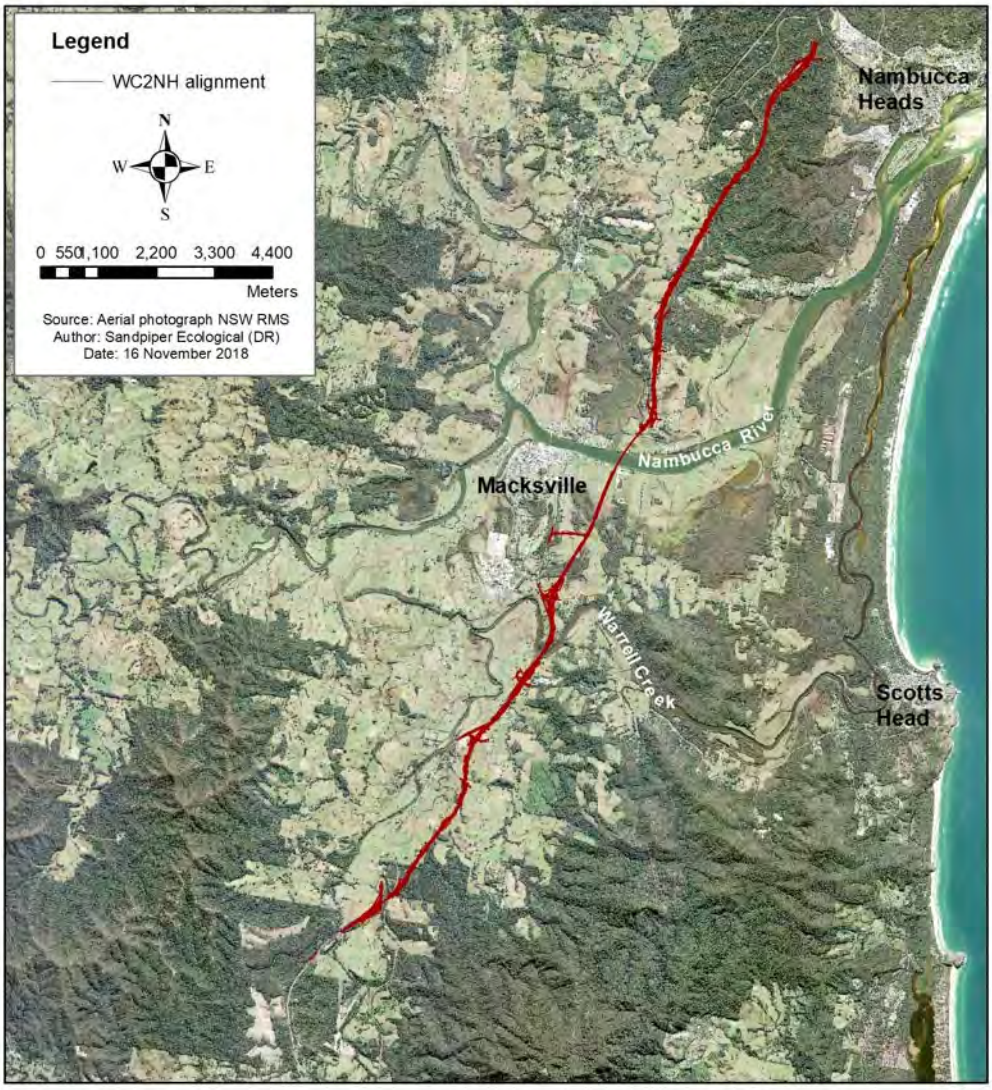


Figure 1: Location of the WC2NH alignment.

2. Methods

2.1 Roadkill surveys

Roadkill surveys were conducted by a two-person team from a vehicle driven at 70km/hr in the left lane with amber (flashing) and hazard lights on. The team consisted of a driver and ecologist with experience identifying road-killed fauna. All surveys commenced within two hours of sunrise, with an interval of seven days between samples. During each survey, both the driver and ecologist scanned the road surface and road shoulder for fauna. When road-killed fauna were detected the vehicle was pulled onto the shoulder/parking bay and the ecologist inspected the subject animal from the closest position behind wire rope and perpendicular to the specimen. Fauna that could not be identified immediately were photographed and images sent to colleagues. Carcasses were removed from the road surface when safe to do so.

Data collected on each roadkill included (Appendix A1):

- Geographic coordinate
- Presence/absence of fauna exclusion fence
- Species/fauna group
- Date of survey
- Roadkill location – north or southbound carriageway

Data collected for threatened species listed on the *Environment Protection and Biodiversity Conservation Act* (EPBC) *1999* and/or the *Biodiversity Conservation Act* (BC) *2016*, included, where possible: sex and age (juvenile/adult); presence of pouch young; presence of flightless young (flying-foxes); distance to a fauna connectivity structure (determined from GIS); distance to a drop-down structure (determined from GIS); damage to fauna fencing; weather conditions; if the animal was a flying-fox – distance to nearest camp, distance to nearest canopy vegetation, and presence of flowering food trees in median or roadside vegetation.

All road-kills were cross referenced with the previous survey results to identify possible duplicates. Using the same team during the survey, GPS coordinates of each specimen, looking at carcass age and location on the carriageway, and detailed location description assisted with identification of duplicates.

Distance to connectivity structure, and distance to drop-down was determined via GIS. All other data were uploaded to an iPad in the field.

2.2 Data summary and analysis

Data from the January 2019 survey were uploaded to Microsoft Excel. The January data were compared with results from October 2018 to identify any duplicate records. Graphs have been produced showing the total number of road-kills in January and the number of road-kills in different fauna groups each week of the survey. The location of January road-kills has been overlaid on the WC2NH alignment to show their distribution. The January 2019 data are compared to the number of road-kills recorded in summer, autumn, winter and spring 2018 (Sandpiper Ecological 2018) (Table 2).

3. Results

3.1 Weather conditions

Weather conditions in the 24hrs preceding each sample were conducive to fauna movement and retention of carcasses on the road surface (Table 1). No rain was recorded during survey days.

Table 1: Weather conditions in the 24hrs preceding each sample event. Data obtained from Envirodata weather station at the southern compound.

Date	Average Relative Humidity (%)	Total Rainfall (mm)	Maximum Temperature (^{0}C)	Average Wind Speed (KPH)	Visibility during survey	Rain during survey
10/1/19	73	0	31.8	3.7	Good	Nil
17/1/19	72.9	0	30.5	14	Good	Nil
24/1/19	71.2	0	36.2	4.2	Good	Nil
31/1/19	70.3	0	31	14.5	Good	Nil

3.2 Species richness and abundance

A total of 57 road-killed fauna were recorded during the January 2019 sample period. This included 19 native species, two introduced species, and seven fauna groups (Table A1, Appendix A). Birds were the most diverse group represented in roadkill with 11 species recorded. Seven species of mammal (including 2 introduced species), and two species of reptile were recorded.

Red-necked wallaby (*Macropus rufogriseus*) and grey-headed flying-fox (*Pteropus poliocephalus*) were the most frequently recorded species with eight records each, followed by black flying-fox (*Pteropus alecto*) with six records (Table 2). Grey-headed flying-fox is listed as vulnerable by the *EPBC Act* 1999 and the *BC Act* 2016. Unidentified mammals accounted for seven records and *Pteropus* spp. accounted for three records. A masked owl (*Tyto novaehollandiae*), which is listed as vulnerable by the *BC Act* 2016, was recorded on the Gumma Floodplain on 10 January 2019. A total of eight target species (all grey-headed flying-foxes) were confirmed during the January 2019 roadkill surveys. It is possible that some of the *Pteropus* spp. records were also grey-headed flying-fox. Of the 57 roadkill records, 17 (or 30%) were individuals expected to be blocked by exclusion fence. The remaining 40 records included birds, snakes, lizards, and small mammals that readily move through or over exclusion fence.

Table 2: Species of vertebrate recorded during seasonal roadkill surveys during the operational phase of the WC2NH upgrade. * denotes threatened species; ** = stage 2a only.

Species	Summer 17/18**	Autumn 2018**	Winter 2018**	Spring 2018	Summer 2019	Total
Birds						
Australian magpie	6	1		1		8
Grey butcherbird			1			1
Magpie-lark	2		1		1	4
Australian white ibis			1			1
Cattle egret				1		1
Little pied cormorant					1	1

Species	Summer 17/18**	Autumn 2018**	Winter 2018**	Spring 2018	Summer 2019	Total
Buff-banded rail					1	1
Purple swamphen	3		2	2		7
Crested pigeon	2					2
Galah	7				1	8
Eastern grass owl*				1		1
Southern boobook			1	1		2
Masked owl*	1				1	2
Barn owl			11	3		14
Tawny frogmouth	1	3	1	2		7
Owlet-nightjar					1	1
Laughing kookaburra	3		2	1		6
Forest kingfisher	1					1
Australian wood duck	20			2	2	24
Pacific black duck	2		1			3
Whistling kite				1		1
Black-shouldered kite					1	1
Toressian crow					1	1
Pied currawong				1		1
Dollarbird					1	1
Green catbird					1	1
Medium bird				1	2	3
Unidentifiable bird	5	4	1		3	13
Mammals						
Short-beaked echidna				3		3
Black flying-fox	2	1			6	9
Grey-headed flying-fox*					8	8
Pteropus spp.					3	3
Common brushtail possum			1	2		3
Common ringtail possum					1	1
Eastern grey kangaroo				3		3
Red-necked wallaby	1		6		8	15
Swamp wallaby	2	1		1		4
Macropod spp	3		2	1	1	7
Northern brown bandicoot	1		1		1	3
Wattled bat spp.				1		1
Microbat spp.					1	1
Small mammal					2	2
Medium mammal				2	4	6
Large mammal				1	1	2
Unidentified Mammal	1			3		4
Reptiles						
Common blue-tongue skink	1			2	1	4
Carpet python	1			2	1	4

Species	Summer 17/18**	Autumn 2018**	Winter 2018**	Spring 2018	Summer 2019	Total
Common tree snake	1	2				3
Eastern long-neck turtle	1			6		7
Macleay river turtle	5	1				6
Unidentified Chelidae (turtle) spp.	6					6
Red-bellied black snake	1					1
Eastern water dragon	1			1		2
Yellow-faced whipsnake				1		1
Frogs						
Green tree frog	2					2
Striped marsh frog	3					3
Medium frog				3		3
Large frog				1		1
Introduced species						
Cat	1					1
European fox	3	1	1	2	1	8
European hare	2			1		3
Rabbit	1					1
Black rat	1					1
House mouse					1	1
Rock pigeon			1	1		2
Domestic goose				1		1
Total	93	14	34	55	57	253

The number of roadkill recorded each week varied during the sample period. A trend of decreasing roadkill abundance was recorded over the first three sample weeks, with roadkill abundance remaining stable in weeks three and four (Figure 2).

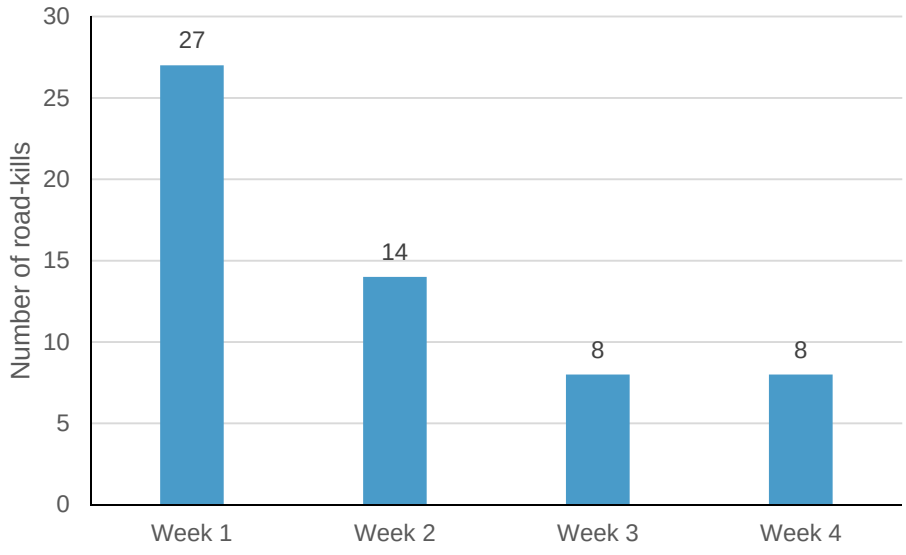


Figure 2: Number of road-kills recorded in each sample week during the January 2019 (summer) sample period.

The abundance of road-killed fauna in the four vertebrate groups varied during the sample period (Figure 3). The number of road-killed mammals went from 17 in week one to nine in week two, eight in week three and five in week four. Likewise, the number of road-killed birds decreased from eight in week one to four in week two and none in week three and back up to three in week four. Reptiles were only represented by one kill in week one and one in week two. No frogs were detected during January 2019 monitoring.

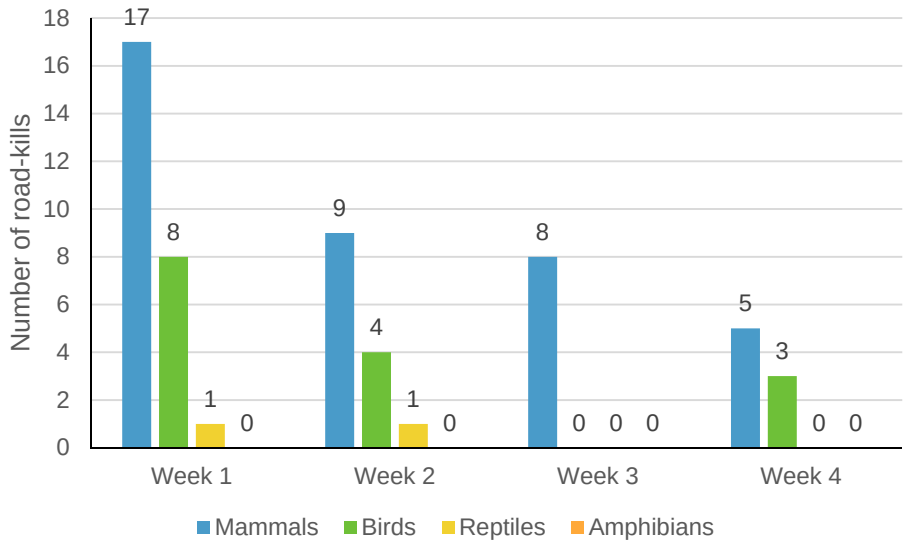


Figure 3: Number of road-killed fauna from four vertebrate classes during each sample week in January 2019.

3.1.3 Opportunistic roadkill information

A single Gould's wattled bat (*Chalinolobus gouldii*) was recorded road-killed as it flew into a company car window on the evening of 21 January 2019 (D. Rohweder pers obs). Driving southbound over the Nambucca River bridge the bat clipped the driver's side window sill and fell into the vehicle.

3.1.4 Distribution of roadkill

In January 2019, road-killed fauna was recorded over the entire WC2NH alignment (Figures 4-13), although the majority of records (93%) were situated between the Nambucca River and the southern end of the project. Within that area, 62% occurred between Albert Drive and the Nambucca River bridge (Figures 8-11) and the remaining 38% occurred between the southern end and Albert Drive (Figures 11-13). The section between the Nambucca River and the southern end of the project traverses predominantly cleared land with three drainage lines and minimal fauna exclusion fence. Four animals (7%) were recorded in the section north of the Nambucca River bridge. Notably, this northern section is entirely fenced with floppy top exclusion fence and in places, frog exclusion fence.

In January 2019, 17 road-kills were recorded in areas with exclusion fence, and 40 were recorded in areas without exclusion fence (Figures 4-13). Two records (or 11.7%) in sections with fence were species that should have been blocked by the fence (i.e. medium and large mammals & medium and large reptiles). In contrast, 35% of road-kills in sections without fence were of species that should have been blocked by an exclusion fence.

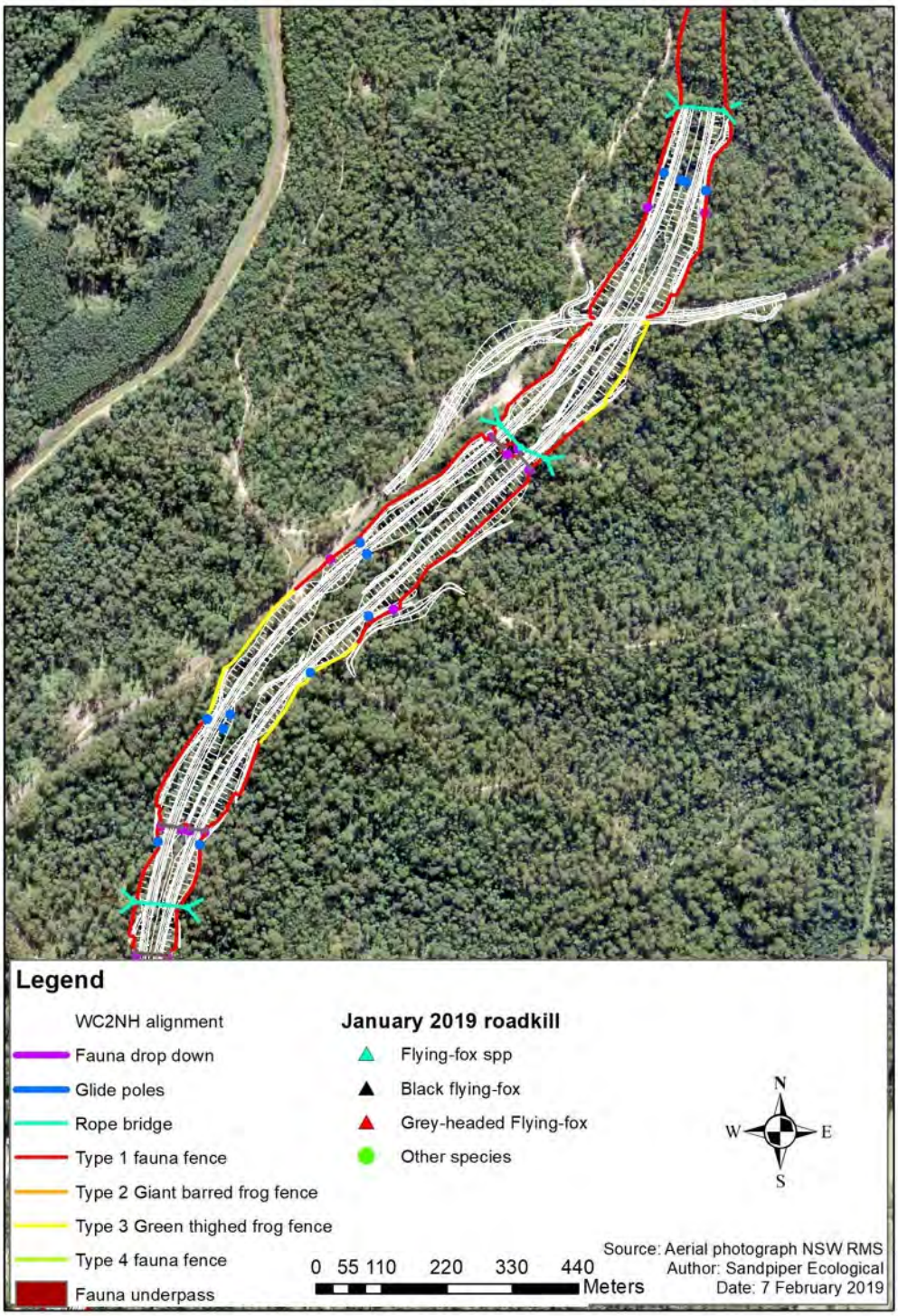


Figure 4: Location of road-killed fauna in January 2019.

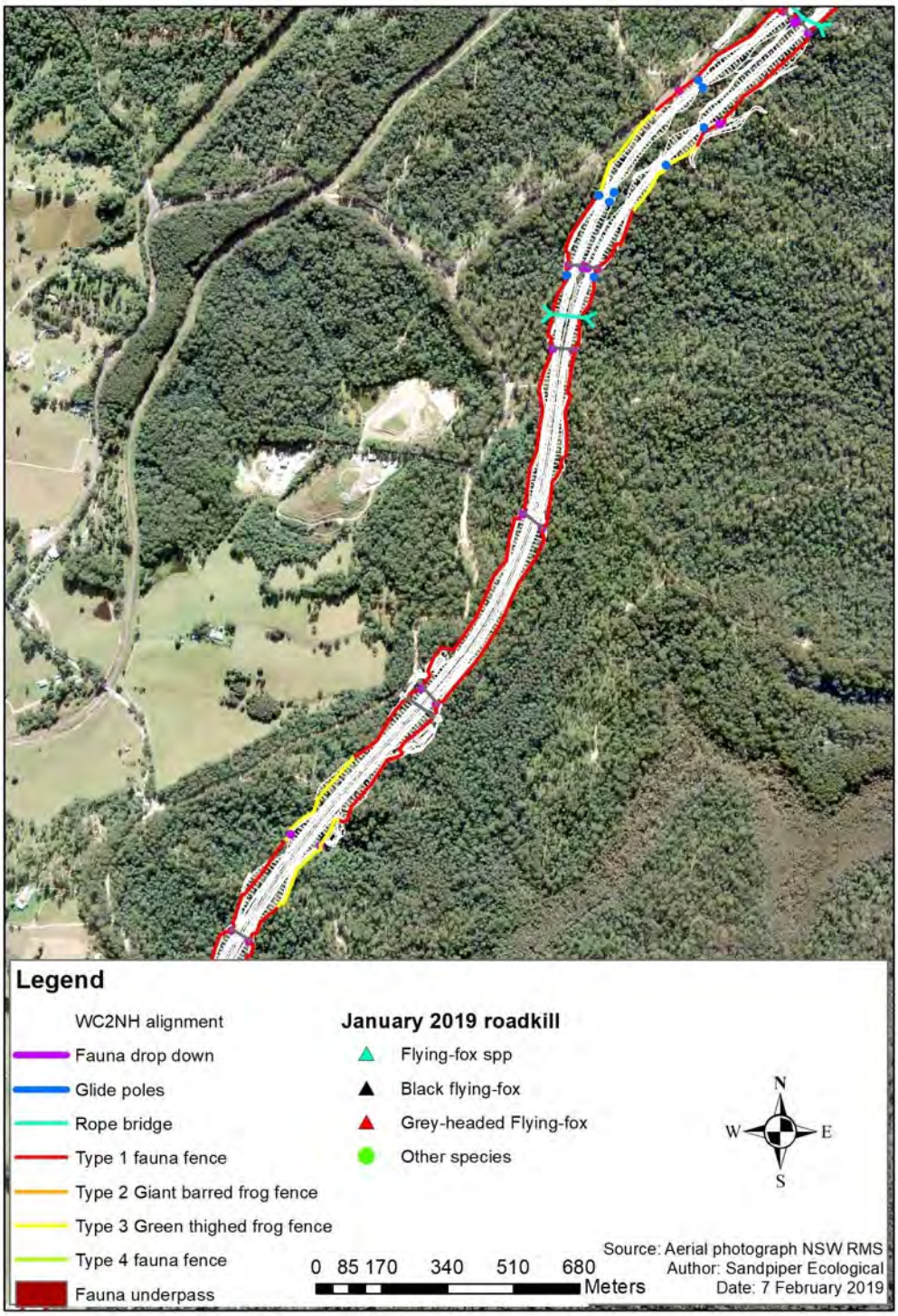


Figure 5: Location of road-killed fauna in January 2019**.**

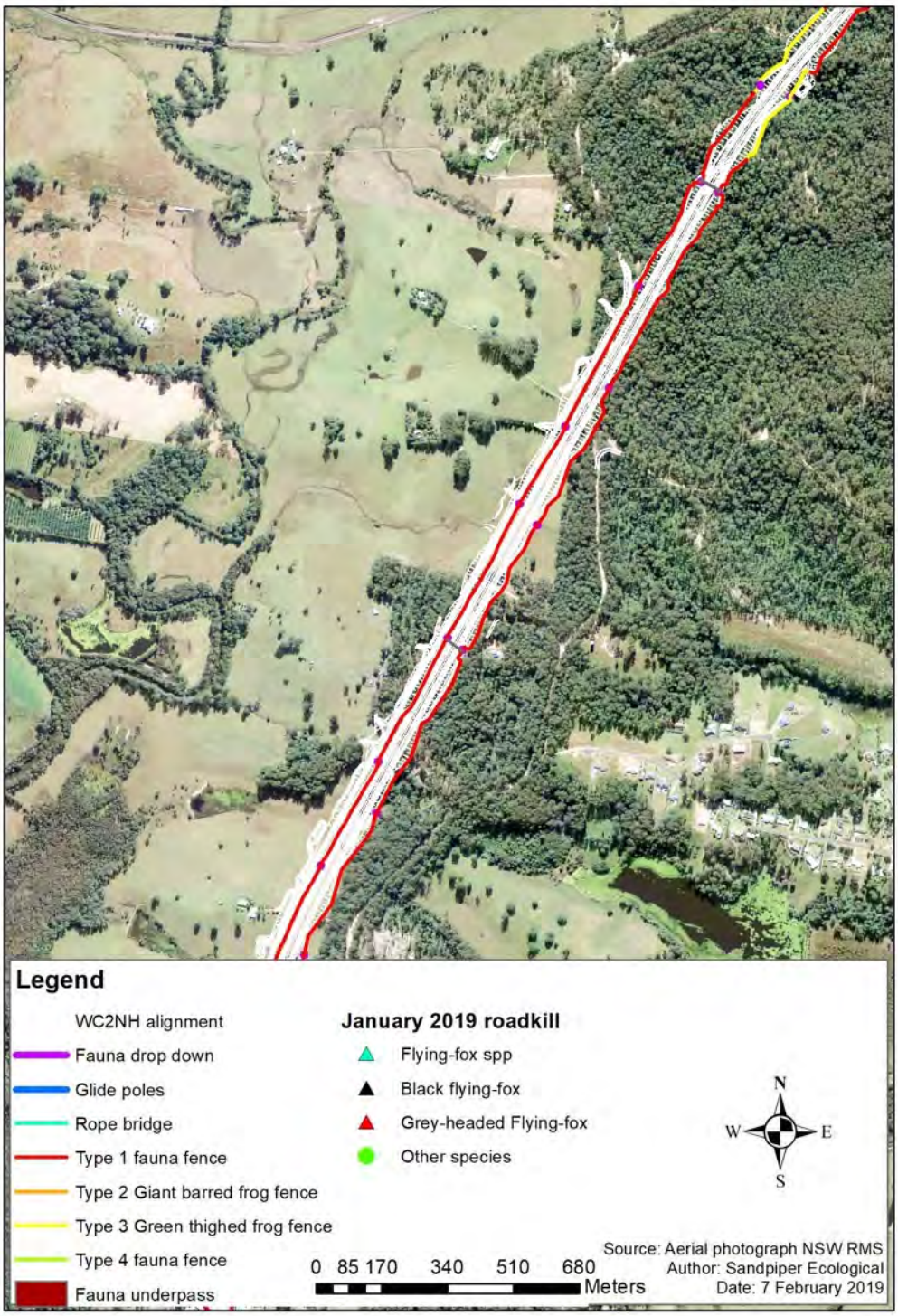


Figure 6: Location of road-killed fauna in January 2019.

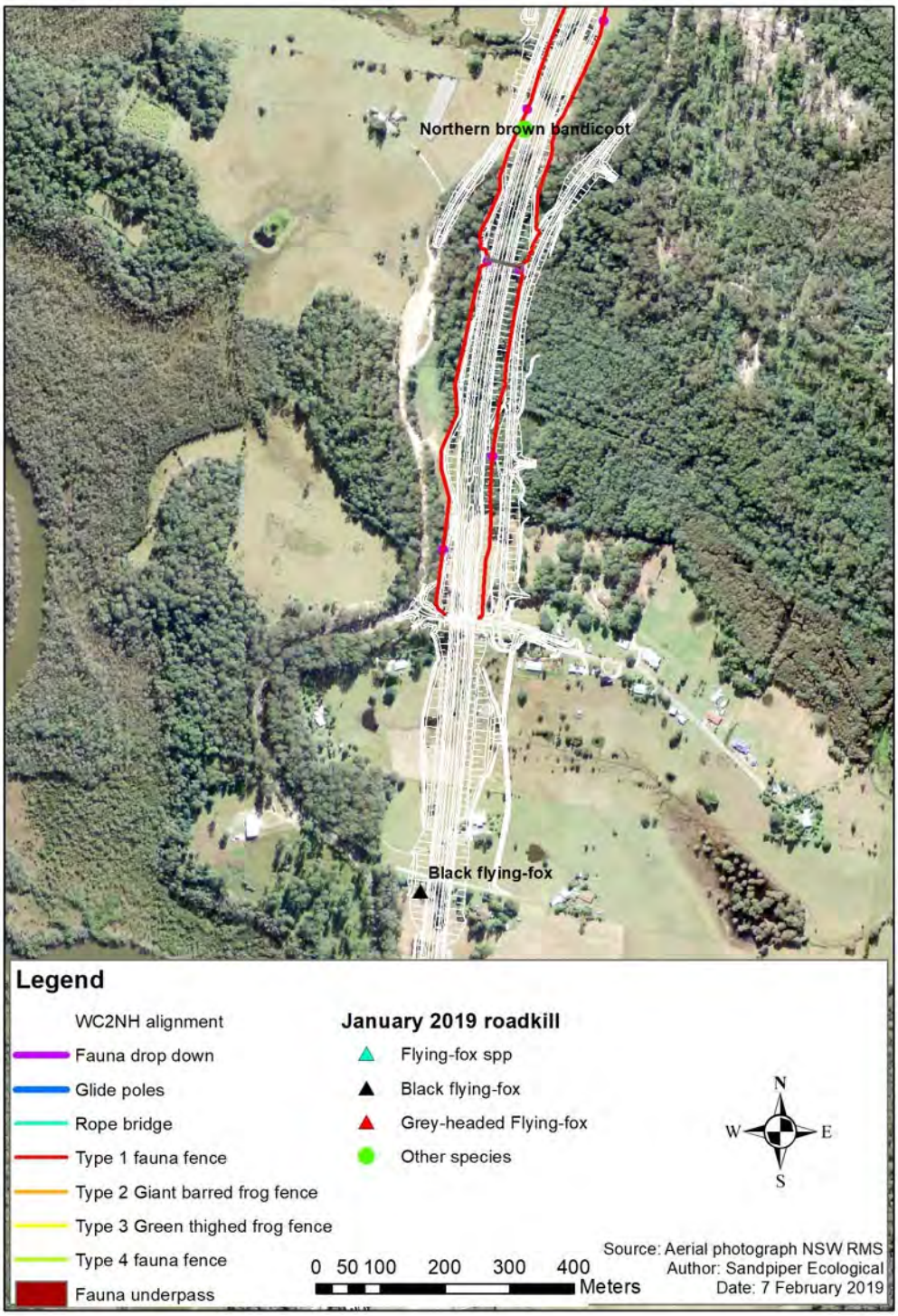


Figure 7: Location of road-killed fauna in January 2019.

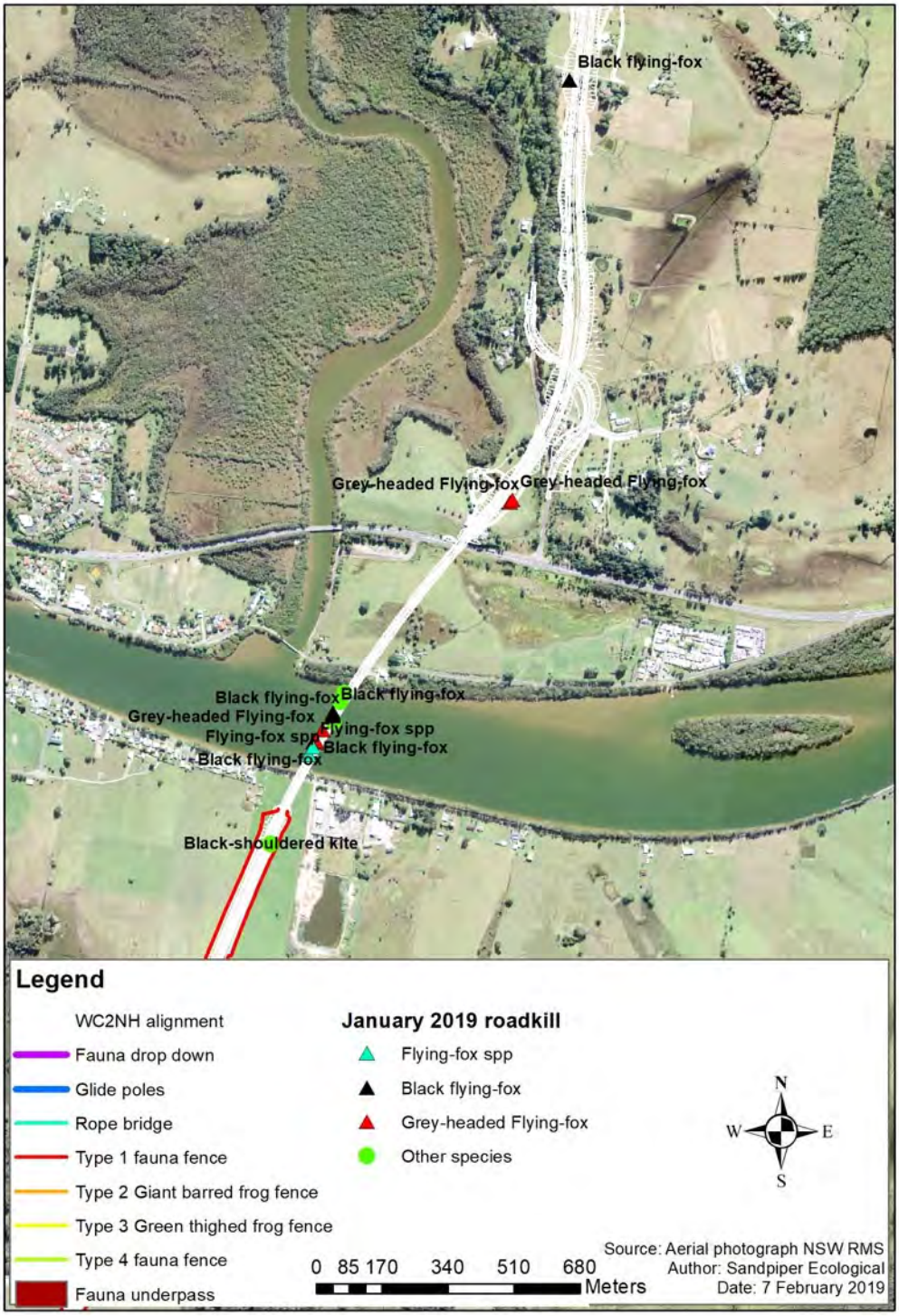


Figure 8: Location of road-killed fauna in January 2019.

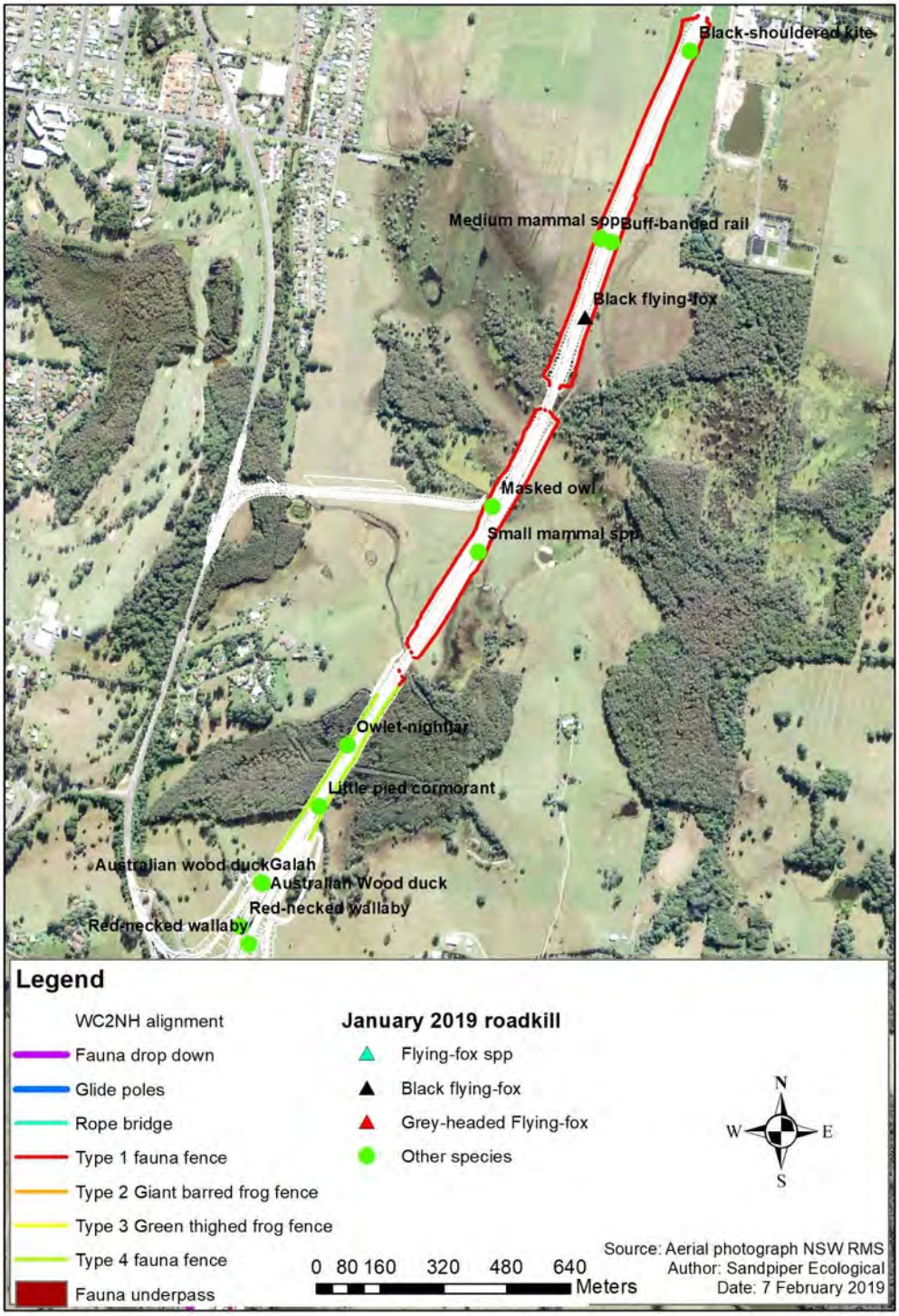


Figure 9: Location of road-killed fauna in January 2019.

.

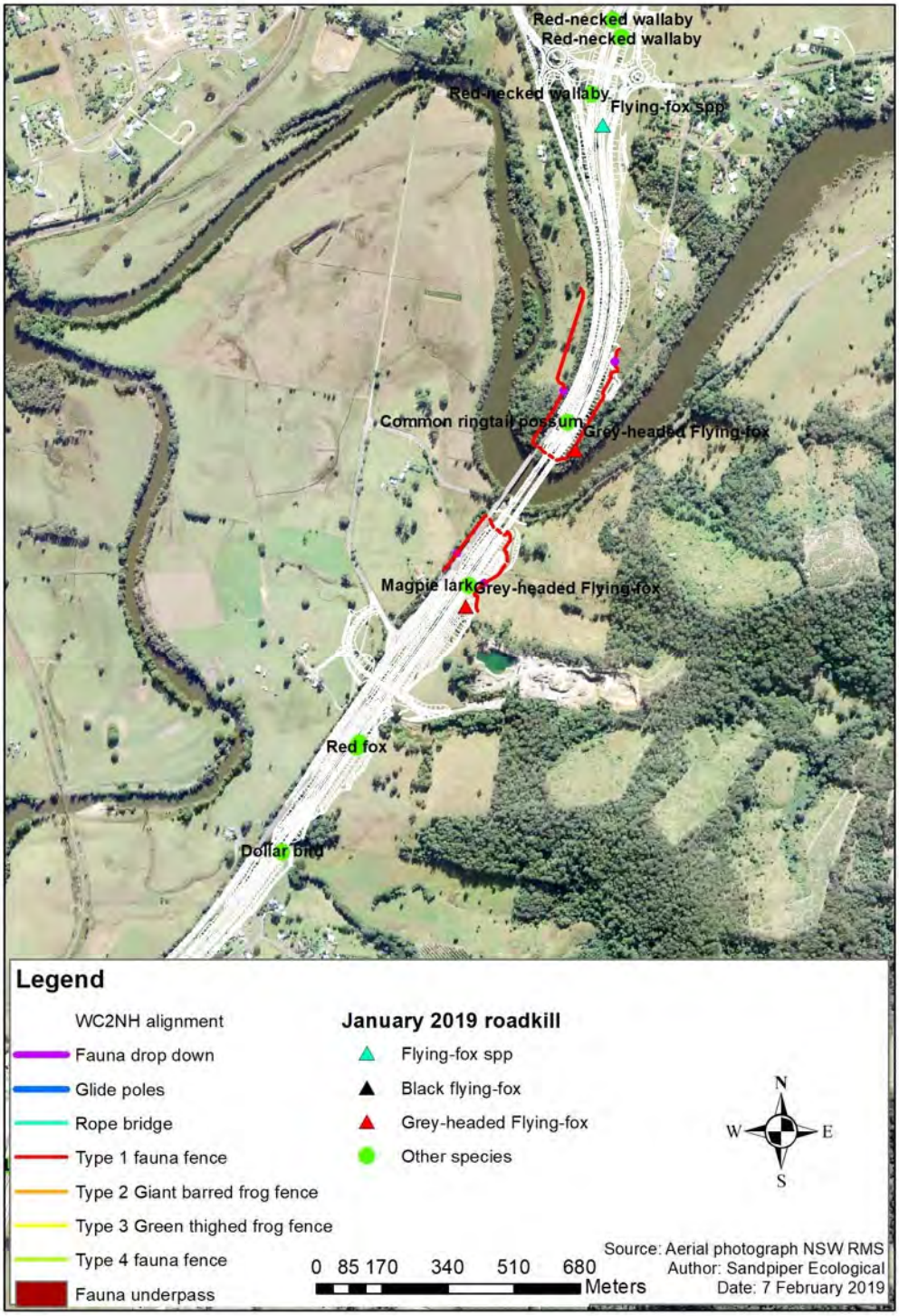


Figure 10: Location of road-killed fauna in January 2019.

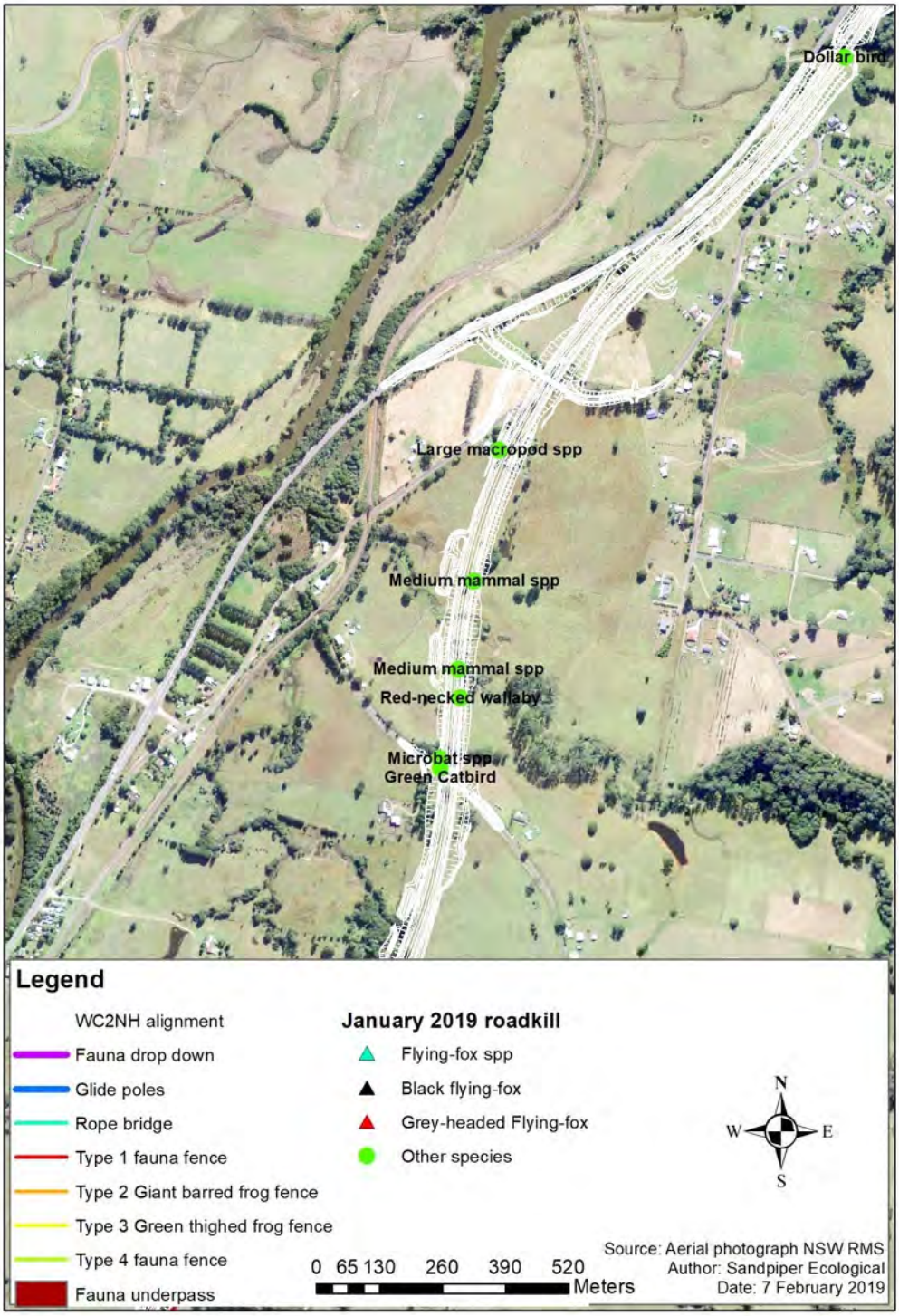


Figure 11: Location of road-killed fauna in January 2019.

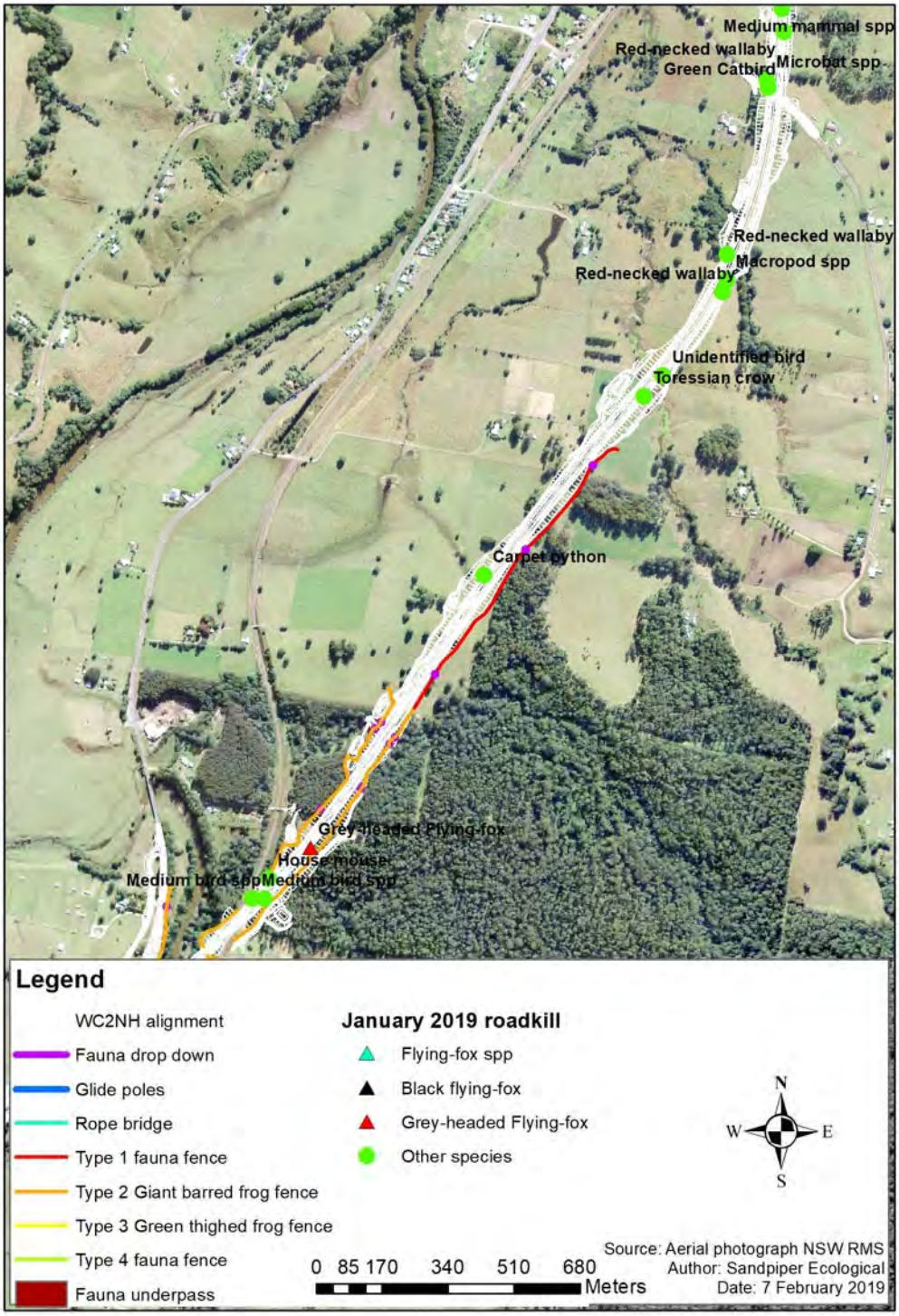


Figure 12: Location of road-killed fauna in January 2019.

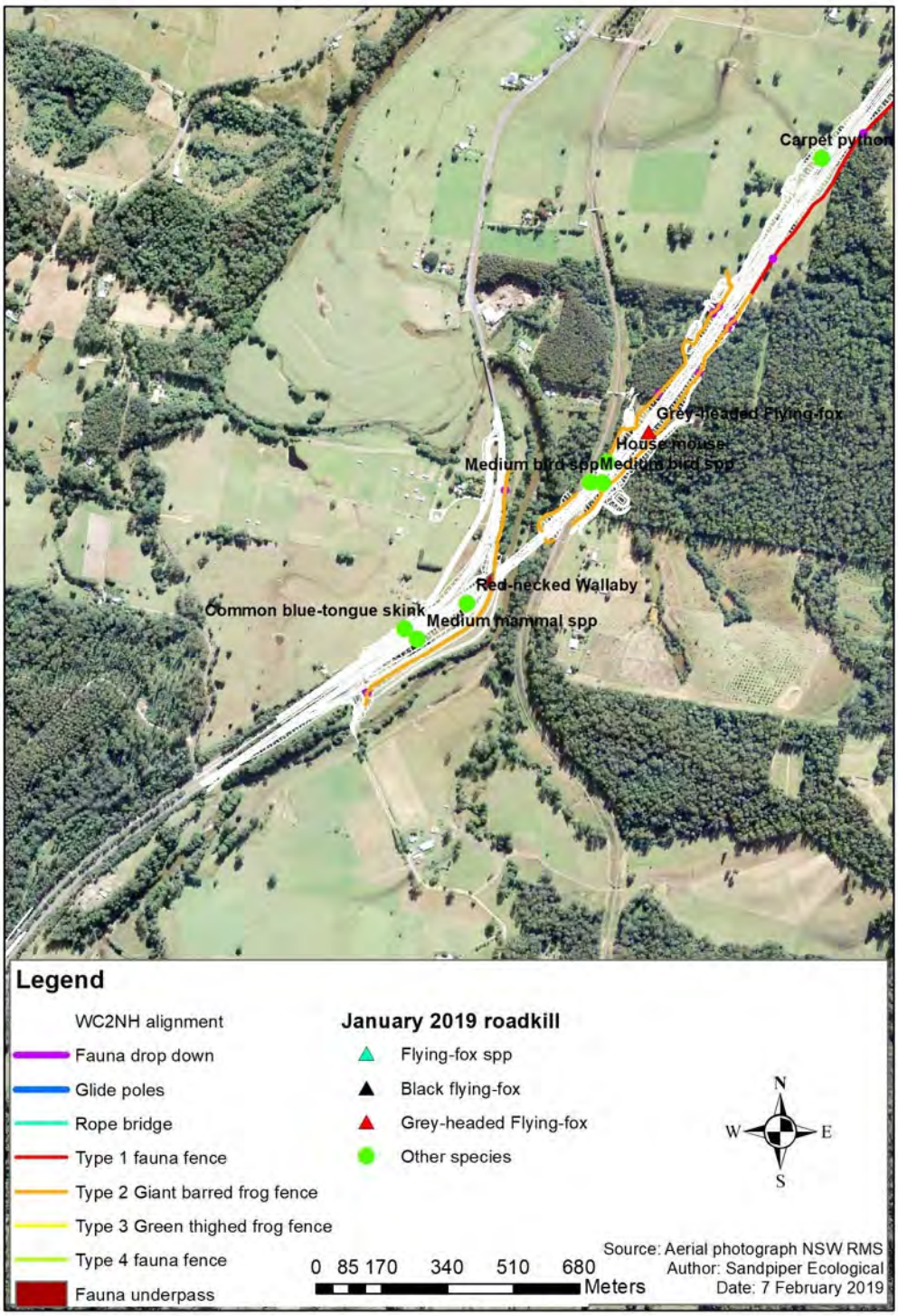


Figure 13: Location of road-killed fauna in January 2019.

4. Discussion

4.1 January 2019

Road-kill monitoring over the entire WC2NH alignment in January indicates that a substantial number of fauna continue to be killed by vehicles seven months after the entire alignment was open to traffic. With a total of 57 animals killed, January 2019 monitoring recorded an increase of 10 animals killed when compared to October 2018. An increase in road kills may be attributable to a number of factors including increased traffic over the summer holiday period and seasonal changes in animal behaviour (see section 4.2). A positive correlation has been recorded between traffic volume and the number of animals struck by vehicles (Jacobson *et al* 2016).

The increase in road-kills recorded in January may be bolstered by the time between samples. The October 2018 sample was conducted immediately after the conclusion of GeoLink monitoring in September. January 2019 monitoring was conducted after two months (November & December) of no monitoring. The higher number of road-kills recorded in the first January 2019 sample reflects the period over which samples could accumulate. This trend is likely to occur in all seasonal sample periods and it means that the number of road-kills recorded during a month overestimates the actual number of animals killed in that month.

Similar diversity and species composition of roadkill was recorded between January 2019 and October 2018 and Stage 2A monitoring, which occurred in summer/autumn 2017/18 (Geolink 2018a). Roadkill hotspots identified in January include the Gumma Floodplain (Albert Drive to Nambucca River bridge), and from the southern end to Albert Drive. This finding is consistent with findings in the annual roadkill report (Sandpiper Ecological 2018). Birds and mammals comprised the majority of road-kills in both locations.

4.2 Seasonal variation and species composition

The observed pattern of increased road-kill in spring and summer is not surprising as fauna tend to be more mobile during the spring/summer period when most species breed and disperse. Geolink (2018a) highlighted the possible influence of grass seeding close to the highway at the time of opening to traffic on galah and wood duck roadkill. Results in October and January have shown a decrease in galah, and wood duck roadkill, which supports the suggestion that grass seeding attracted these species to the road. The absence of freshwater turtles in the January 2019 sample corresponds with the drying of roadside waterbodies and lends support to the suggestion that turtles may have been residing within the road corridor rather than moving through the fence (Geolink 2018a). Nonetheless, this will not be confirmed until sampling occurs during the next turtle breeding season when the species become more mobile.

Red-necked wallabies may also be attracted to freshly sown grass on the highway verge, possibly explaining the high incidence of wallaby road-kill. Results of monitoring in October 2018 and January 2019 raise concerns about the effect of roadkill on the local red-necked wallaby population in the Albert Drive to upper Warrell Creek area. Continued roadkill at present rates is likely to reduce the abundance of wallabies in habitat adjoining the road (Huijser & Bergers 2000).

January monitoring detected no road-killed frogs. Along with the difficulty in detected frogs via a vehicle this decrease may also be explained by climatic conditions which have not been conducive for

frog dispersal. The projects' southern compound weather station recorded only 6.4mm of rain over three rain days in January 2019.

Second to mammals, birds were the most impacted group of fauna. This highlights the susceptibility of the group to road-kill. The composition of birds in roadkill is predicted to change over time as larger species habituate to, and avoid, the highway and small birds take up residence on revegetated batters making some cover-dependant species more susceptible to road strike. Nonetheless, the results provide further evidence of the impact that roads have on bird populations (Husby 2016). Of particular concern is the impact on threatened species such as masked owl (Loss *et al.* 2014). The January 2019 record was the second masked owl road-kill since monitoring began.

4.3 Flying-fox impacts

A total of 18 flying-foxes were detected during January monitoring. Of these, eight were grey-headed flying-fox, seven were black flying-fox and three were unidentified *Pteropus* spp. Grey-headed flying-fox is listed as a vulnerable species by the *EPBC Act* and *BC Act*. Twelve of the 18 individuals were recorded on the Nambucca River bridge. As it is unsafe to stop or walk on the bridge none of these individuals could be examined for young, and no young were recorded with any of the adults that could be assessed. Five black flying-fox and one grey-headed flying-fox were deemed to be juveniles based on size. February corresponds with the approximate time when black and grey-headed flying-foxes become independent and begin to leave camps to forage (Australian Museum 2019; Department of the Environment 2019). It is possible that juveniles comprised a larger proportion of individuals than was recorded due to the inability to closely inspect several individuals. Juvenile bats are likely to be more susceptible to road strike as they tend to be less agile flyers and unfamiliar with their surroundings.

The direct distance to the nearest flying-fox camp, Gordon Park in Nambucca Heads, is approximately 9.8km from the Nambucca River bridge. Road-killed grey-headed flying foxes were also recorded north and south of Warrell Creek and south of upper Warrell Creek. During summer, flying-foxes often use waterways during their evening dispersal. As they fly along larger creeks and rivers individuals often drag their undersides in the water as a means of cooling themselves (Vardon *et al* 2001). The high incidence of flying-fox roadkill close to major river/creek crossings along the WC2NH upgrade is attributed to individuals flying low over the water and then trying to fly over the bridge but not gaining sufficient elevation. This is thought to be a seasonal impact and may reduce as the camp disperses and temperatures decline.

There was very little evidence of flowering or fruiting trees in proximity to roadkilled flying foxes. Whilst some blackbutt (*Eucalyptus pilularis*) trees were flowering in late January these were patchily distributed. The absence of food trees close to the highway further highlights the association between waterbodies and roadkill.

5. Recommendations

1. Continue seasonal roadkill surveys during year two of the operational phase using the same methods applied in year one.
2. Continue to monitor the distribution and frequency of flying-fox road kills.
3. Explore correlations between drop-downs and the distribution of target species in the year two annual report.

6. References

Australian Museum (2019). *Black flying-fox (Pteropus alecto).* https://australianmuseum.net.au/learn/animals/mammals/black-flying-fox/

Department of the Environment (2019). *Pteropus poliocephalus* in Species profile and threats database, Department of the Environment, Canberra. Available from http://www.environment.gov.au/sprat.

Geolink (2018a). *Roadkill monitoring report: WC2NH Stage 2A*. Report prepared for NSW Roads and Maritime Services.

Geolink (2018b). *Roadkill monitoring summary report: autumn (April) 2018*. Letter report prepared for NSW Roads and Maritime Services.

Geolink (2018c). *Roadkill monitoring summary report: winter (July) 2018*. Letter report prepared for NSW Roads and Maritime Services.

Geolink (2018d). *Roadkill monitoring report - initial 12 weeks WC2NH Stage 2B*. Report prepared for NSW Roads and Maritime Services.

Huijser, M. P. & Bergers, P. J. M. (2000) The effect of roads and traffic on hedgehog (Erinaceus europaeus) populations. *Biological Conservation*. 95, (1), 111-116.

Husby, M. (2016). Factors affecting road mortality in birds. *Ornis Fennica*, 93 (4), 212-224.

Jacobson, S. L., Bliss-Ketchum, L. L., de Rivera, C. E. & Smith, W. P. (2016). A behavior-based framework for assessing barrier effects to wildlife from vehicle traffic volume. *Ecosphere*, 7 (4).

Loss, S. R., Will, T., & Marra, P. P. (2014). Estimation of bird-vehicle collision mortality on U.S. roads. *The Journal of Wildlife Management:* https://doi.org/10.1002/jwmg.721

Roads and Maritime (2018). *Warrell Creek to Nambucca Heads Stage 2 Ecological Monitoring Program*. Report prepared by NSW Roads and Maritime Services.

Sandpiper Ecological (2018). *Pacific Highway Upgrade, Warrell Creek to Nambucca Heads: operational phase roadkill monitoring – annual report 2018*. Report prepared for NSW Roads and Maritime Services.

Vardon, M. J., Brocklehurst, P. S., Woinarski, J, C. Z. & Cunningham, R. B. (2001). Seasonal habitat use by flying-foxes, *Pteropus alecto* and *P. scapulatus* (Megachiroptera), in monsoonal Australia. *Journal of Zoology*, 253 (4), 523-535.

Appendix A – Field Survey Data

Table A1: January (summer) 2019 roadkill results. DR = David Rohweder; LA = Luke Andrews; NP = Nick Priest; NB = northbound; SB = southbound, Y = yes, N = no, prox = proximity, xing = crossing, cond. = condition; * Gordon Park, Nambucca Heads

Date	Obs	Start time	End time	Carriage way	Species	Sex & age class	Presence of pouch or back young	RK general location	RK easting	RK northing	Cleared off Rd?	Fauna fence & prox.	Fence cond.	Prox. to crossing structure	Prox. to drop-down	If Fly-fox, prox. to camp*; canopy vegt & food
10/1/2019	DR & LA	0650	1130	SB	Small mammal spp.	Adult	NA	Nambucca River bridge	493814	6602762	N	A	NA	2700m		
				SB	Black flying fox	Juvenile	Nil	Gumma floodplain	493359	6601705	Y	P	Good	110m	100m	11km; 130m; >1km
				SB	Small mammal spp.	Adult	NA	Gumma floodplain	493091	6601115	N	P	Good	200m	250m	
				SB	Little pied cormorant	Adult	NA	Gumma floodplain	492691	6600473	Y	P	Good		50m	
				SB	Red-necked wallaby	Adult	Nil	Bald Hill Road	492514	6600128	N	A	NA		NA	
				SB	Magpie-lark	Adult	NA	Sth Warrell Creek	492121	6598716	Y	P – east side	Good	100m		
				SB	Red-necked wallaby	Adult	Nil	100m nth Bald Hill Rd	491839	6598308	N	A	NA			
				SB	Red fox	Adult	NA	100m nth Bald Hill Rd	491831	6598297	N	A	NA			
				SB	Dollarbird	Adult	NA	Williamson's Ck bridge	491639	6598028	N	A	NA			
				SB	Mammal spp. (poss Bandicoot)	Adult	Nil	400m nth rosewood rd	490875	6596949	N	A	NA			
				SB	Macropod spp.	Adult	Nil	400m Sth Rosewood rd	490701	6596066	N	A	NA			
				SB	Red-necked	Adult	Nil	450m Sth	490689	6596035	N	A	NA			

Date	Obs	Start time	End time	Carriage way	Species	Sex & age class	Presence of pouch or back young	RK general location	RK easting	RK northing	Cleared off Rd?	Fauna fence & prox.	Fence cond.	Prox. to crossing structure	Prox. to drop-down	If Fly-fox, prox. to camp*; canopy vegt & food
					wallaby			Rosewood Rd								
				SB	Unidentifiable bird	Unknown	NA	Rosewood Creek	490535	6595820	N	A	NA			
				SB	Toressian Crow (poss)	Adult	NA	Rosewood Creek	490486	6595766	N	A	NA			
				SB	Undentified bird (medium)	Unknown	NA	Railway overpass	489508	6594470	N	P	Good	50m		
				SB	Medium mammal (poss hare)	Adult	UK	Sth Upper Warrell Creek	489031	6594066	N	P	Good	100m		
				NB	House mouse	Adult	NA	Nth Upper Warrell Creek	489519	6594522	N	P	Good	150m		
				NB	Unid bird (medium)	Unknown	NA	Railway	489478	6594471	N	P	Good	100m		
				NB	Carpet python	Adult	NA	500m nth Butchers Creek	490074	6595306	Y	A	NA	500m		
				NB	Red-necked wallaby	Adult	Nil	Sth Rosewood Rd	490700	6596132	N	A	NA			
				NB	Large mammal (macropod)	Unknown	Nil	Albert Drive	490927	6597219	N	A	NA			
				NB	Common ringtail possum	Juvenile	Nil	Nth Albert Drive	492375	6599137	N	A	NA			
				NB	Red-necked wallaby	Adult	Nil	Bald Hill Rd	492438	6599982	N	A	NA			
				NB	Red-necked wallaby	Adult	Nil	Bald Hill Rd	492492	6600172	N	A	NA			
				NB	Masked owl	Adult	NA	Gumma floodplain	493127	6601230	N	P	Good	150m		

Date	Obs	Start time	End time	Carriage way	Species	Sex & age class	Presence of pouch or back young	RK general location	RK easting	RK northing	Cleared off Rd?	Fauna fence & prox.	Fence cond.	Prox. to crossing structure	Prox. to drop-down	If Fly-fox, prox. to camp*; canopy vegt & food
				NB	Medium mammal spp.	Unknown	NA	Gumma floodplain	493399	6601903	N	P	Good			
				NB	Unidentifiable animal	Unknown	NA	Nambucca River bridge	493803	6602741	N	A	NA	2700m		
17/1/2019	DR & LA	0745	1100	SB	Black flying-fox x 3	Juveniles	NA	Nambucca River bridge	493784	6602708	N	P	Good	NA	NA	10km; 250m; >1km
				SB	Grey-headed flying-fox	Juvenile	UK	Nambucca River bridge	493758	6602667	N	P	Good	NA	NA	10km; 250m; >1km
				SB	Red-necked wallaby	Adult	Nil	100m nth Rosewood road	490847	6596706	N	A	NA		NA	
				SB	Red-necked Wallaby	Adult	Nil	50m nth Warrell Creek	489159	6594159	N	P	Good	100m		
				NB	Green catbird	Adult	NA	Rosewood Rd bridge	490806	6596561	Y	A	NA		NA	
				NB	Microbat spp.	Adult	Nil	Rosewood Rd bridge	490804	6596581	Y	A	NA		NA	
				NB	Aust wood duck	Adult	NA	Nth Bald Hill Road	492545	6600281	N	A	NA		NA	
				NB	Galah	Adult	NA	Nth Bald Hill Road	492545	6600281	N	A	NA		NA	
				NB	Owlet-nightjar	Adult	NA	300m nth Bald Hill Road/ Gumma flood plain	492762	6600628	Y	P	Good	250m	100m	
				NB	Black flying-fox x 2	Juvenile	NA	Nambucca River	493708	6602642	N	A	NA	NA	NA	10km; 250m; >1km
				NB	Common blue-tongue skink	Adult	NA	Nth end project	497469	6610816	Y	P	Good			

Date	Obs	Start time	End time	Carriage way	Species	Sex & age class	Presence of pouch or back young	RK general location	RK easting	RK northing	Cleared off Rd?	Fauna fence & prox.	Fence cond.	Prox. to crossing structure	Prox. to drop-down	If Fly-fox, prox. to camp*; canopy vegt & food
				SB	Flying fox spp.	Unknown	UK	Nambucca River bridge	493722	6602603	N	P	Good	NA	NA	10km; 250m; >1km
24/1/2019	NP & LA	0750	0930	SB	Flying Fox spp.	Unknown	Nil	100 m s Bald hill road	492466	6599901	N	A		NA	NA	13km; 100m; none recorded
				SB	Medium mammal	Unknown	Nil	200 m N RoseWood Rd Bridge	490843	6596765	No	A				
				NB	Grey-headed flying fox	Adult	Nil	Cockburns Bridge	489627	6594601	No	A				18km; 50m; >1km
				NB	Grey-headed flying fox	Adult	Nil	150m sth Warrell Creek	492113	6598661	N	A	Good	No	Na	14km; 320m; >1km
				NB	Grey-headed flying fox	Adult	Nil	Lower Warrell Creek Bridge	492396	6599065	N	A				19km; 30m; none recorded
				NB	Grey-headed flying fox x 2	Adult	UK	Nambucca river bridge	494254	6603250	No	A				10km; 250m; >1km
				NB	Aus wood duck	Adult	Na	150m nth Bald Hill Rd	492549	6600280	No	A	Na	300m	150m	
31/1/2019	DR & SR	0715	1000	NB	Grey-headed flying fox x 2	Adult	UK	Nambucca River bridge	493741	6602634	No	A	Na	Na	Na	10km; 250m; >1km
				NB	Black flying-fox	Adult	Nil	420m Sth Mattick Rd	494394	6604343	No	A	Na	Na	Na	8.3km; 70m; none recorded
				NB	Northern brown bandicoot	Sub-adult	Nil	769m nth Mattick Rd	494555	6605523	No	P	Good	150m		
				SB	Flying-fox spp.	Adult	Nil	Nambucca river bridge	493732	6602624	No	A	Na	Na	Na	10km; 250m; >1km
				SB	Black-shouldered kite	Adult	NA	50m Sth Nambucca River bridge	493623	6602374	Yes	P	Good	100m	5m	

Date	Obs	Start time	End time	Carriage way	Species	Sex & age class	Presence of pouch or back young	RK general location	RK easting	RK northing	Cleared off Rd?	Fauna fence & prox.	Fence cond.	Prox. to crossing structure	Prox. to drop-down	If Fly-fox, prox. to camp*; canopy vegt & food
				SB	Buff-banded rail	Adult	NA	720m Sth Nambucca river	493426	6601894	Yes	P	Good	300m		

Appendix I Landscape Monitoring

MEMORANDUM

WC2NH PACIFIC HIGHWAY UPGRADE

Date 28th February 2018

Subject Summer Landscape Monitoring Summary 2018

Background and Scope

Landscape monitoring was undertaken by the Pacifico Environment Team on the 27th of February 2018. Landscape monitoring is required quarterly during Year 3 of construction in accordance with the Ecological Monitoring Program (EMP) and the Urban Design and Landscape Plan (UDLP). The purpose of the monitoring is to determine if the objectives of the UDLP have been met and whether any maintenance/management measures are required. The UDLP also requires monthly photo points to be taken of the landscape monitoring sites to track the progress. The photographs collected during the previous quarter are attached in Appendix A of this memorandum.

The landscape monitoring scope was originally determined by Geolink to cover the RMS Specification, UDLP and EMP requirements. Upon review of the scope provided by Geolink, Pacifico have devised a brief checklist which covers the general requirements of the monitoring scope. The completed checklist for each of the monitoring locations is provided in Appendix B of this memorandum.

The landscape monitoring scope includes 12 monitoring sites that have been determined across the Project. Monthly photo points are taken for each of the monitoring locations. A 50m transect is walked each quarter and the checklists attached in Appendix B are completed for each transect.

Results

The Pacifico Environment Team undertook a review of the monitoring sites on the 27th of February 2018 in order to determine if the objectives in the UDLP were being achieved.

Monitoring Site no.	Location	General Cover %	% of cover = native species	General plant health	Condition of soil and batter	Maintenance Comments	Compliance with UDLP objectives
1	Fill 4 East	95	20	Good	Good – no evidence of rilling or slumping	Nil – Weed's appear well managed. Seteria grass most common species present due to presence in nearby pasture. Batter meets the objectives of the UDLP as the batter assimilates with the surrounding landscape. Batter is stable with good robust growth. Annual Ragweed was noted within verge topsoiled areas with treatment undertaken 23/2/2018.	SM1 mix (Native grasses) Although there is mostly Setaria grass present, the batter has assimilated with the surrounding landscape.
2	Fill 4 West	95	15	Good	Good – no evidence of rilling or slumping	Nil – Weed's appear well managed. Setaria grass most common species present due to presence in nearby pasture. Batter meets the objectives of the UDLP as the batter assimilates with the surrounding landscape. Batter is stable with good robust growth. Annual Ragweed was noted within verge topsoiled areas with treatment undertaken 23/2/2018.	SM2 mix (Native Pasture grasses) Although there is mostly Setaria grass present, the batter has assimilated with the surrounding landscape.
3	Cut 2 East	95	10	Good	Good – no evidence of	Setaria grass most common species present due to nearby pasture. Native shrub species are emerging and growing.	SM3 mix (Native shrub mix). Good compliance, shrub growth is improving

Monitoring Site no.	Location	General Cover %	% of cover = native species	General plant health	Condition of soil and batter	Maintenance Comments	Compliance with UDLP objectives
					rilling or slumping	Hydroseeding of SM3 occurred on this batter in June 2017 with natives noted during inspection. Weeds appear well managed.	over time. Hydroseeding occurred in June 2017 with native cover increasing from Spring 2017.
4	Fill 19 West	20	3	Average	Good – no evidence of rilling or slumping	Native species growth is minimal however additional natives noted from Spring 2017. Area was revegetated by tractor seeding and application of fertiliser in July 2017.	SM4 mix (Pastoral Grass, Ancillary Site Mix). Poor compliance, area was revegetated with tractor seeding and fertiliser application in July 2017. Natives noted during Summer 2017 in line with surrounding vegetation
5	Fill 5	80	15	Good	Good – no evidence of rilling or slumping	Native species growth is good, native shrub species emerging, however the swale is now concreted and therefore does not require swale species (SM5)	This location was originally designated as SM5 (Indigenous Swale Drain grasses and plants). As swale is now concrete at this location mix design has been changed to SM2 (Native Pasture grasses) as per areas adjacent to the swale drain. Although there is mostly Setaria grass present, the batter has assimilated with the surrounding landscape

Monitoring Site no.	Location	General Cover %	% of cover = native species	General plant health	Condition of soil and batter	Maintenance Comments	Compliance with UDLP objectives
							with native species noted during Summer 2017.
6	Cut 22 East	40	20	Good	Good – no evidence of rilling or slumping	Native growth good, minimal weed growth. Re-spray with Hydroseed upper section of batter undertaken September 2017 with new native growth noted during Summer 2018.	BRC – North CC05. Good compliance, batter is assimilating with surrounding landscape.
7	Cut 22 West	60	20	Good	Good – no evidence of rilling or slumping	Native growth good, minimal weed growth. Re-spray with hydroseed completed May 2017 on lower section of batter where previous slumps have been rectified. New Native Growth noted in Summer 2018.	BRC – North CC05. Good compliance, batter is assimilating with surrounding landscape.
8	Fill 20 East	90	20	Good	Good – no evidence of rilling or slumping	Native growth emerging through Setaria grass growth. No other weed species to treat. Native species will continue to grow and shade out Setaria grass.	BRC – North CC04. Good compliance, batter is assimilating with surrounding landscape.
9	Cut 18 East	80	65	Good	Good – no evidence of rilling or slumping	Very good native species growth, native species growth dominant on batter with minimal weed growth. Good progress on growth.	BRC – North CC04 Very good compliance, batter is assimilating with surrounding landscape.
10	Williamsons Creek	80	5	Good – minimal native species	Good	Poor native species growth. Planting of additional beds undertaken September 2017 post removal of haul road crossing point. Planting pockets are overgrown with exotic grasses (i.e. Seteria). Removal of	Williamsons Creek. Average compliance, planting of additional beds undertaken September 2017. Maintenance items

Monitoring Site no.	Location	General Cover %	% of cover = native species	General plant health	Condition of soil and batter	Maintenance Comments	Compliance with UDLP objectives
						weeds from planting pockets is required, application of jute mat required to supress exotic species and replanting of planting pockets required. To be completed during Autumn 2018.	to be actioned in Autumn 2018. Continue to monitor
11	Stony Creek	80	40	Good	Good	Good native species growth and stabilisation of waterway. Successful use of soft treatments. Spot spray completed September 2017 with an additional spot spray required prior to opening of Stage 2B.	Stoney Creek. Very good compliance, soft landscaping treatment has been successful at stabilising the creek line.
12	Butchers Creek	10 (100% cover with scour rock)	4	Good	Good	Planting of lomandra into sandbags of topsoil has not been successful. Area has been hydromulched into pockets of sediment collected in scour rock with SM5 Mix. Spot spray required prior to operation.	Butchers Creek. Poor success of soft scour treatments. Hydromulching with SM5 (Indigenous Swale Drain grasses and plants) showing signs of successful treatment with various natives noted during inspection in Summer 2019. Good compliance with SM5.

Recommendations

1. Commence weed removal program leading up to road opening for priority areas and weed species.
2. Continue to monitor growth and re-apply hydroseed or hydromulch where appropriate for areas of poor growth.
3. SM5 swale mix has been changed from Site 5 (Fill 5) to Site 12 (Butchers Creek).
4. Williamson Creek shall have maintenance items listed above completed in Autumn 2018 with a jute mat applied to the planting pockets post weed removal. Replanting is to be undertaken in Autumn 2018.

Alex Dwyer

Environment Manager

Pacifico Acciona Ferrovial JV

Appendix A – Photo records

Site 1 (Fill 4 EAST)

December 2017

January 2018

February 2018

Site 2 (Fill 4 WEST)

December 2017

January 2018

February 2018

Site 3 (Cut 2 EAST)

December 2017

January 2018

February 2018

Site 4 (Fill 19 WEST)

December 2017

January 2018

February 2018

Site 5 (Fill 5 WEST)

December 2017

January 2018

February 2018

Site 6 (Cut 22 EAST)

December 2017 January 2018 February 2018

Site 7 (Cut 22 WEST)

December 2017

January 2018

February 2018

Site 8 (Fill 20 EAST)

December 2017

January 2018

February 2018

Site 9 (Cut 18 (EAST)

December 2017

January 2018

February 2018

Site 10 (Williamson Creek)

December 2017

January 2018

February 2018

Site 11 (Stony Creek)

December 2017

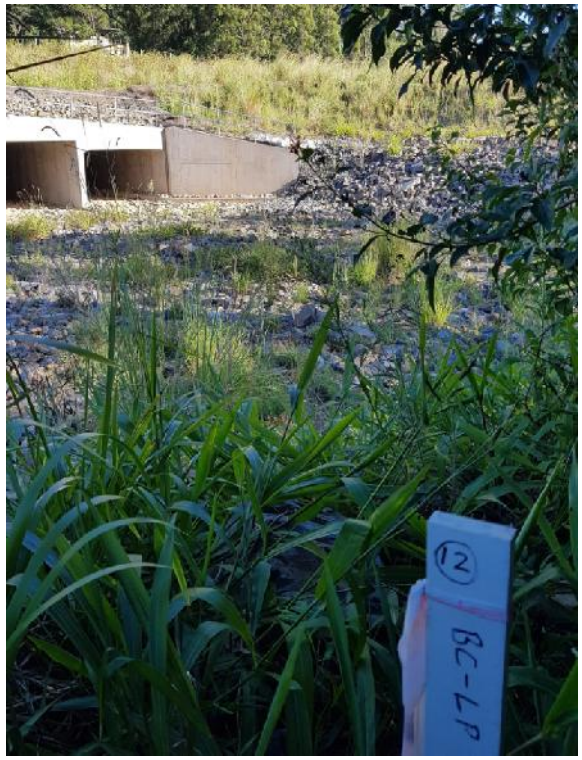
January 2018

February 2018

Site 12 (Butchers Creek)

December 2017

January 2018



February 2018

Appendix B – Landscape Monitoring Checklists (Summer 2018)

Date: 27/2/18

Photo Taken? (Y)/N

Site	1
Location	Fill 4 EAST
Weather	Overcast
Rainfall Average	Below average for Summer (288mm recorded vs 430mm median)
Walk 50m transect (as per photo) what general species are present?	Seteria Acacia sp. Banksia sp. Kennedia rubicunda Hardenbergia violacea Indigofera australis
What is general total ground cover?	95%
What percentage of native vegetation cover?	20%
What is the general plant height?	800mm - 2000mm
Comments on growth of batter: e.g condition of soil?	Good growth on batter no rills or erosion noted no signs of stress noted
Maintenance recommendations: e.g are there any weeds that need treating?	Nil NT - ragweed treated on verge in Feb 18 (browning noted)
Overall compliance / UDLP Comments e.g does batter look like surrounding landscape?	compliant with UDLP. for SMI Natives noted w/ good growth above seteria grass

Date: 27/2/18

Photo Taken? Y/N

Site	2
Location	Fill 4 WEST
Weather	Overcast
Rainfall Average	Below average for Summer (288mm recorded vs 430mm median)
Walk 50m transect (as per photo) what general species are present?	Acacia sp. Paddy's lucerne Kennedia rubicunda Glycine clandestine Hardenbergia violacea Indigofera australis.
What is general total ground cover?	95%
What percentage of native vegetation cover?	15%
What is the general plant height?	700mm - 2000mm
Comments on growth of batter: e.g condition of soil?	Good growth noted w/ established native vegetation no signs of stress or predation
Maintenance recommendations: e.g are there any weeds that need treating?	Nil NT - verge spray of annual ragweed completed Feb 18 - stress of weeds noted (browning off)
Overall compliance / UDLP Comments e.g does batter look like surrounding landscape?	compliant w/ UDLP. Setaria is noted from adjacent agricultural paddock's.

Date: 27/2/18

Photo Taken? (Y)/N

Site	3
Location	Cut 2 EAST
Weather	Overcast
Rainfall Average	Below average rainfall Summer
Walk 50m transect (as per photo) what general species are present?	Acacia Sp. Banksia sp. Seteria Grass
What is general total ground cover?	95%
What percentage of native vegetation cover?	10%
What is the general plant height?	500mm – 1200mm
Comments on growth of batter: e.g condition of soil?	Natives growing above and within seteria no rills on batter
Maintenance recommendations: e.g are there any weeds that need treating?	Nil seteria due to adjacent agricultural grasses.
Overall compliance / UDLP Comments e.g does batter look like surrounding landscape?	compliant with UDLP. Native strike noted post hydroseed SM3 seteria consistent with adjacent land (agricultural)

Date: 27/2/18

Photo Taken? (Y)/N

Site	4
Location	Fill 19 WEST
Weather	Overcast
Rainfall Average	Below average rainfall (Summer)
Walk 50m transect (as per photo) what general species are present?	Seteria rhodes grass acacia sp.
What is general total ground cover?	20%
What percentage of native vegetation cover?	3%
What is the general plant height?	150mm
Comments on growth of batter: e.g condition of soil?	only small amount of pastoral grasses, high mulch content native strike noted improved cover from Spring 2017
Maintenance recommendations: e.g are there any weeds that need treating?	Tractor seeding completed July 17. Continue monitoring of growth.
Overall compliance / UDLP Comments e.g does batter look like surrounding landscape?	ongoing monitoring required. natives noted as per adjacent vegetation

Date: 27/2/18

Photo Taken? (Y)/N

Site	5
Location	Fill 5 WEST
Weather	Overcast
Rainfall Average	Below average rainfall (Summer)
Walk 50m transect (as per photo) what general species are present?	Acacia Sp. couch Setaria
What is general total ground cover?	80%
What percentage of native vegetation cover?	15%
What is the general plant height?	600mm - 2000mm
Comments on growth of batter: e.g condition of soil?	Good growth adjacent to drain No sign of stress to natives. reduction in weed spies from spring 2017.
Maintenance recommendations: e.g are there any weeds that need treating?	Nil
Overall compliance / UDLP Comments e.g does batter look like surrounding landscape?	compliant with UDLP and matches surrounding landscape Note - shotcrete lined drain so no SMS SMS applied to Butchers Creek so SMS now at site 12.

Date: 27/2/18

Photo Taken? (Y)/N

Site	6
Location	Cut 22 EAST
Weather	Overcast
Rainfall Average	Below average rainfall (Summer)
Walk 50m transect (as per photo) what general species are present?	Acacia Sp. Callistemon Sp. Indigofera australis Acacia longifolia Kennedia rubicunda Hardenbergia violacea
What is general total ground cover?	40%
What percentage of native vegetation cover?	20%
What is the general plant height?	400mm – 700mm
Comments on growth of batter: e.g condition of soil?	no weeds noted no signs of stress or disease
Maintenance recommendations: e.g are there any weeds that need treating?	Nil
Overall compliance / UDLP Comments e.g does batter look like surrounding landscape?	Compliant with UDLP (Bushland Reconstruction)

Date: 27/2/18

Photo Taken? (Y)/N

Site	7
Location	Lot 22 WEST
Weather	Overcast
Rainfall Average	Below average rainfall (Sommer)
Walk 50m transect (as per photo) what general species are present?	Acacia sp. Hakea sericea Kennedia rubicunda Hardenbergia violacea Goodenia sp.
What is general total ground cover?	60%
What percentage of native vegetation cover?	20%
What is the general plant height?	300mm – 500mm
Comments on growth of batter: e.g condition of soil?	no weeds noted no signs of stress or disease
Maintenance recommendations: e.g are there any weeds that need treating?	Bottom half of batter shows poor growth. Respray occured 2017 awaiting native strike
Overall compliance / UDLP Comments e.g does batter look like surrounding landscape?	Compliant w/ UDLP (Bushland Reconstruction).

Date: 27/2/18

Photo Taken? Y/N

Site	8
Location	Fill 20 EAST
Weather	Overcast
Rainfall Average	Below average rainfall Summer
Walk 50m transect (as per photo) what general species are present?	Acacia Sp. Hardenbergia violacea Centella asiatica Seteria Kennedia Rubicunda Solanum lacianatum Echinochloa sp.
What is general total ground cover?	90%
What percentage of native vegetation cover?	20%
What is the general plant height?	400mm – 900mm
Comments on growth of batter: e.g condition of soil?	Good growth with natives above seteria no sign of stress or predation no slips noted
Maintenance recommendations: e.g are there any weeds that need treating?	Nil
Overall compliance / UDLP Comments e.g does batter look like surrounding landscape?	Compliant w/ BDLP (Bushland Reconstruction) w/ seteria from adjacent lands.

Date: 27/2/18

Photo Taken? (Y)/N

Site	9
Location	Cut 18 EAST
Weather	Overcast
Rainfall Average	Below average rainfall (Summer)
Walk 50m transect (as per photo) what general species are present?	Acacia Sp. Kennedia rubiconda Hardenbergia violacea Callistemon sp. Eucalyptus sp. seteria cymbopogon refractus. Centella asiatica
What is general total ground cover?	80%
What percentage of native vegetation cover?	65%
What is the general plant height?	700mm - 1500mm
Comments on growth of batter: e.g condition of soil?	good growth. no slips noted no signs of stress or predation
Maintenance recommendations: e.g are there any weeds that need treating?	Nil
Overall compliance / UDLP Comments e.g does batter look like surrounding landscape?	Compliant w/ UDLP (Bushland Reconstruction)

Date: 27/2/18

Photo Taken? Y/N

Site	10
Location	Williamson Creek
Weather	Overcast
Rainfall Average	Below average rainfall (Summer)
Walk 50m transect (as per photo) what general species are present?	Seteria paspalum (BL) maundia Bolrush Spike rush cotton bush
What is general total ground cover?	80%
What percentage of native vegetation cover?	5%
What is the general plant height?	300mm - 400mm
Comments on growth of batter: e.g condition of soil?	Good growth on new beds (PM4A) but high amount grasses noted
Maintenance recommendations: e.g are there any weeds that need treating?	removal of weeds and replacement of dead natives (PM4A) post spray and jute mat in beds required (March 18)
Overall compliance / UDLP Comments e.g does batter look like surrounding landscape?	average compliance with UDLP replacement planting and installation of jute mat in planting beds required.

Date: 27/2/18

Photo Taken? (Y)/N

Site	11
Location	Stoney Creek
Weather	Overcast
Rainfall Average	Below average rainfall (Summer)
Walk 50m transect (as per photo) what general species are present?	Lomandra longifolia Carex appressa juncus usitatus. Indigofera australis centella asiatica Eleocharis acuta setaria purple verbena fleabane.
What is general total ground cover?	80%
What percentage of native vegetation cover?	40%
What is the general plant height?	400mm – 800mm
Comments on growth of batter: e.g condition of soil?	Good growth noted no rills creek flowing with clear water tadpoles noted during inspection
Maintenance recommendations: e.g are there any weeds that need treating?	Spot spray completed – sep 17
Overall compliance / UDLP Comments e.g does batter look like surrounding landscape?	compliant with UDLP soft landscape treatment is established no movement of placed logs/structure noted

Date: 27/2/18

Photo Taken? (Y)/N

Site	12
Location	Butcher's Creek
Weather	Overcast
Rainfall Average	Below average rainfall (Summer)
Walk 50m transect (as per photo) what general species are present?	lomandras, camphor laurels, bullrush, seteria, Dianella sp., lantana (minor), juncos planifolios.
What is general total ground cover?	10% Hard scour treatment
What percentage of native vegetation cover?	4%
What is the general plant height?	300mm
Comments on growth of batter: e.g condition of soil?	Good growth post SMS application
Maintenance recommendations: e.g are there any weeds that need treating?	Spot Spray completed - Feb 18
Overall compliance / UDLP Comments e.g does batter look like surrounding landscape?	compliant with UDLP Hard scour treatment transitioning to soft treatment

MEMORANDUM

WC2NH PACIFIC HIGHWAY UPGRADE

Date 26th June 2018

Subject Autumn Landscape Monitoring Summary 2018

Background and Scope

Landscape monitoring was undertaken by the Pacifico Environment on Tuesday 29th May 2018. Landscape monitoring is required quarterly during Year 3 of construction in accordance with the Ecological Monitoring Program (EMP) and the Urban Design and Landscape Plan (UDLP). The purpose of the monitoring is to determine if the objectives of the UDLP have been met and whether any maintenance/management measures are required. The UDLP also requires monthly photo points to be taken of the landscape monitoring sites to track the progress. The photographs collected during the previous quarter are attached in Appendix A of this memorandum.

The landscape monitoring scope was originally determined by Geolink to cover the RMS Specification, UDLP and EMP requirements. Upon review of the scope provided by Geolink, Pacifico have devised a brief checklist which covers the general requirements of the monitoring scope. The completed checklist for each of the monitoring locations is provided in Appendix B of this memorandum.

The landscape monitoring scope includes 12 monitoring sites that have been determined across the Project. Monthly photo points are taken for each of the monitoring locations. A 50m transect is walked each quarter and the checklists attached in Appendix B are completed for each transect.

Results

The Pacifico Environment Team undertook a review of the monitoring sites on the 29th May 2018 in order to determine if the objectives in the UDLP were being achieved.

Monitoring Site no.	Location	General Cover %	% of cover = native species	General plant health	Condition of soil and batter	Maintenance Comments	Compliance with UDLP objectives
1	Fill 4 East	97	22	Good	Good – no evidence of rilling or slumping	Seteria grass most common species – observed in adjacent pasture. Batter meets the objectives of the UDLP as the batter assimilates with the surrounding landscape. Batter is stable with good robust growth. Weed's appear well managed.	SM1 mix (Native grasses) Although there is mostly Setaria grass present, the batter has assimilated with the surrounding landscape.
2	Fill 4 West	98	20	Good	Good – no evidence of rilling or slumping	Setaria grass most common species - – observed in adjacent pasture. Batter meets the objectives of the UDLP as the batter assimilates with the surrounding landscape. Batter is stable with good robust growth. Weed's appear well managed.	SM2 mix (Native Pasture grasses) Although there is mostly Setaria grass present, the batter has assimilated with the surrounding landscape.
3	Cut 2 East	97	18	Good	Good – no evidence of rilling or slumping	Setaria grass most common species present – observed in adjacent pasture. Native shrub species have emerged and are growing. Weeds appear well managed.	SM3 mix (Native shrub mix). Good compliance, shrub growth is improving over time.
4	Fill 19 West	25	5	Average	Good – no evidence of	Native species growth is minimal however additional natives noted since end of	SM4 mix (Pastoral Grass, Ancillary Site Mix). Poor

Monitoring Site no.	Location	General Cover %	% of cover = native species	General plant health	Condition of soil and batter	Maintenance Comments	Compliance with UDLP objectives
					rilling or slumping	Summer 17-18. Area was revegetated by tractor seeding and application of fertiliser in July 2017. Reapplication of SM4 mix is required to disturbed areas.	compliance, area was revegetated with tractor seeding and fertiliser application in July 2017. Natives noted during end of Summer 17-18 in line with surrounding vegetation.
5	Fill 5	85	20	Good	Good – no evidence of rilling or slumping	Native species growth is good, native shrub species emerging. Note: swale is concrete lined and therefore does not require swale species (SM5)	This location was originally designated as SM5 (Indigenous Swale Drain grasses and plants). As swale is now concrete at this location mix design has been changed to SM2 (Native Pasture grasses) as per areas adjacent to the swale drain. Although there is mostly Setaria grass present, the batter has assimilated with the surrounding landscape with native species growth noted during since Summer 17 - 18.
6	Cut 22 East	50	25	Good	Good – no evidence of	Native growth good, minimal weed growth. Note: Re-spray with Hydroseed upper section of batter undertaken September	BRC – North CC05. Good compliance, batter is

Monitoring Site no.	Location	General Cover %	% of cover = native species	General plant health	Condition of soil and batter	Maintenance Comments	Compliance with UDLP objectives
					rilling or slumping	2017 with native growth noted since Summer 17-18.	assimilating with surrounding landscape.
7	Cut 22 West	65	25	Good	Good – no evidence of rilling or slumping	Native growth good, minimal weed growth. Note: Re-spray with hydroseed completed May 2017 on lower section of batter where previous slumps have been rectified. Initial Native Growth noted on resprayed area.	BRC – North CC05. Good compliance, batter is assimilating with surrounding landscape.
8	Fill 20 East	95	25	Good	Good – no evidence of rilling or slumping	Native growth emerging through Setaria grass growth. No other weed species to treat. Native species continues to grow and shade out Setaria grass.	BRC – North CC04. Good compliance, batter is assimilating with surrounding landscape.
9	Cut 18 East	80	65	Good	Good – no evidence of rilling or slumping	Very good native species growth, native species growth dominant on batter with minimal weed growth.	BRC – North CC04 Very good compliance, batter is assimilating with surrounding landscape.
10	Williamsons Creek	85	5	Good – minimal native species	Good	Poor native species growth. Planting of additional beds undertaken September 2017 post removal of haul road crossing point. Planting pockets are overgrown with exotic grasses (i.e. Seteria). Removal of weeds from planting pockets is required, application of jute mat required to supress exotic species and replanting of planting pockets required. To be completed during Winter 2018.	Williamsons Creek. Average compliance, planting of additional beds undertaken September 2017. Maintenance items to be actioned in Winter 2018. Continue to monitor.

Monitoring Site no.	Location	General Cover %	% of cover = native species	General plant health	Condition of soil and batter	Maintenance Comments	Compliance with UDLP objectives
11	Stony Creek	80	40	Good	Good	Good native species growth and stabilisation of waterway. Successful use of soft treatments.	Stoney Creek. Very good compliance, soft landscaping treatment has been successful at stabilising the creek line.
12	Butchers Creek	10 (100% cover with scour rock)	4	Good	Good	Planting of lomandra into sandbags of topsoil has not been successful. Note: hydromulch was applied into pockets of sediment collected in scour rock with SM5 Mix.	Butchers Creek. Poor success of soft scour treatments. Hydromulching with SM5 (Indigenous Swale Drain grasses and plants) showing signs of successful treatment with various natives noted during Autumn inspection. Good compliance with SM5.

Recommendations

1. Following the completion of the 6 monthly Weed Report, treat identified weeds prior to opening of Stage 2.
2. Fill 19 (West) - reapplication of SM4 mix in disturbed areas.
3. Williamson Creek - Removal of weeds from planting pockets, application of jute mat and replanting of planting pockets is required.

4. Continue to monitor growth and re-apply hydroseed or hydromulch where appropriate for areas of poor growth.

Jason Haslett

Environment Manager
Pacifico Acciona Ferrovial JV

Appendix A – Photo records

Site 1 (Fill 4 EAST)

March 2018

April 2018

May 2018

Site 2 (Fill 4 WEST)

March 2018

April 2018

May 2018

Site 3 (Cut 2 EAST)

March 2018

April 2018

May 2018

Site 4 (Fill 19 WEST)

March 2018

April 2018

May 2018

Site 5 (Fill 5 WEST)

March 2018

April 2018

May 2018

Site 6 (Cut 22 EAST)

March 2018

April 2018

May 2018

Site 7 (Cut 22 WEST)

March 2018

April 2018

May 2018

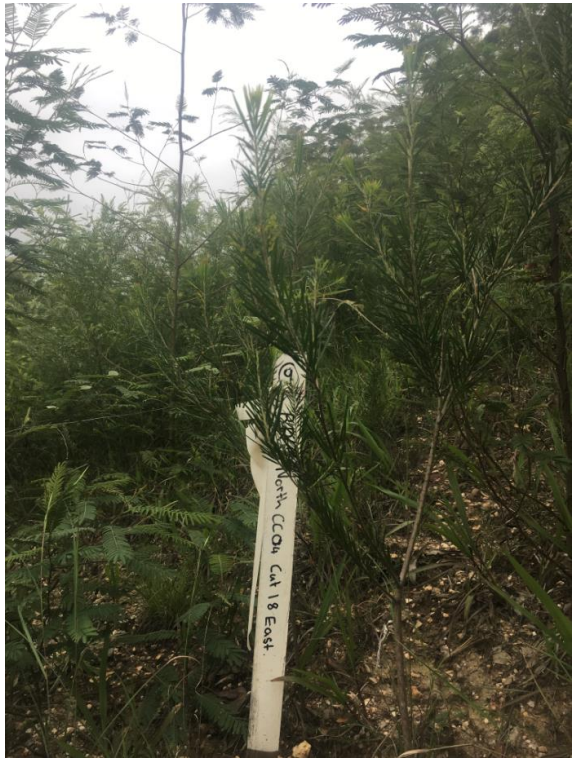
Site 8 (Fill 20 EAST)

March 2018

April 2018

May 2018

Site 9 (Cut 18 (EAST)



March 2018

April 2018

May 2018

Site 10 (Williamson Creek)

March 2018

April 2018

May 2018

Site 11 (Stony Creek)

March 2018

April 2018

May 2018

Site 12 (Butchers Creek)

March 2018

April 2018

May 2018

Appendix B – Landscape Monitoring Checklists (Autumn 2018)

Date: 29/05/2018

Photo Taken? (Y)/N

Site	1
Location	Fill 4 East
Weather	Fine - Clear
Rainfall Average	397.4mm in Autumn.
Walk 50m transect (as per photo) what general species are present?	Acacia, Seteria, Banksia, Kennedia rubicunda, Hardenbergia violacea, Indigofera australis
What is general total ground cover?	97%
What percentage of native vegetation cover?	22%
What is the general plant height?	800mm - 2100mm
Comments on growth of batter: e.g condition of soil?	Growth is good, no erosion observed.
Maintenance recommendations: e.g are there any weeds that need treating?	Nil
Overall compliance / UDLP Comments e.g does batter look like surrounding landscape?	SM1 ✓ Some seteria grass present, but present in surrounding landscape.

Date: 29/05/2018

Photo Taken? Y/N

Site	2
Location	Fill 4 West
Weather	Fine – Clear
Rainfall Average	397.4 mm in Autumn
Walk 50m transect (as per photo) what general species are present?	Kennedia rubicunda, Acacia, Glycine claudestine, Hardenbergia violacea, Indigofera australis, Paddy's Lucerne
What is general total ground cover?	98%
What percentage of native vegetation cover?	20%
What is the general plant height?	700mm – 2000mm
Comments on growth of batter: e.g condition of soil?	Establish native vegetation
Maintenance recommendations: e.g are there any weeds that need treating?	No
Overall compliance / UDLP Comments e.g does batter look like surrounding landscape?	Compliant SM2 mix, setaria grass present + present in adjacent land.

Date: 29/05/2018

Photo Taken? Y / N

Site	3
Location	Cut 2 East
Weather	Fine - Clear
Rainfall Average	397.4mm in Autumn
Walk 50m transect (as per photo) what general species are present?	Banksia, Acacia + Seteria grass
What is general total ground cover?	97%
What percentage of native vegetation cover?	18%
What is the general plant height?	600mm - 1400mm
Comments on growth of batter: e.g condition of soil?	Natives growing above + within seteria. No erosion.
Maintenance recommendations: e.g are there any weeds that need treating?	No
Overall compliance / UDLP Comments e.g does batter look like surrounding landscape?	SM3 ✓ Shrub growth observed from Summer

Date: 29/05/2018

Photo Taken? Y/N

Site	4
Location	Fill 19 West
Weather	Fine - Clear
Rainfall Average	421.8mm in Autumn
Walk 50m transect (as per photo) what general species are present?	Acacia, Setaria + Rhodes grass
What is general total ground cover?	25%
What percentage of native vegetation cover?	5%
What is the general plant height?	150 - 200mm
Comments on growth of batter: e.g condition of soil?	No erosion. Minimal native growth
Maintenance recommendations: e.g are there any weeds that need treating?	Re-application of SM4 is required on disturbed areas.
Overall compliance / UDLP Comments e.g does batter look like surrounding landscape?	Natives observed consistent with adjacent vegetation.

Date: 29/05/2018

Photo Taken? (Y)/N

Site	5
Location	Fill 5
Weather	Fine - Clear
Rainfall Average	397.4 mm in Autumn.
Walk 50m transect (as per photo) what general species are present?	Couch, Setaria + Acacia species
What is general total ground cover?	85%
What percentage of native vegetation cover?	20%
What is the general plant height?	600 - 2100mm
Comments on growth of batter: e.g condition of soil?	Growth of natives is good, with ~~shrub~~ shrub species developing. No erosion Concrete lined drain negates need for SM5.
Maintenance recommendations: e.g are there any weeds that need treating?	No
Overall compliance / UDLP Comments e.g does batter look like surrounding landscape?	SM2 ✓ Setaria in surrounding landscape.

Date: 29/05/2018

Photo Taken? Y/N

Site	6
Location	Cut 22 East
Weather	Fine - Clear
Rainfall Average	421.8mm in Autumn
Walk 50m transect (as per photo) what general species are present?	Acacia longifolia, Kennedia rubicunda, Acacia sp., Hardenbergia violacea, Indigofera australis, Callistemon Sp.
What is general total ground cover?	50 %
What percentage of native vegetation cover?	25%
What is the general plant height?	500mm - 900mm
Comments on growth of batter: e.g condition of soil?	No erosion
Maintenance recommendations: e.g are there any weeds that need treating?	No Good native growth
Overall compliance / UDLP Comments e.g does batter look like surrounding landscape?	BRC - North CC05 (Bushland Re-construction) ✓

Date: 29/05/2018

Photo Taken? (Y)/N

Site	7
Location	Cut 22 West
Weather	Fine - Clear
Rainfall Average	421.8mm in Autumn
Walk 50m transect (as per photo) what general species are present?	Hardenbergia violacea, kennedia rubicunda, Hakea sericea, ~~Hardenbergia~~ goodenia sp. Acacia Sp.
What is general total ground cover?	65%
What percentage of native vegetation cover?	25%
What is the general plant height?	300. - 700mm
Comments on growth of batter: e.g condition of soil?	No erosion/rilling. No weeds
Maintenance recommendations: e.g are there any weeds that need treating?	Re-spay in 2017 of bottom half of batter has now some signs of inital strike.
Overall compliance / UDLP Comments e.g does batter look like surrounding landscape?	Bushland Re-generation CC05 ✓

Date: 29/05/2018

Photo Taken? Y/N

Site	8
Location	Fill 20 East
Weather	Fine - Clear
Rainfall Average	421.8mm in Autumn
Walk 50m transect (as per photo) what general species are present?	Seteria, Acacia Species, Echinochloa species, Solanum laciniatum, centella asiatica, hardenbergia violacea, kennedia rubicunda
What is general total ground cover?	95%
What percentage of native vegetation cover?	25%
What is the general plant height?	500mm - 1,200mm
Comments on growth of batter: e.g condition of soil?	Good native growth outcompeting seteria grass No erosion / rilling.
Maintenance recommendations: e.g are there any weeds that need treating?	No
Overall compliance / UDLP Comments e.g does batter look like surrounding landscape?	Bushland regeneration - North CC04 Batter is assimulating to surrounding landscape

Date: 29/05/2018

Photo Taken? (Y)/N

Site	9
Location	Cat 18 East
Weather	Fine - Clear
Rainfall Average	421.8mm in Autumn.
Walk 50m transect (as per photo) what general species are present?	Acacia Sp, Setaria grass, Cymbopogon refractus, Kennedia rubicunda, Hardenbergia violacea, centella asiatica, eucalyptus species, callistemon species.
What is general total ground cover?	80%
What percentage of native vegetation cover?	65%
What is the general plant height?	750 - 1800mm.
Comments on growth of batter: e.g condition of soil?	No erosion / rilling.
Maintenance recommendations: e.g are there any weeds that need treating?	Native species dominant - good growth. Minimal weeds
Overall compliance / UDLP Comments e.g does batter look like surrounding landscape?	Bushland Regeneration (BRC - North CC04) ✓ Assimulating with surrounding landscape ✓

Date: 29/05/2018

Photo Taken? (Y)/N

Site	10
Location	Williamson Ck
Weather	Fine - clear
Rainfall Average	397.4 mm in Autumn
Walk 50m transect (as per photo) what general species are present?	Setaria grass, Bulrush, maundia, paspalum (BL), cotton bush, spike rush.
What is general total ground cover?	85%
What percentage of native vegetation cover?	5%
What is the general plant height?	300 - 450mm
Comments on growth of batter: e.g condition of soil?	Poor native species growth. Overgrown with exotic grasses. PM4A species overgrown
Maintenance recommendations: e.g are there any weeds that need treating?	Removal of weeds required, application of jute matting and replanting of pockets required.
Overall compliance / UDLP Comments e.g does batter look like surrounding landscape?	Average compliance - need to undertake maintenance as detailed above.

Pacifico
Acciona Ferrovial JV

Date: 29/05/2018 **Photo Taken? Y/N**

Site	11
Location	Stoney Ck
Weather	Fine clear
Rainfall Average	397.4mm in Autumn.
Walk 50m transect (as per photo) what general species are present?	Seteria, Carex appressa, lomandra longifolia, juncus ositatus, centella asiatica, eleocharis acta., purple verbena, indigofera australis.
What is general total ground cover?	80%
What percentage of native vegetation cover?	40%
What is the general plant height?	500mm – 900mm
Comments on growth of batter: e.g condition of soil?	Soft treatments successful, waterway stable. Native species growth is good
Maintenance recommendations: e.g are there any weeds that need treating?	Weeds identified in 6 monthly report in June 18 to be treated prior to opening.
Overall compliance / UDLP Comments e.g does batter look like surrounding landscape?	Compliant ✓

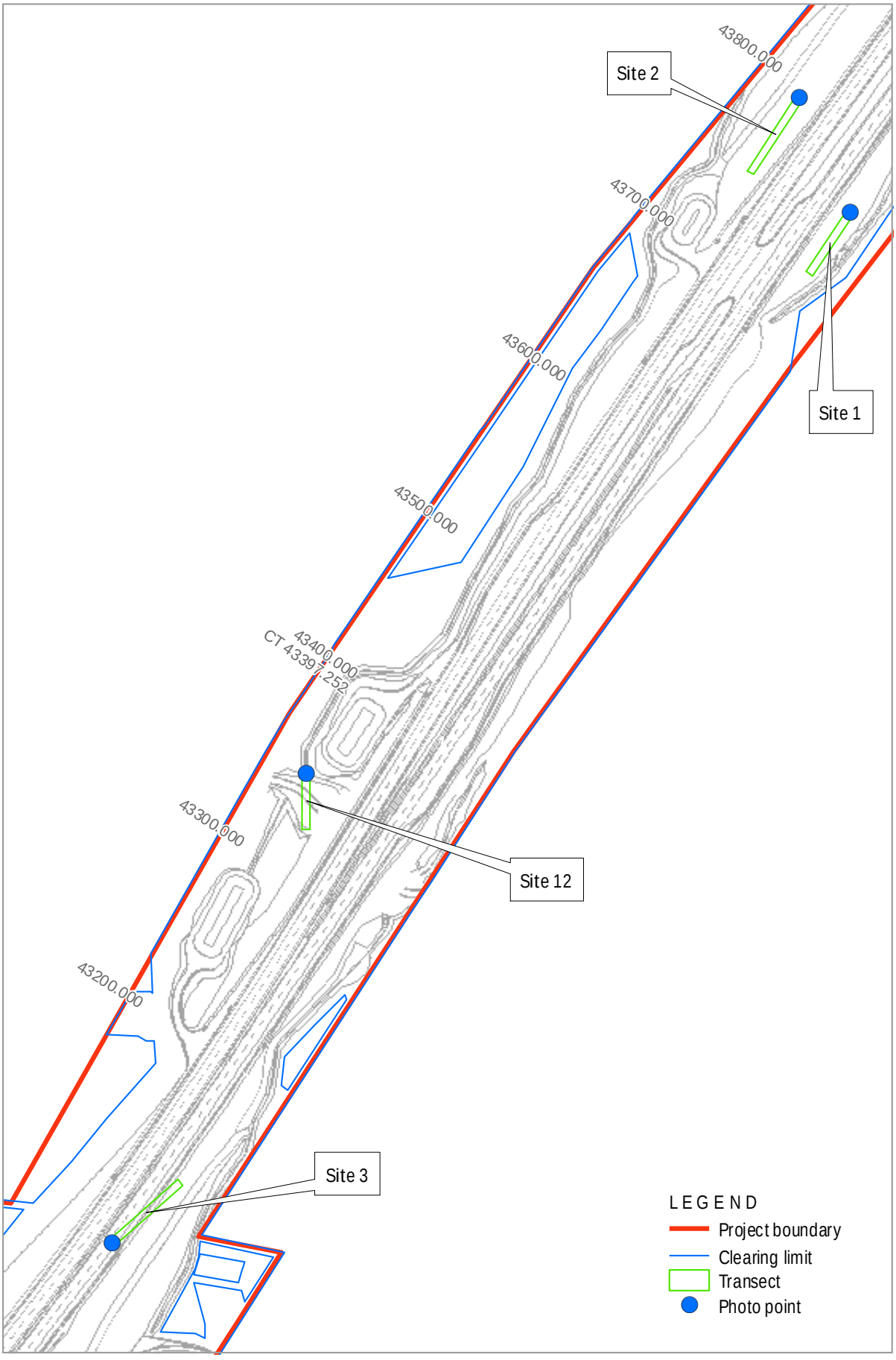
Date: 29/05/2018 Photo Taken? Y/N

Site	12
Location	Butchers Ck
Weather	Fine - clear
Rainfall Average	397.4mm in Autumn.
Walk 50m transect (as per photo) what general species are present?	Seteria, lomandras, Dianella species, camphor laureds, lantana, bullrush, juncuss planifolius
What is general total ground cover?	10% (100% cover with scour rock)
What percentage of native vegetation cover?	4%
What is the general plant height?	300 - 400mm
Comments on growth of batter: e.g condition of soil?	- Poor success of soft scour treatments - planting of Lomandra into sandbags of topsoil was not successfull - Swale drain grasses + plants (SMS) observed.
Maintenance recommendations: e.g are there any weeds that need treating?	Treat weeds identified in 6 monthly weed report (June 18) prior to opening.
Overall compliance / UDLP Comments e.g does batter look like surrounding landscape?	Good compliance SMS ✓

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 30/11/2016

Information shown is for illustrative purposes only

Source of base data: AFJV



0 60

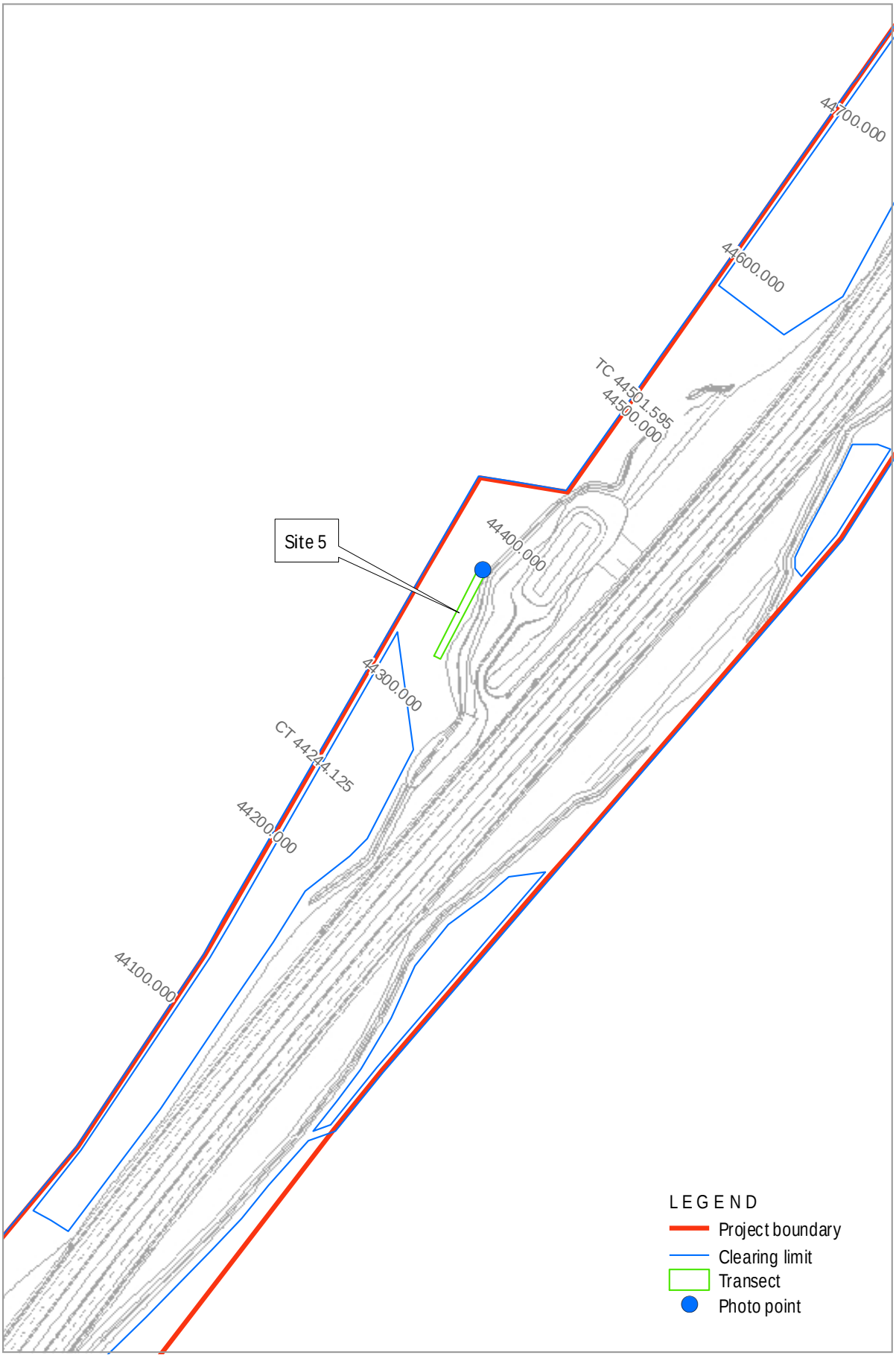
North

Monitoring Location

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 30/11/2016

Information shown is for illustrative purposes only

Source of base data: AFJV



North

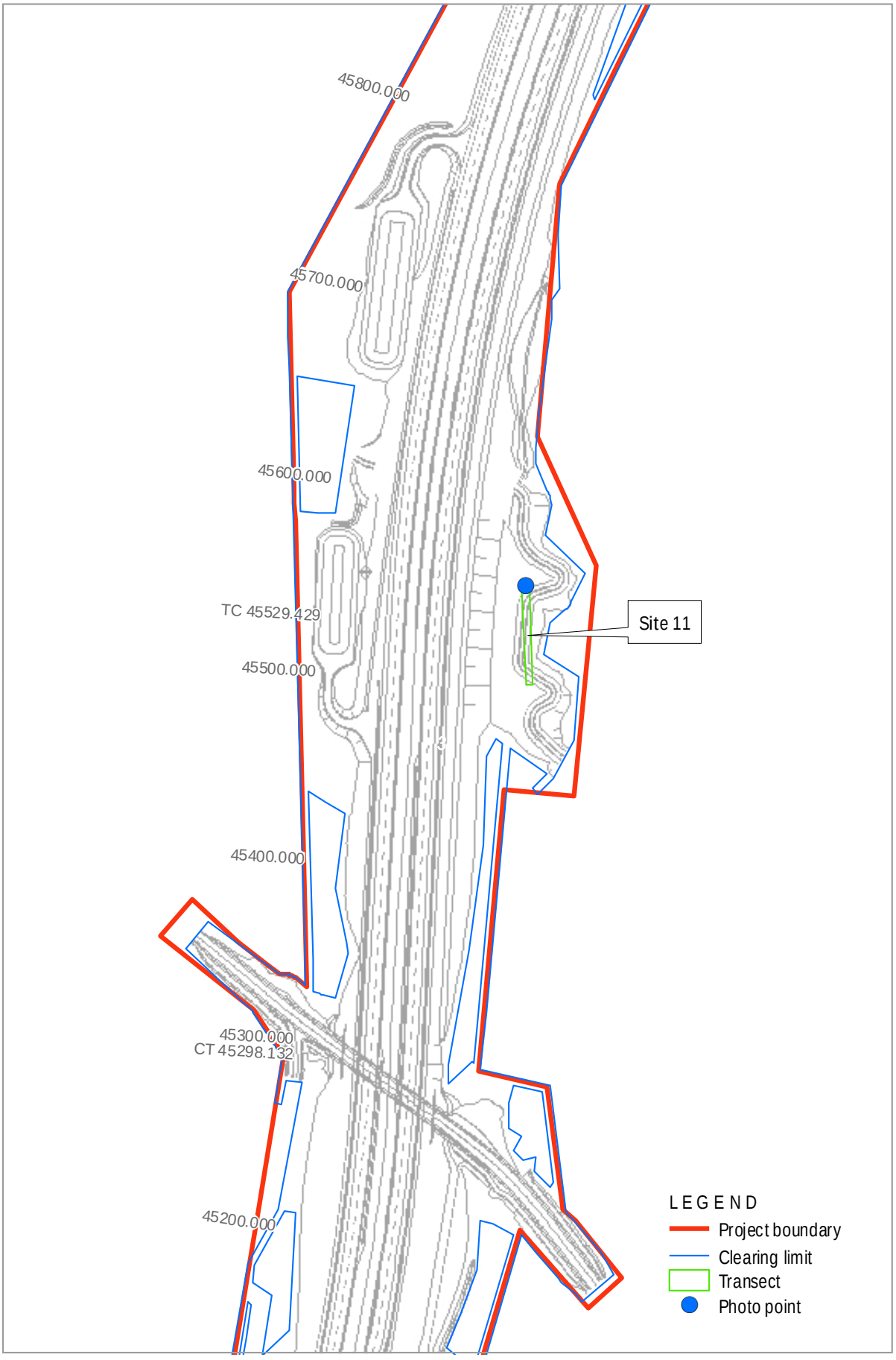
0 60

Monitoring Location

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 30/11/2016

Information shown is for illustrative purposes only

Source of base data: AFJV



0 60

North

Monitoring Location

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 30/11/2016

Information shown is for illustrative purposes only

Source of base data: AFJV

North

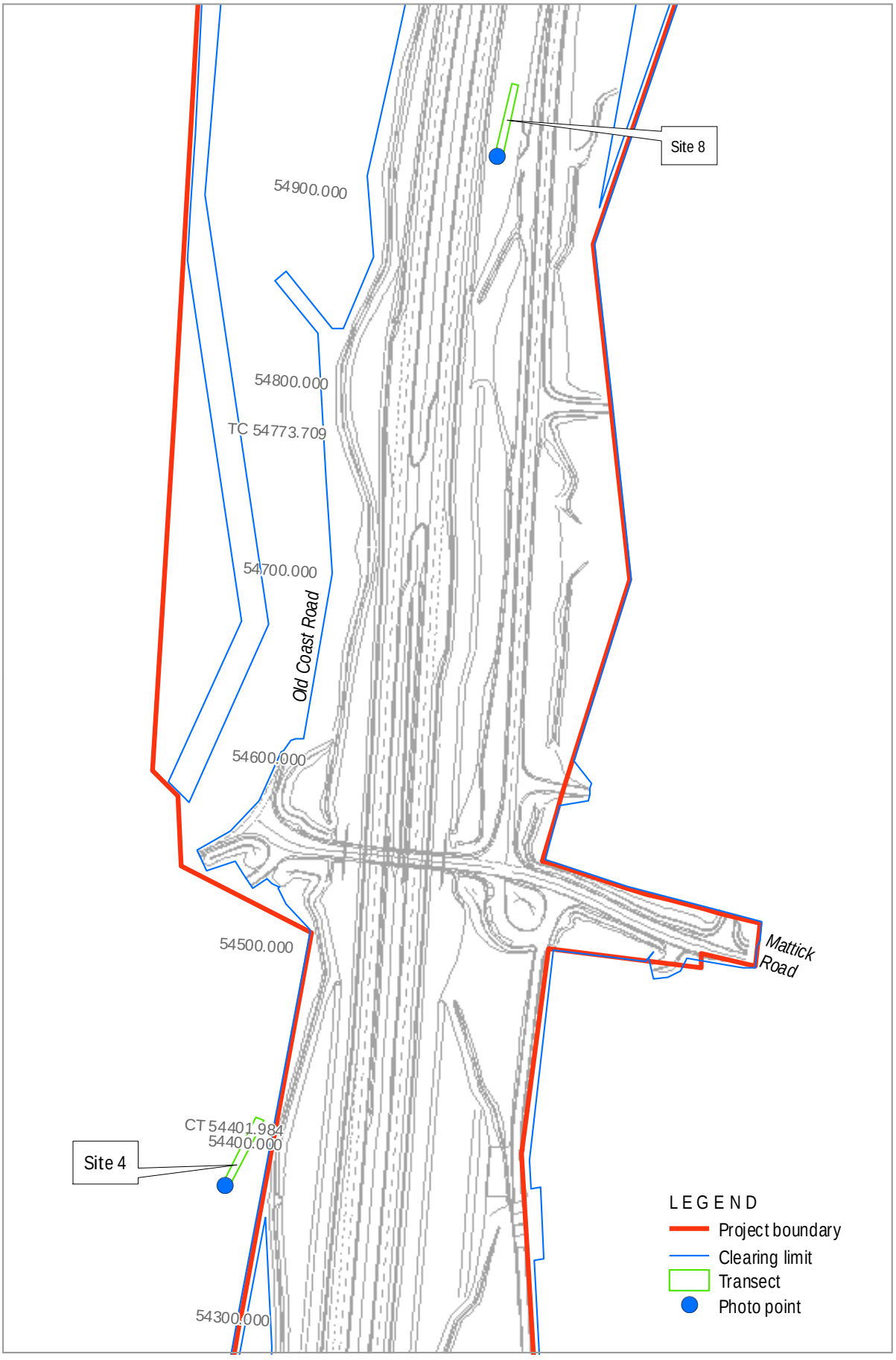
0 60

Monitoring Location

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 30/11/2016

Information shown is for illustrative purposes only

Source of base data: AFJV



North

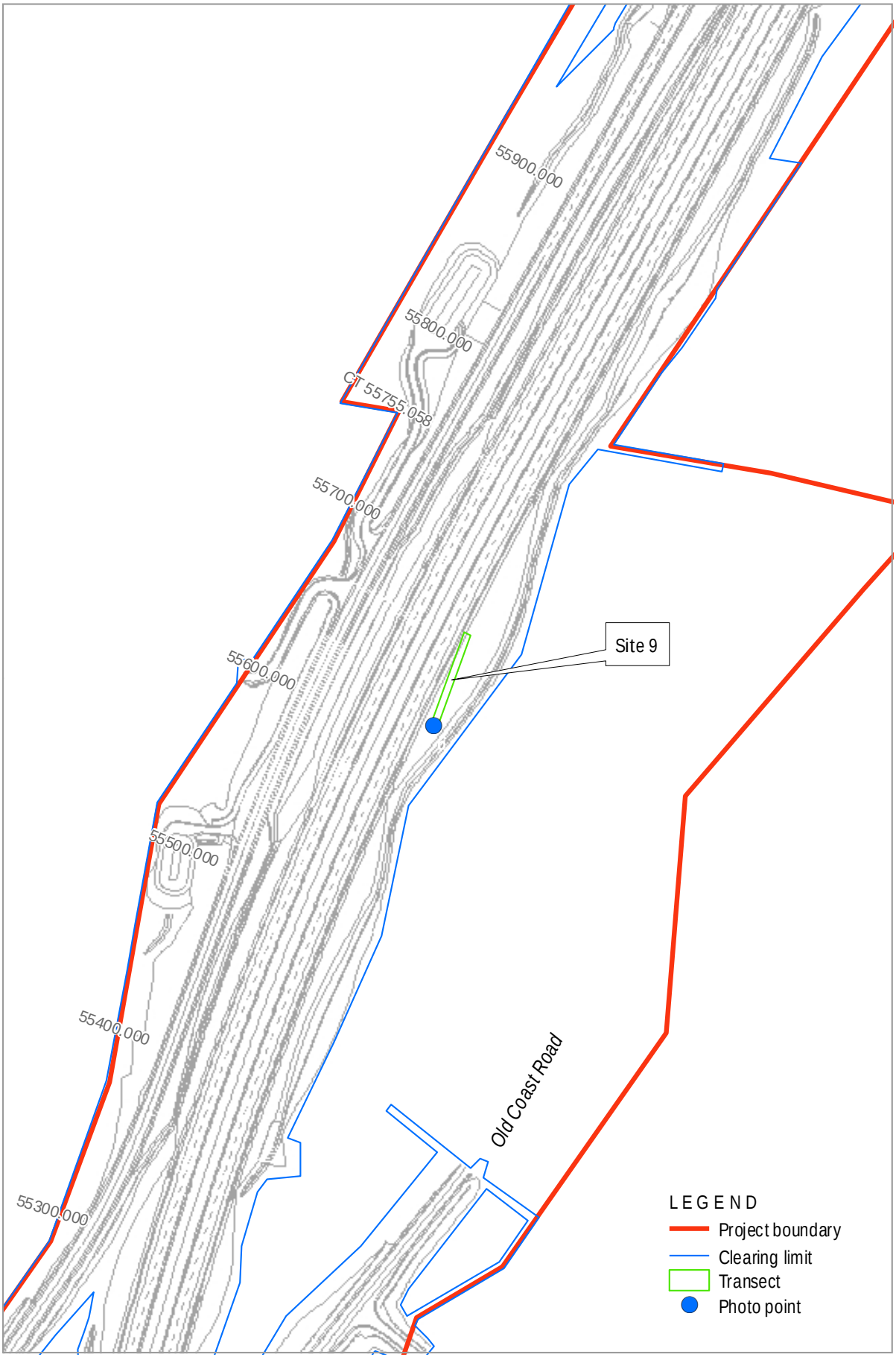
0 60

Monitoring Location

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 30/11/2016

Information shown is for illustrative purposes only

Source of base data: AFJV



North

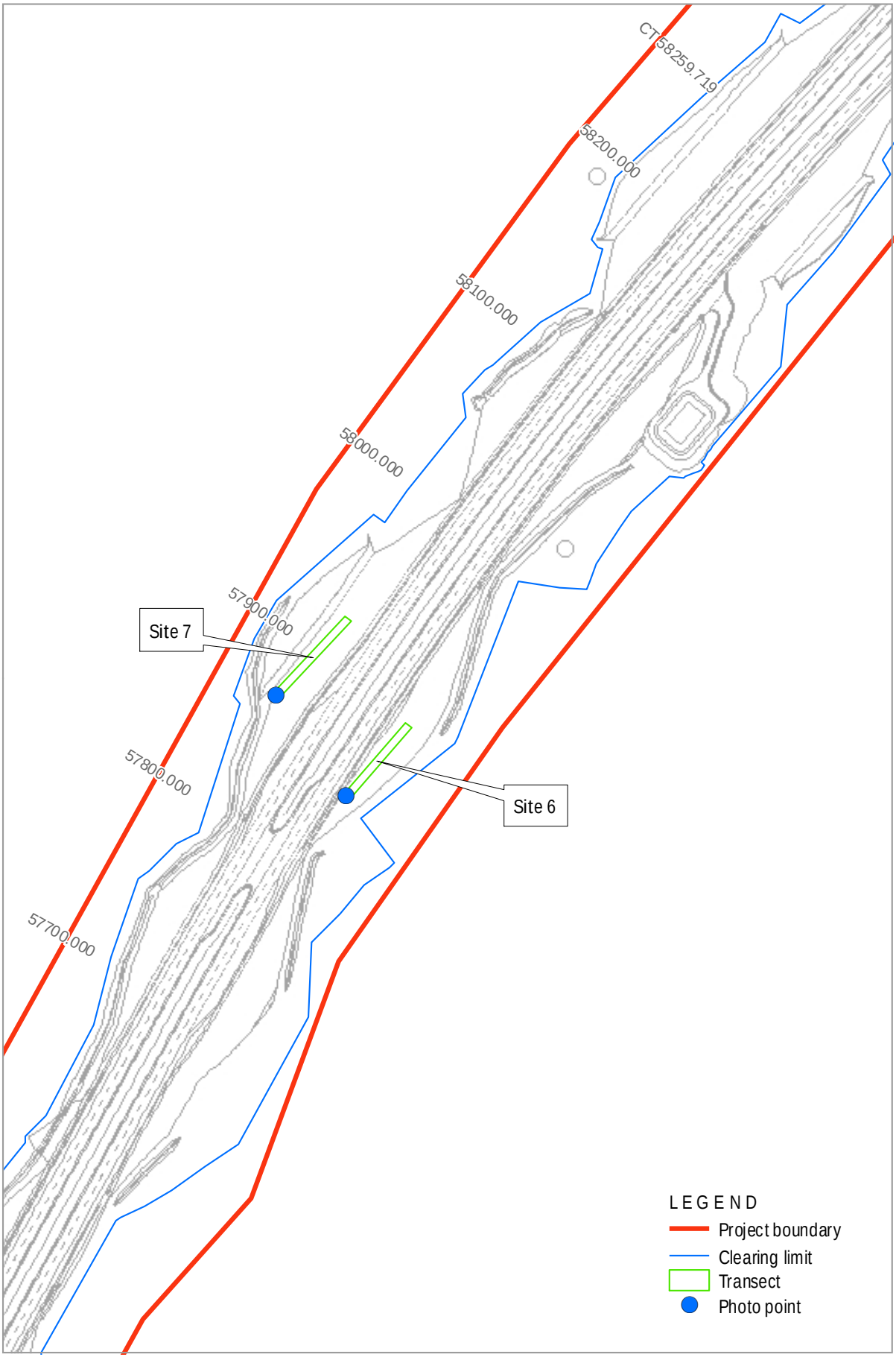
0 60

Monitoring Location

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 30/11/2016

Information shown is for illustrative purposes only

Source of base data: AFJV



North

0 60

Monitoring Location

GeoLINK environmental management and design

Landscape Monitoring Report
2378-1304

Illustration 2.7

Appendix H Threatened Flora

Warrell Creek to Nambucca Heads

Operational Phase Monitoring of Threatened Flora Translocations, In-situ Threatened Plants and Slender Marsdenia and Woolls' Tylophora Habitat Condition- Year 1

Roads and Maritime Services | December 2018

THIS PAGE LEFT INTENTIONALLY BLANK

Document Review

Date	Version	Status	Sent to	Represent	Delivered Format	Dispatched By
18/12/18	A	Draft	S. Hardiman	RMS	MSW	D. Rohweder

Document Distribution

Date	Version	Status	Sent to	Represent	Delivered Format	Dispatched By
20/12/2018	B	Final	S. Hardiman	RMS	MSW & PDF	D. Rohweder

Project team:

Dr A. Benwell (field survey, reporting)
Dr Jeremy Benwell-Clarke (field survey, reporting)
Dr D. Rohweder (project management, report review)

Report prepared for:

Roads and Maritime Services NSW

© Sandpiper Ecological Surveys 2018
ABN: 82 084 096 828

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

Cover Photo: NA.

Disclaimer:
This report has been prepared in accordance with the scope of services described in the contract or agreement between Sandpiper Ecological Surveys (ABN 82 084 096 828) and Roads and Maritime Services NSW. The report relies upon data, surveys and measurement obtained at the times and locations specified herein. The report has been prepared solely for Roads and Maritime Services and Sandpiper Ecological Surveys accepts no responsibility for its use by other parties. Sandpiper Ecological Surveys accepts no responsibility or liability for changes in context, meaning, conclusions or omissions caused by cutting, pasting or editing the report.

Operational Phase Monitoring of Threatened Flora Translocations, In-situ Threatened Plants and Slender Marsdenia and Woolls' Tylophora Habitat Condition on the Warrell Creek to Nambucca Heads Section of the Pacific Highway Upgrade – Year 1

Prepared for:

Sandpiper Ecological Surveys

PO Box 401, Alstonville 2477

Prepared by:

Dr Andrew Benwell and Jeremy Benwell-Clarke

ECOS Environmental Pty Ltd

PO Box 641 Mullumbimby, NSW 2482

ph 0487050005; email: andrewbenwell@bigpond.com

17/12/2018

CONTENTS

1 Introduction 1
2 Threatened Flora Translocation 3
2.1 Aim and Species Translocated 3
2.2 Methods 3
2.2.1 Receival Sites 3
2.2.2 Direct Transplanting 5
2.2.3 Slender Marsdenia 6
2.2.3.1 Salvage Transplanting 6
2.2.3.2 No Fertiliser 6
2.2.3.3 Propagation of Population Enhancement Plants 6
2.2.4 Woolls' Tylophora 7
2.2.4.1 Species Identification 7
2.2.4.2 Salvage Transplanting and Population Enhancement 7
2.2.5 Rusty Plum 8
2.2.5.1 Salvage Transplanting 8
2.2.5.1 Population Enhancement by Direct Seeding 8
2.2.6 Spider Orchid 8
2.2.6.1 Salvage Transplanting 8
2.2.6.2 Population Enhancement 8
2.2.7 Koala Bells 9
2.2.7.1 Salvage Transplanting 9
2.2.7.2 Population Enhancement 9
2.2.8 Floyds Grass 9
2.2.8.1 Topsoil Stripping 9
2.2.8.2 Salvage Transplanting 9
2.2.8.3 Population Enhancement 10
2.2.9 Monitoring and Data Analysis 10
2.3 Results 12
2.3.1 Species Survival Summary 12
2.3.2 Slender Marsdenia (*Marsdenia longiloba*) 14
2.3.2.1 Summary 14
2.4.2.2 Causes of Mortality 14
2.4.2.3 Height/Performance 14
2.4.2.4 Response Syndromes of Transplanted Individuals 15
2.4.3 Rusty Plum (*Niemeyera whitei*) 18
2.4.4 Wooll's Tylophora (*Tylophora woollsii* – unconfirmed) 18
2.4.5 Spider Orchid (Dendrobium melaleucaphilum) 19
2.4.6 Floyds Grass (*Alexfloydia repens*) 19
2.4.7 Koala Bells (*Artanema fimbriatum*) 19
2.5 Performance Assessment 20
2.6 Evaluation of Methods and Cost-effectiveness 20
2.7 Work Plan for Year 5 (December 2018 – December 2019) 21
3 In-Situ Threatened Flora Populations 21

3.1 Methods 21
3.2 Results 28
3.2.1 Maundia (Maundia triglochinoides) 28
3.2.2 Spider Orchid (Dendrobium melaleucaphilum) 28
3.2.3 Rusty Plum (*Niemeyera whitei*) 28
3.2.4 Slender Marsdenia (*Marsdenia longiloba*) 28
3.3 Conclusion 35
4 Slender Marsdenia and Woolls' Tylophora Habitat Condition 37
4.1 Methodology 37
4.2 Results 42
4.3 Conclusion 47
5 References 48
Appendix 1: Photos of Threatened Flora Translocations, WC2NH, Nov 2018 49
Appendix 2: Photos of in-situ threatened plant species, WC2NH, November 2018 64
Appendix 3: Photos of Slender Marsdenia and Woolls' Tylophora habitat condition monitoring plots, Nov 2018 69
Appendix 4: Vegetation structure of Slender Marsdenia and Woolls' Tylophora habitat monitoring quadrats Recorded BY GeoLINK (2017) 74

Executive Summary

This report presents the results of the year one operational phase monitoring of threatened plant species along the Warrell Creek to Nambucca Heads (WC2NH) section of the Pacific Highway upgrade. Specifically, it relates to three monitoring components that were planned in the *Warrell Creek to Urunga Upgrade Threatened Flora Management Plan* (RMS and Ecos 2016) - In-situ Threatened Flora Populations, Slender Marsdenia and Woolls' Tylophora Habitat Condition, and Threatened Flora Translocation Areas.

Five threatened and one nationally rare plant species occur within the highway upgrade area:

- Slender Marsdenia (*Marsdenia longiloba*) (listed as endangered under the *Biodiversity Conservation (BC) Act 2016* and vulnerable under the *Environment Protection and Biodiversity Conservation (EPBC) Act 1999*)
- Woolls' Tylophora (Tylophora woollsii) (listed as endangered under the BC Act and the EPBC Act)
- Rusty Plum (*Niemeyera whitei*) (listed as vulnerable under the BC Act)
- Spider Orchid (*Dendrobium melaleucaphilum*) (listed as endangered under the BC Act)
- Floyds Grass (*Alexfloydia repens*) (listed as endangered under the BC Act)
- Koala Bells (*Artanema fimbriatum*) (nationally rare and has been proposed for State listing).

Ecos Environmental conducted year one operational phase monitoring in November 2018, which followed on from pre-construction and construction phase monitoring undertaken also by Ecos Environmental, and GeoLINK.

In November 2018, survival of the translocated species was 67-100% and of the surviving plants most were in healthy condition. Survival of the threatened in-situ populations was 100% and no plants were in poor condition. The condition of Slender Marsdenia and Woolls' Tylophora habitat along the edge of clearing appears to have remained the same since construction of the WC2NH section began.

The results of the first year of operation phase monitoring mostly meet the performance criteria and no corrective actions are required.

1 Introduction

The *Warrell Creek to Urunga Upgrade Threatened Flora Management Plan* (TFMP) was prepared by NSW Roads and Maritime Service and Ecos Environmental as part of the Project Environmental Assessment for the Warrell Creek to Urunga (WC2U) Pacific Highway upgrade (RMS & Ecos 2016). The Minister for Planning approved the project on 19 July 2011 under Part 3A (now repealed), Section 75J of the Environmental Planning and Assessment Act 1979 (EP&A Act). One of the Minister's Conditions of Approval (CoA) was a monitoring program for threatened flora likely to be impacted by the project, as outlined in the TFMP. The monitoring program would comprise three components - In-situ Threatened Flora Populations, Slender Marsdenia and Woolls' Tylophora Habitat Condition, and Threatened Flora Translocation Areas – and would be undertaken during the pre-construction, construction and operation phases of the project.

The WC2U upgrade was completed in two stages: Nambucca Heads to Urunga (NH2U) and Warrell Creek to Nambucca Heads (WC2NH). The following report addresses operational phase monitoring for the WC2NH stage, which extends for 19.6km from Warrell Creek in the south to Nambucca Heads (Figure 1). Construction of the WC2NH upgrade began on 9 February 2015 and the entire alignment was open to traffic in July 2018.

Operation phase monitoring in the WC2NH section of the upgrade is to be conducted yearly for four years, as specified in *Warrell Creek to Nambucca Heads Operational Ecological and Water Quality Monitoring Brief* (Roads and Maritime Services 2018). In November 2018, Ecos Environmental conducted the first yearly operation phase monitoring of In-situ Threatened Flora Populations, Slender Marsdenia and Woolls' Tylophora Habitat Condition, and Threatened Flora Translocation Areas. The results are described in this report in the following sections:

- Section 2: Threatened Flora Translocation Areas
- Section 3: In-situ Threatened Flora Populations
- Section 4: Slender Marsdenia and Woolls' Tylophora Habitat Condition.

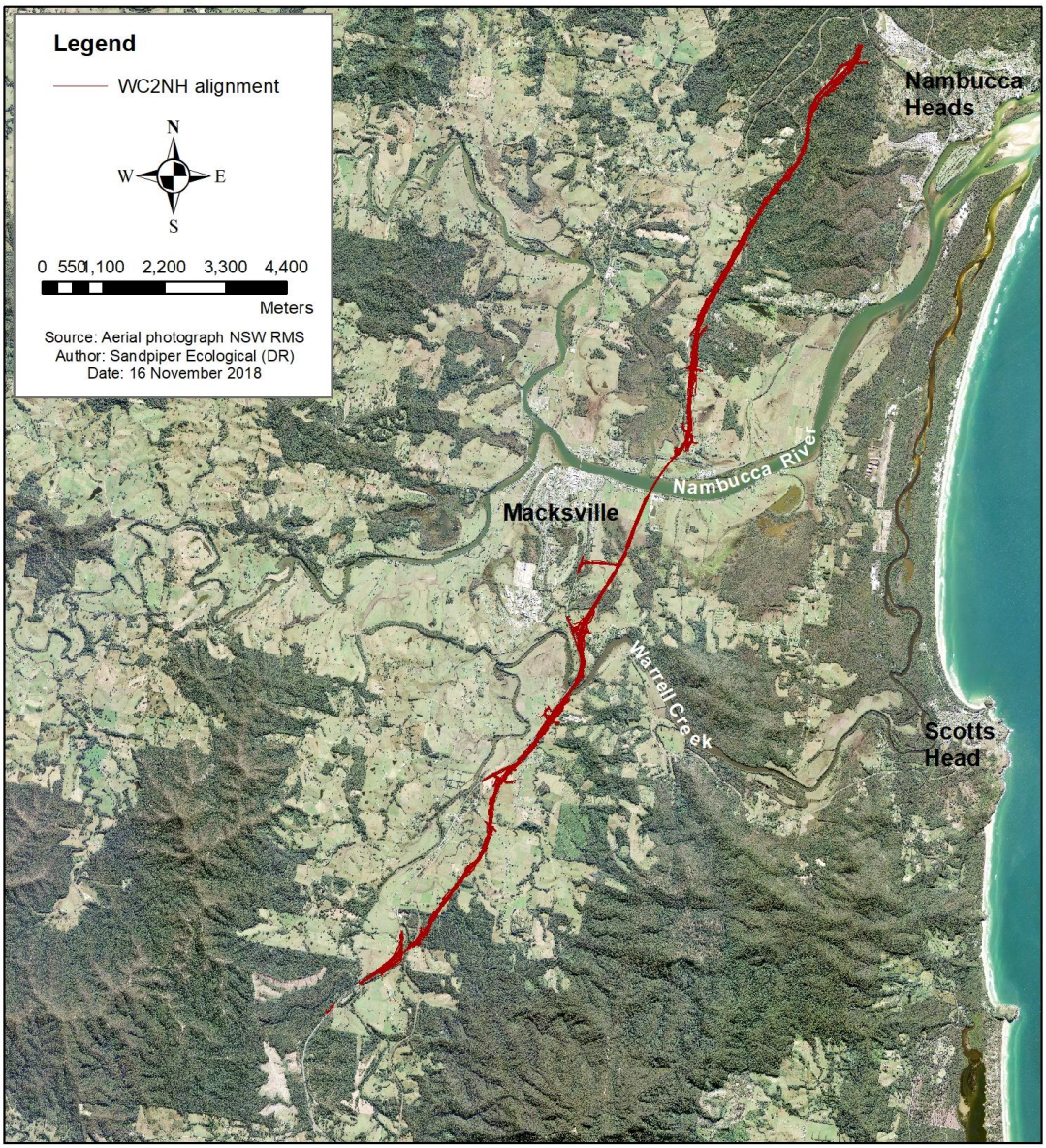


Figure 1: Location of the WC2NH alignment.

2 Threatened Flora Translocation

2.1 Aim and Species Translocated

The translocation component of the WC2U TFMP was prepared according to the Australian Network for Plant Conservation guidelines for planning threatened flora translocations (ANPC 2004). The overall translocation aim was to maintain population numbers of threatened plant species in the local area by salvaging plants impacted by construction and re-establishing them in suitable habitat alongside the highway corridor. A propagation component would make up for potential losses incurred during salvage transplanting. Translocation of each species involved three main actions:

- Salvage transplanting of impacted individuals and establishing them at receival sites with habitat closely approximating the donor sites
- Population enhancement by propagating and introducing additional individuals
- Habitat restoration to ensure the receival sites provided good quality habitat.

Five threatened and one nationally rare plant species were translocated on the WC2NH project:

- Slender Marsdenia (*Marsdenia longiloba*) (listed as endangered under the *BC Act* and vulnerable under the *EPBC Act*)
- Woolls' Tylophora (*Tylophora woollsii*) (listed as endangered under the *BC Act* and the *EPBC Act*)
- Rusty Plum (*Niemeyera whitei*) (listed as vulnerable under the *BC Act*)
- Spider Orchid (*Dendrobium melaleucaphilum*) (listed as endangered under the *BC Act*)
- Floyds Grass (*Alexfloydia repens*) (listed as endangered under the *BC Act*)
- Koala Bells (*Artanema fimbriatum*) (nationally rare and has been proposed for State listing).

2.2 Methods

2.2.1 Receival Sites

Nine receival sites were selected for the species being translocated. All were located in the road reserve (i.e. RMS property) – seven where the highway corridor crossed Nambucca State Forest, one adjacent to the new highway bridge at Warrell Creek, and one at the southern end of the upgrade (Table 1 and Figure 2). For further information on the receival site selection process and a description of each site, refer to any of the construction phase monitoring reports: (Ecos Environmental 2016a (construction phase Yr 1), 2017 (construction phase Yr 2), 2018 (construction phase Yr 3)).

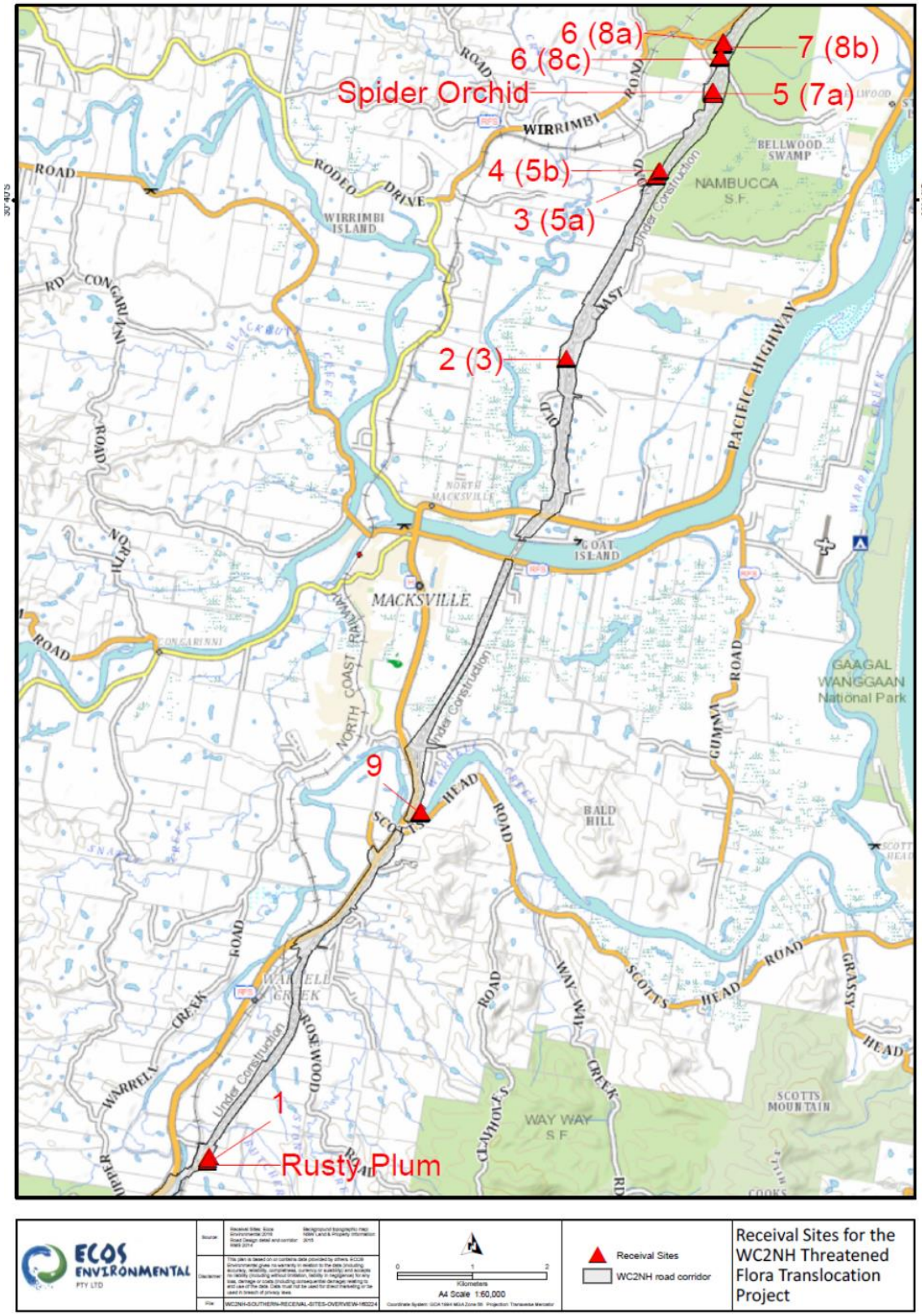


Figure 2: Location of threatened flora translocation receival sites for the WC2NH section of the Pacific Highway upgrade.

Table 1: Translocation receival sites and species translocated. The bracketed identifier is the original number used in selecting the receival sites. Both numbers are still being used.

Receival Site	Species
1 (Cockburns Lane)	Slender Marsdenia, Rusty Plum
2 (3)	Slender Marsdenia
3 (5a)	Slender Marsdenia
4 (5b)	Slender Marsdenia
5 (7a)	Slender Marsdenia, Spider Orchid, Rusty Plum direct seeding, Slender Marsdenia population enhancement.
6 (8a)	Slender Marsdenia, Woolls' Tylophora(?)
7 (8b)	Koala Bells
8 (8c)	Slender Marsdenia
9 (Warrell Creek)	Floyds Grass, Koala Bells population enhancement

2.2.2 Direct Transplanting

All threatened species were translocated from the construction footprint using the direct transplanting method. Direct transplanting involves excavation, transport to the receival site and replanting in one action rather than as a gradual process. Excavation is carried out with an excavator or with hand tools if plants are small. The objective is to remove the shoot system and enough of the root system to enable regeneration and plant survival. Basic horticultural measures are applied such as pruning and watering to minimise transpiration stress, which is the principal cause of mortality during transplanting. Substantial pruning of the shoot system and watering, to ensure high soil moisture is maintained, in the first months are essential to achieve a high survival rate using the direct transplanting method.

Advantages of direct transplanting over other transplanting methods include:

- Relatively fast and cost-effective
- Suited to rough terrain and significant numbers of individuals
- Minimises duration of the translocation process and therefore potential risk of disease and pest transfer to the wild (a risk of propagation)
- Natural soil microflora conditions are maintained by transferring plant and soil material together.

Primack (1996) pointed out other advantages of transplanting: "There are nonetheless ecological advantages to using transplanted plants rather than seeds in reintroduction (translocation) efforts. Plants, particularly adult plants have a higher likelihood of successful establishment than seeds (or seedlings) if they are planted into a suitable site and well-tended. These plants have overcome the most vulnerable stages in their life cycle (seed germination and seedling establishment) so that their chances of surviving in the new habitat are greatly increased. These individuals also have proven genotypes that are free of lethal mutations and adapted to the general environmental conditions. When reintroduction efforts involve reproductively mature adult plants, the new population has the potential to flower, produce and disperse seeds and create a second generation of plants within a year (or so) of transplantation".

Translocation methods applied to each species are described in more detail below.

2.2.3 Slender Marsdenia

2.2.3.1 Salvage Transplanting

Slender Marsdenia transplanting began by marking plants with pink tape at the base and higher up so as not to damage them while digging. The stem usually with leaves was removed in a block of soil about 40 cm wide by 20 cm deep with a spade. Mapped points from the TFMP often included more than one stem at varying distance apart (e.g. 10-50 cm or more). All stems were transplanted, each being treated as a 'stem-individual', although some may have been connected underground. Plants and soil were kept damp during transport to the receival site. The 'stem-individuals' were planted in approximate rows at points pre-marked with pink tape. These points were at regular intervals (5 m) along a row and therefore essentially random (i.e. planting location determined by distance and not a selective bias).

Slender Marsdenia plants (stem individuals) were salvaged and planted at seven receival sites (refer to Table 12016) in February 2015. Additional plants were translocated in 2016 due to a modification to the road design. During transplanting, several individuals found that were not specified in the TFMP were also salvaged. It is not unusual for plants of the species to be missed during surveys because of their well camouflaged growth form. In total, 175 Slender Marsdenia plants were translocated.

The transplants received a thorough watering straight after planting, then watered once every two days for one week and once a week for four weeks, ensuring the soil remained damp. Chicken wire cylinders were installed around individuals to prevent damage by animal grazing, to act as a climbing frame and to facilitate monitoring. Flagging tape was attached to the base of each stem just above the ground, which made it easier to check any stems that died back to see if it was still alive. Flagging tape was attached to each wire cage showing the individual's monitoring number and source code as per the TFMP. Multiple individuals at the same mapped point were indicated by an additional suffix on the source code – e.g. Ml46-7.

2.2.3.2 No Fertiliser

As previous use of fertiliser and soil improvement during translocation of Slender Marsdenia had an adverse effect on growth and survival, fertiliser was not applied during the WC2NH translocation. Experimental comparison of fertiliser and no fertiliser treatments on the NH2U project indicate that even light applications of slow release fertiliser resulted in depressed plant growth (Ecos Environmental 2016).

2.2.3.3 Propagation of Population Enhancement Plants

Propagation of Slender Marsdenia from rhizome pieces collected during transplanting had poor results, as on the NH2U project. Less than 5% of cuttings produced shoots and shoot growth was very slow. The few plants propagated were grown-on for two years and planted out in November 2017.

Slender Marsdenia had previously been recorded flowering in November and ripe pods were collected in December. It is not known if pods grow rapidly to maturity after flowering (i.e. in one or two months), or take longer, although the scant observations suggest they grow rapidly to maturity. On the NH2U project approximately 100 seedlings of Slender Marsdenia were propagated from one seed pod. In contrast to rhizome/tuber cuttings, seedlings grew rapidly, both in the nursery and after planting-out (Ecos Environmental 2016). Propagation of Slender Marsdenia from seed to 30 cm tall seedlings ready for planting-out took only about 8 months on the NH2U project (Ecos Environmental 2016).

Seed propagation was the preferred method of propagation on WC2NH, but no seed pods were found. Large individuals of Slender Marsdenia were located and checked for pods adjacent to the Nambucca Heads to Urunga and the Sapphire to Woolgoolga sections of the Pacific Highway, and Nambucca State Forest adjacent to WC2NH in December 2016.

The study of population genetic structure in Slender Marsdenia conducted for the WC2NH and NH2U projects (Shapcott *et al.* 2016) found genetic evidence that out-crossing was common in Slender Marsdenia, which implied that seed was produced quite frequently. Given the difficulty of finding seed pods for propagation this result was intriguing and two possible explanations have been put forward: (i) it is possible the genetic evidence of outcrossing relates to recent, pre-European ecological conditions when cross-pollination and seed production were more frequent. Forestry, clearing and other impacts have disrupted the ecology of this species, so cross-pollination and seed set occur less frequently now although the genetic imprint of pre-settlement conditions persists. (ii) It is also possible that seed pods are more common than realised. They may be forming on tall individuals in the forest mid-stratum, where the sparse foliage and similar green colouration of Slender Marsdenia vines make them difficult to see. However, tall individuals with thicker stems (still only a few millimetres in diameter) are few and far between. Most stem individuals are small. Also, only one instance of possible seedling recruitment has been observed under natural conditions (a cluster of small plants – probably seedlings – on NH2U). These observations suggest that seed production in current populations is rare.

2.2.4 Woolls' Tylophora

2.2.4.1 Species Identification

Woolls' Tylophora has not been positively identified on the WC2NH project, as no flowering plants were observed. A few plants were identified as possibly this species during TFMP surveys, based on leaf features. However, the leaves of Slender Marsdenia vary in shape and texture and some are similar to Woolls Tylophora leaves. Typically, Slender Marsdenia has a more elongated leaf, pinnate venation, cordate leaf base, paler green colour and is glabrous (without hairs). Woolls' Tylophora, on the other hand, has a broader leaf with purplish tinges, tends to be more 3-veined at the base and is sparsely hairy. The two species flower at different times - Woolls' Tylophora from the Bonville project flowered in late August, whereas Slender Marsdenia populations from the Mid North Coast flowered in November and occasionally later as well.

Only Slender Marsdenia were observed flowering on the WC2NH footprint. If Woolls' Tylophora is in fact present, it appears to be much rarer than Slender Marsdenia.

2.2.4.2 Salvage Transplanting and Population Enhancement

Individuals tentatively identified as Woolls' Tylophora were transplanted using the same method applied to Slender Marsdenia. Both species are vines with tuberous roots. Woolls' Tylophora was translocated to Receival Site 8a, which also received some Slender Marsdenia.

No population enhancement was carried out for Woolls Tylophora as it was not possible to positively identify the species in the absence of flowers. Without knowing we were definitely dealing with plants of this species, propagation efforts were likely to be a waste of time and resources. Seed pods are likely to be as rare as for Slender Marsdenia.

2.2.5 Rusty Plum

2.2.5.1 Salvage Transplanting

Direct transplanting of larger Rusty Plums trees (~10 m high) began by trenching to form a soil-root ball about 1-1.5 m wide and 0.7 m deep. After undercutting the root ball, the trunk-branch system was cut back by at least 50% to remove all foliage. Depending on the size and intactness of the root ball, the trunk was sometimes reduced further. Previous transplanting of this species by Ecos Environmental on the Bonville and S2W projects had shown that survival rate was increased by cutting back the trunk to bring the shoot system (i.e. above ground plant) into balance with the reduced root system of the relatively small root ball (compared to the original in-situ root system) (ref).

All Rusty Plums occurred at Cockburn's Lane at the southern end of the project and were translocated from the footprint to the adjacent road reserve (Receival Site 1). Several Rusty Plums that occurred at Cockburn's Lane but outside the clearing boundary remained in-situ. The transplants received additional watering for a month. Sugar cane mulch was spread around each plant to provide a mild growth stimulant and hessian barriers erected for additional shade as the site was exposed to the afternoon sun. No other fertilisers were used.

2.2.5.1 Population Enhancement by Direct Seeding

The enhancement component of the Rusty Plum translocation aimed to establish additional individuals by direct seedling. Only three Rusty Plum seeds were found in Nambucca State Forest in November 2016 but the same location was searched at the start of November 2017 and about 50 fruits collected. Three seeds were also found beneath a Rusty Plum in the Coffs Harbour Regional Botanical Gardens. Rusty Plum produces a large black fruit containing a single seed about the size of a golf-ball. Seeds were separated from the fleshy outer layer and direct seeded into an area next to Receival Site 5 (7a) on 7 December 2017. This site is a minor gully with moist open forest and a mesic, small tree mid-stratum. As seeds may be taken by animals, and seedlings can also be grazed quite heavily (Ecos Environmental 2015), seed were sown inside wire mesh cylinders. Fourteen cylinders were set up and three or four seeds placed on the soil surface in each cylinder then covered lightly with leaf litter. The cylinders were tagged for monitoring and locations recorded with a GPS.

2.2.6 Spider Orchid

2.2.6.1 Salvage Transplanting

Two mature Spider Orchid plants were salvaged from the highway footprint from Prickly Paperbark (*Melaleuca stypheloides*) trees. The orchids were translocated by cutting off the branch or stem supporting the orchids so there was minimal disturbance of the orchids root system. The branch with orchids was then attached to a suitable small rainforest tree in a gully at Receival Site 5 (7a) in a shaded situation. Apart from watering during transport, no additional watering or other treatment was applied.

2.2.6.2 Population Enhancement

The TFMP aims to propagate additional Spider Orchid plants for population enhancement. As there were not sufficient wild plants to sacrifice some for vegetative division, propagation by seed was proposed. Both plants translocated from the WC2NH upgrade flowered in

spring 2015, 2016 and 2017, but no seed pods were formed. On the NH2U project, one seed pod was formed in a translocated population of 55 Spider Orchids in Spring 2016, but the pod opened in November between site visits before seed could be collected.

2.2.7 Koala Bells

2.2.7.1 Salvage Transplanting

Transplanting of Koala Bells was carried out by digging plants out in a block of soil 40 cm wide by 20 cm deep, pruning the stems back, planting the soil block and watering. Receival Site 8 was the only site in the road reserve with swamp forest similar to Koala Bells habitat. Follow-up watering was carried out. No fertilisers were applied.

2.2.7.2 Population Enhancement

Cuttings of Koala Bells were propagated at Ecos Environmental's nursery in summer 2015-2016 and grown-on in pots. The plants grew rapidly and flowered in summer-autumn 2016, died back over winter then reshot in spring 2016, all while the plants were still in pots. Regrowth in 2016 was less vigorous and small adventitious shoots were produced around the edge of the pots, as observed in some transplanted specimens in the field on NH2U. Twenty plants were introduced to Receival Site 9 at Warrell Creek in January 2017. This site is on alluvial soil and has open ground layer habitat with little competition from other plants, the type of situation Koala Bells seems to prefer.

2.2.8 Floyds Grass

2.2.8.1 Topsoil Stripping

Receival site no. 9 for Floyds Grass on the northern bank of Warrell Creek consisted of two areas – 9a and 9b. As the site was overgrown with exotic Broad-leaved Paspalum (BLP), it was necessary to remove this grass before translocating Floyds Grass to the site. Killing BLP with herbicide would have left seedlings of this species and myriad other weeds from the soil seedbank to contend with. Follow-up spraying of weed germination from the soil seedbank would be impractical, as it is not possible to spray weed seedlings without hitting Floyds Grass which also sends out long runners.

To create conditions suitable for establishment of Floyds Grass, BLP and the uppermost topsoil seedbank was stripped off with an excavator bucket. As the site was on a floodplain with relatively deep topsoil, it was expected that sufficient depth of topsoil would remain for Floyds Grass to establish after carrying out the stripping operation. Preparation of the site was carried out as follows. Firstly, the ground layer vegetation consisting mainly of BLP and Lantana was scrapped off with an excavator bucket. After exposing the soil surface, the top 10 cm of soil was scrapped off and placed to the side of the site. The soil beneath the uppermost 10 cm had a higher clay content, but had reasonable texture and drainage for young plant growth. Sediment fencing was installed around the site to prevent run-off to Warrell Creek and to act as a barrier to deter wallaby grazing.

2.2.8.2 Salvage Transplanting

Small clumps of Floyds Grass approximately 10 cm^2 were dug up with a spade and planted at area 9a. The clumps were watered thoroughly and sugar cane mulch (weed free) spread lightly over the soil surface to protect from raindrop compaction. Follow-up watering was carried out as conditions were dry. 'Seasol' seaweed and fish emulsion fertiliser was applied

two weeks after introduction to stimulate growth. As the site was exposed to the afternoon sun, shade-cloth fences approximately 1 m high and running north-south were erected to provide additional shade. These have since been removed from area 9a.

2.2.8.3 Population Enhancement

To promote population establishment by increasing initial population size, approximately 100 additional Floyds Grass clumps were propagated at Ecos Environmental's nursery and planted at area 9b in March 2016. These plants were propagated from small pieces of runner that broke off during transplanting. As area 9b was more exposed than area 9a, the shade cloth fences installed had a roof to protect from the overhead sun. Hand weeding to remove competing exotic and native species was carried out by Pacifico (the project construction contractors for the Warrell Creek to Nambucca Heads section of the upgrade) workers under the supervision of the plant ecologist, as in area 9a. Although most the soil seedbank had been removed, seed germination occurred from seed buried deeper in the soil of a range of native and exotic species. The density of exotic species was very low but some grew rapidly into large plants, particularly *Phytolacca octandra* (Ink Weed), a large herbaceous shrub. Very little BLP germinated.

2.2.9 Monitoring and Data Analysis

During the construction phase, monitoring was conducted quarterly in 2015 (start of translocations project), biannually in 2016 and yearly in 2017. Monitoring during the operation phase will be carried out annually, including for this report (2018). Andrew Benwell and Jeremy Benwell-Clarke of Ecos Environmental carried out the first operation phase monitoring on 7 and 8 November 2018.

Plant growth and survival was monitored by recording the following data:

- All species except Spider Orchid: Monitoring Number, Date, Line, Source Label (species translocation plant label), Species (Current ID), Overall Condition (see below), Height (cm), New Shoots (Y/N), Comments, Significant Growth (+) or Significant Dieback (-), Coordinates.
- Spider Orchid: Monitoring Number, Date, Source Label, Species, Number of Pseudobulbs with Leaves, Length of the Longest Pseudobulb, New growth, Overall Condition, Coordinates.

The data were entered into an Excel file with separate sheets for each monitoring event.

In analysing the results, species performance and survival were evaluated in terms of species survival and plant condition, the latter scored on a scale of 0 to 5, where zero is dead and 5 is fully mature and reproductive. The scale is defined slightly differently for each species, as indicated in Tables 2-4 below.

Percent Survival was calculated as follows: number of individuals in condition classes (2+3+4+5/total)*100.

When mean species height was calculated it was averaged for all plants present at the start of monitoring in June 2015, therefore included plants that had died back to ground level (i.e. height = 0; condition class 1 or 0 in the case of Slender Marsdenia).

Table 2: Condition scores applied to Slender Marsdenia and Woolls' Tylophora.

Score	Condition
0 – dead	Dead, no sign of reshooting after 1 year
1 –poor	Stem died back to ground level, possibly dead, live stem stub may be present
2 – fair	Plant <75 cm tall, with leaves or leafless, new shoots or active growth present or absent
3 – good	Plant >75 cm tall, stem with leaves, new shoots or active growth present or absent, if stem leafless or leaves discoloured score as 2
4 – advanced	Plant >2.5m tall with >15 leaves
5 – mature	Mature, plant flowering or seeding

Table 3: Condition scores applied to Rusty Plum and Koala Bells.

Score	Condition
0	Dead
1	Leafless and no sign of re-shooting
2	Pruned foliage retained, or small amount of re-shooting after defoliating, or foliage sparse/discoloured (<40 cm tall for Koala Bells)
3	Vigorous re-shooting (>40 cm tall for Koala Bells)
4	Crown recovering, foliage healthy
5	Growing actively, flowering or seeding recorded

Table 4: Condition scores applied to Spider Orchid.

Score	Condition
0	Dead
1	Pseudobulbs discoloured or grazed or withering, no new growth
2	Pseudobulbs healthy in colour, not withering, no new growth
3	Plant small, few healthy pseudobulbs, new growth occurring
4	Several healthy pseudobulbs present, new growth occurring
5	Several good sized, healthy pseudobulbs, flowering or seeding recorded

Species survival rate does not really indicate how individuals are performing. Some may be thriving and others may be barely alive. Breaking down survival into condition classes provides more information on how a species is responding to translocation. In the case of Slender Marsdenia, a more nuanced response was needed so that a closer analysis could shed more light on factors underlying individual growth and survival. Although survival rates for Slender Marsdenia on WC2NH are quite high (see below), plants often remain small or repeatedly grow and die back, and flowering has not been recorded over four years, even though some plants have grown substantially.

To analyse the response of Slender Marsdenia to translocation in more detail, thirteen response categories were defined in terms of the pattern of change in plant height over three years, as shown in Table 5. These were derived by merging the seven monitoring events into a single sheet for each receival site and ascertaining the main syndromes of regrowth pattern and height change. The response syndromes of individuals at each site were tallied and expressed as a percentage of the site total.

Table 5: Definition of categories of plant response (response syndromes) over four years in Slender Marsdenia after translocation. Three main categories of response syndrome were exhibited – D, S and T, which were divided into sub-categories

Code	Response syndromes of transplanted individuals
D	**Dead (or appears to be dead)**
D1	Didn't reshoot
D2	Small shoot then died
D3	Reshot, reached small to medium height (<1.2 m) then died back to ground, some bell-shaped, some db-rs-db
D4	Reshot, grew tall (~2 m+) then died back to ground, possibly dead
S	**Alive but small, growing very slowly, or declining**
S1	Stayed small, most less than 10 cm tall (to 40 cm), little change in 4 years
S2	Continuously small (mostly <0.5 m), dieback to ground and reshot once or twice, still alive
S3	Declining or bell shaped (increase-decrease), to ~130cm at peak, not tiny, continuously alive
S4	Fluctuating – i.e. 'small-medium/tall-small'; or 'grew medium/tall then died back to small'
S5	Delayed response – no reshooting for 6-12 months, small (<1 m)
T	**Thriving, plant tall, continuing to grow, or maintaining size, healthy**
T1	Thrived – tall (1.5 m+), substantial increase in height/number of leaves, or ~maintained tall height (some decreased slightly Nov 18)
T2	Thrived – moderate increase in height (0.5 – 1 m+), or constant height (1 m+)
T3	Died back to ground then reshot vigorously (>1 m)
T4	Small for 5 or 6 events then suddenly grew big

Initial plant size is one of the many factors that may determine an individuals' regrowth response and survival. For Slender Marsdenia, the size of each stem-individual including its rhizome was not recorded during transplanting as this would have meant separating the rhizome from soil. The direct transplanting method aimed to keep soil and rhizome as intact as possible to promote survival. Instead, initial plant size (including rhizome) was assumed to be roughly proportional to and proximated by plant height at the first monitoring event.

2.3 Results

2.3.1 Species Survival Summary

Transplant survival rates after four years for all threatened species excluding Koala Bells were 67-100% (Table 6). The survival rate of Koala Bells after four years was 43%, but this was due to most individuals exhibiting an annual or biennial life cycle (i.e. rapid growth, flowering and seeding, then dying off) after transplanting. Results are described in more detail in Table 6.

See Appendix 1 for photos of translocation sites and species in 2018.

Table 6: Species survival rates (expressed as a proportion of live individuals) four years after translocation (transplanting) on the WC2NH project.

Species/Receival Site	**No. of plants translocated**	**Survival (%)**				
		Aug 2015 (~6 mth)	**Feb 2016 (~1 Yr)**	**Jan 2017 (~2 Yrs)**	**Nov 2017 (~3 Yrs)**	**Nov 2018 (~4 Yrs)**
Slender Marsdenia (*Marsdenia longiloba*)						
Receival Site 1 - Cockburns Lane	27	93	93	75	63	59
Receival Site 2 (3) – Old Coast Rd	17	100	91	93	88	88
Receival Site 3 (5a) – Old Coast Rd	22	81	81	91	73	77
Receival Site 4 (5b) – Old Coast Rd	16	100	94	81	69	69
Receival Site 5 (7a) – Old Coast Rd	57	90	90	72	74	72
Receival Site 6 (8a) – Old Coast Rd	8	88	75	75	75	88
Receival Site 8 (8c) – Old Coast Rd	28	93	100	86	82	79
Total	175	92	91	80	74	74
Rusty Plum (*Niemeyera whitei*)						
Receival Site 1 - Cockburns Lane	7	100	100	86	86	86
Wooll's Tylophora (*Tylophora woollsii* – unconfirmed)						
Receival Site 6 (8a) – Old Coast Rd	6	100	100	100	83	67
Spider Orchid (*Dendrobium melaleucaphilum*)						
Receival Site 5 (7a) – Old Coast Rd	2	100	100	100	100	100
Floyds Grass (*Alexfloydia repens*)						
Receival Site 9a – Warrell Creek	54 clumps	100	94	Substantial cover	Substantial cover	Substantial cover
Receival Site 9b – Warrell Creek	61 clumps	Not planted yet	Not planted yet	98	93	70
Koala Bells (*Artanema fimbriatum*)						
Receival Site 7 (8b) – Old Coast Rd	16	75	63	25	13	6
Receival Site 9 – Warrell Creek	14	Not planted yet	Not planted yet	Not yet planted	57	86
Total	30	75	63	25	34	43

2.3.2 Slender Marsdenia (*Marsdenia longiloba*)

2.3.2.1 Summary

Combining the receival sites, the survival rate of Slender Marsdenia in year 4 had not changed since year 3, remaining at 74% (Table 6). Survivorship per site in year 4 ranged from 59% to 88%, which is almost the same as for year 3 (63% to 88%). Note that for some receival sites there has been an increase in survivorship between monitoring events. For example, survivorship at Receival Site 6 was 75% in November 2017 and 88% in November 2018. This is because Slender Marsdenia often dies back and appears to be dead but then reshoots and grows again.

Approximately 25% of transplants appeared to be dead in November 2018. Understanding why mortalities occur is important for improving translocation methods and assessing whether translocation is feasible for a species. This is discussed in more detail below.

2.4.2.2 Causes of Mortality

Possible causes of mortality identified in previous monitoring reports by Ecos Environmental included:

- Disturbance and damage to the stem and/or root system during transplanting.
- Interactions between plant and habitat, including environmental stress arising from lack of sunlight, water and soil nutrients, or inter-specific competition for scarce resources.
- Inherent growth processes (e.g. stem individuals genetically programmed to grow suddenly drawing on stored food reserves in the tuberous rhizome, but unable to maintain growth, or an imbalance between growth and resources available to sustain growth).
- Natural thinning due to factors that affect survival.
- Sensitivity to microsite/microhabitat heterogeneity.

With regard to the last point, within an area of generally suitable habitat, a likely factor determining whether a translocated individual survives or not is the microsite or point at which it happens to be planted (either deliberately or haphazardly). This is particularly the case for small plant species. Natural habitats generally have high microsite heterogeneity, which partly underlies the difficulty of translocating most small plant species. Some microsites may favour survival and growth more than others. Planting points for the WC2NH project were essentially random with respect to a variable microsite surface, although points with more shade, near rotting logs and away from tree trunks were preferred by some planters. Perhaps this was a mistake and points next to large trees and away from rotting logs would have been better. Regardless of slight biases in choice of site, planting points were random with respect to microsite patterning, so a degree of thinning or population decrease over time seems inevitable.

2.4.2.3 Height/Performance

Mean plant height of Slender Marsdenia for each receival site in year 4 ranged from 24 cm to 84 cm. Note that as mean height was calculated by averaging across all individuals including those with zero height (i.e. appeared to be dead), the mean height of live plants is under-estimated to a minor degree.

There has been a minor decrease in mean height since year 3 for receival sites 1, 2, 4, 5 and 6, but a slight increase for receival sites 3 and 7. No signs of habitat deterioration at the receival sites, or disease or herbivory on plants were observed, therefore, it appears that declines in mean plant height since year 3 (for some sites) were not caused by these factors.

Mean plant height for receival sites has not consistently increased or decreased throughout the monitoring program, rather it has fluctuated. For example, mean plant height for Receival Site 8 in June 2015 was 43.68 cm, it then increased to 69.57 cm in February 2016, decreased to 50.82 cm in January 2017, continued to decrease to 43.96 cm in November 2017 but then increased again to 62.21 cm in November 2018 (this monitoring event).

Monitoring of Slender Marsdenia for the WC2NH project and previously for the NH2U project revealed that the species has an unpredictable life history. Multiple reshooting and dieback events were recorded in a substantial number of plants during four years of monitoring. No one pattern of growth is observed at a site, rather individuals differ in their translocation response, with some growing larger, some declining and some remaining the same, and this varies from year to year.

Changes in mean plant height indicate how well Slender Marsdenia is generally performing at each site but this index can be misleading and does not consider the varying growth syndromes (patterns) that appear to be part of the species life cycle. For this reason a more detailed analysis of individual translocation response syndromes was carried out, the results of which are described below.

Table 7: Mean height (cm) ± standard error of Slender Marsdenia per receival site from the first monitoring in June 2015 to November 2018 (four years after translocation).

Receival site	n	June 2015 (6 months)	Feb 2016 (~1 yr)	Jan 2017 (~2 yrs)	Nov 2017 (~3 yrs)	Nov 2018 (~4 yrs)
Receival Site 1	27	26.51±6.48	39.0±10.43	39.26±10.60	31.07±10.30	24.37±9.54
Receival Site 2 (3)	11	25.64±10.09	60.82±15.50	67.27±13.57	97.09±14.23	84.76±12.73
Receival Site 3 (5a)	22	29.29±7.46	49.76±11.16	46.41±9.51	45.73±9.34	46.27±10.81
Receival Site 4 (5b)	16	38.69±11.44	47.00±14.84	29.44±9.45	31.88±10.67	29.44±11.52
Receival Site 5 (7a)	57	29.54±3.72	51.74±6.78	47.74±7.62	43.78±8.11	35.02±6.35
Receival Site 6 (8a)	8	55.13±22.24	53.00±17.92	60.57±17.55	84.79±18.35	82.13±19.12
Receival Site 8 (8c)	28	43.68±6.39	69.57±9.16	50.82±5.29	43.96±5.43	62.21±10.67

2.4.2.4 Response Syndromes of Transplanted Individuals

As described in the Monitoring and Data Analysis section of this report, responses of Slender Marsdenia individuals to transplanting after four years were placed into three main categories (dead, surviving but weak or declining, and thriving) and 13 sub-categories, as defined in Table 5).

Looking at the ‘dead’ category in Table 8 and Figure 4 we can see that for those individuals that appeared to be dead in spring 2018 (i) a small proportion died without reshooting (D1),

(ii) most either produced a small shoot then died (D2) or grew moderately then died (D3), and (iii) none grew vigorously/tall and then died (D4).

In the second category – alive but small or declining – there are five sub-categories. Out of the 68 individuals that were alive but small most fell into S1 (often less than 10 cm, little change in 4 years). S2 (small individuals that have died back and reshot once or more times) accounted for 17 individuals (Figure 4), followed by S3 (14 individuals), then S4 (8 individuals). No 'S' category individuals fell into S5 (delayed response – no reshooting for 6-12 months).

The third category includes the most vigorous plants, including the tallest and those with most leaves, which in spring 2018 accounted for 61 of the 175 translocated Slender Marsdenia individuals. Out of the 61 'T' category individuals, nearly all (53) fell into T2 (moderate increase in height (0.5 – 1 m+) or constant height (1 m+). T1 accounted for 5 individuals and T3 accounted for 3 individuals. T4 (small for long time then grew large) did not include any individuals in spring 2018.

The overall picture is one of wide variation in individual response to transplanting. In other species such variation is generally related to initial plant size, microsite factors such as sun exposure and a range of other variables related to implementation, follow-up maintenance and other physiological and ecological factors. Slender Marsdenia is a particularly difficult species to interpret results for as many occurrences are apparently clonal (Shapcott *et al.* 2018) and clones are probably broken up during transplanting. Some transplants clearly had larger rhizomes than others, but it was difficult to record this trait consistently during transplanting of 175 individuals. Each individual was excavated in a roughly standardised volume of soil, but the size of the rhizome in that volume varied.

Table 8: Percentage of Slender Marsdenia individuals with specific regrowth response syndromes after translocation (transplanting) at each receival site.

			Receival site					
	Response syndromes of transplanted individuals	**1**	**2 (3)**	**3 (5a)**	**4 (5b)**	**5 (7a)**	**6 (8a)**	**8 (8c)**
D	**Dead (or appears to be dead)**							
D1	Didn't reshoot	3.7	0	4.5	0	5.3	0	0
D2	Small shoot then died	18.5	11.8	9.1	18.8	10.5	0	3.6
D3	Reshot, reached small to medium height (<1.2 m) then died back to ground, some bell-shaped, some db-rs-db	18.5	0	4.5	12.5	8.8	12.5	10.7
D4	Reshot, grew tall (~2 m+) then died back to ground, possibly dead	0	0	4.5	0	3.5	0	7.1
	Sub-total	40.7	11.8	22.7	31.3	28.1	12.5	21.4
S	**Alive but small, growing very slowly, or declining**							
S1	Stayed small, most less than 10 cm tall (to 40 cm), little change in 4 years	11.1	17.64	9.1	43.8	19.3	0	10.7
S2	Continuously small (mostly <0.5 m), dieback to ground and reshot once or twice, still alive	14.8	0	13.6	6.3	10.5	12.5	7.1
S3	Declining or bell shaped (increase-decrease), to ~130cm at peak, not tiny, continuously alive	11.1	0	18.2	0	10.5	0	3.6
S4	Fluctuating – i.e. 'small-medium/tall-small'; or 'grew medium/tall then died back to small'	7.4	0	0	0	5.3	0	10.7
S5	Delayed response – no reshooting for 6-12 months, small (<1 m)	0	0	0	0	0	0	0

	Sub-total	40.7	17.64	40.9	50	46.4	12.5	32.1
T	**Thriving, plant tall, continuing to grow, or maintaining size, healthy**							
T1	Thrived – tall (1.5 m+), substantial increase in height/number of leaves, or ~maintained tall height (some decreased slightly Nov 18)	3.7	0	0	0	1.8	12.5	7.1
T2	Thrived – moderate increase in height (0.5 – 1 m+), or constant height (1 m+)	11.1	70.6	31.8	18.8	24.6	50	35.7
T3	Died back to ground then reshot vigorously (>1 m)	0	0	4.5	0	0	12.5	3.6
T4	Small for 5 or 6 events then suddenly grew big	0	0	0	0	0	0	0
	Sub-total	14.8	70.6	36.4	18.8	26.3	75	46.4
	% Survivorship 4 yrs	59.3	88.2	77.3	68.8	71.9	87.5	78.6
	Total individuals	27	17	22	16	57	8	28

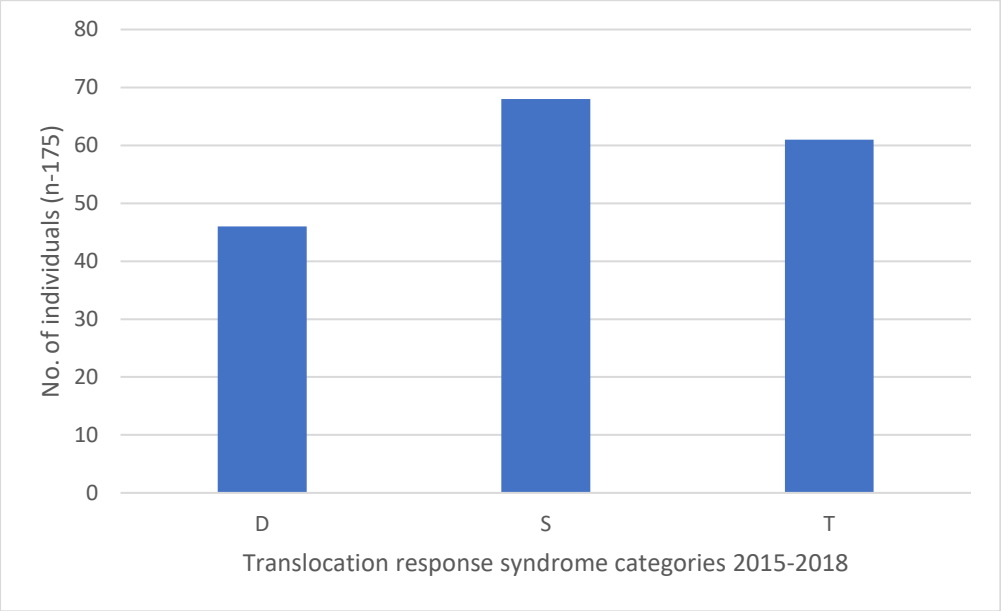


Figure 3: Slender Marsdenia translocation response syndromes across four years for seven receival sites. D = dead, S = surviving, T = thriving.

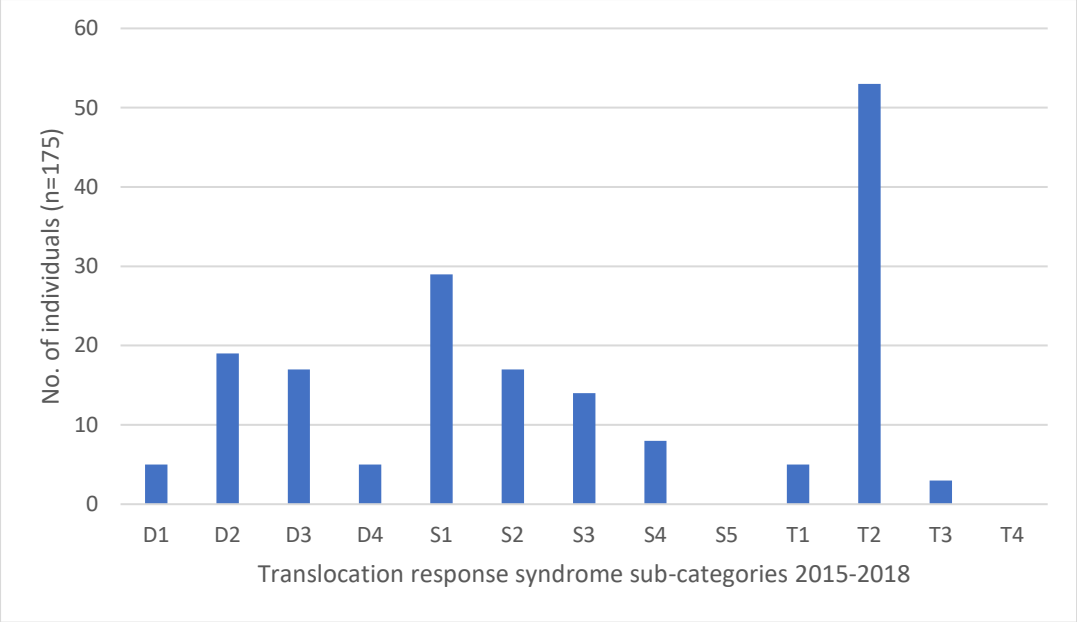


Figure 4: Slender Marsdenia translocation response syndromes across four years, data combined for seven receival sites (see Table 1 for receival sites). D = dead, S = surviving, T = thriving. See Table 5 for definition of each response syndrome sub-category.

2.4.3 Rusty Plum (*Niemeyera whitei*)

Six out of the seven translocated Rusty Plums at Receival Site 1 (Cockburns Lane) survived to year 4. All have continued to increase in height and foliage area since they were transplanted but it will probably be 5-10 years before the largest individuals reach reproductive maturity.

The single transplant mortality was caused by installation of a shade cloth shelter including a roof so the plant was completely enclosed. The shade cloth was high density and with additional shade from vegetation, light exclusion was probably ~80%. This together with increased humidity probably encouraged fungal rot which killed the whole plant, not just the leaves. The plant failed to reshoot after removal of the shade cloth roof.

At Receival Site 5, Rusty Plum seeds had germinated in 8 of the 14 chicken-wire cylinders that were direct-seeded with Rusty Plum seeds in 2017. A total of 11 seedlings were observed ranging from 8-18 cm. Three seeds were sown into each cylinder. A substantial number of seed rooted and failed to germinate, which is probably due to the poor quality of the seed. Few seeds could be found in 2017, Rusty Plum being an intermittent seeder, and most seeds were undersized due to dry conditions.

2.4.4 Wooll's Tylophora (*Tylophora woollsii* – unconfirmed)

At Receival Site 6, four out of six transplanted individuals that are possibly Woolls' Tylophora survived to year 4. These four plants are in good condition, ranging from 79-145 cm in height and new shoots were observed on three of the six plants.

2.4.5 Spider Orchid (Dendrobium melaleucaphilum)

The two translocated Spider Orchid plants survived to year 4 and are in good condition. Both plants flowered in spring 2015 six months after translocation, again in 2016 and 2017, and in 2018. One plant appeared to have flowered recently, most likely earlier in spring. None of the flowering events, however, produced seed pods, possibly due to a lack of pollinators. New pseudobulbs (stem units) were produced each year since translocation demonstrating active growth.

2.4.6 Floyds Grass (*Alexfloydia repens*)

At Receival Site 9 (Warrell Creek), survival and growth of the 54 clumps of Floyds Grass transplanted to Area 9a was 94% in spring 2018 which is equal to or better than in spring 2017 (Table 6). The clumps have spread out and coalesced so it is no longer possible to count individuals. Approximately 44% of the original clumps survived, mostly in the rows closest to Warrell Creek but these have spread out and probably cover one third to a half of the fenced translocation area. This is a considerably larger area than impacted by the highway.

Survival of the 61 clumps introduced to area 9b was about 70% in spring 2018. These have grown slower than in Area 9a as the site is somewhat drier, yet the translocation appears to be progressing successfully.

Removal of exotic ground layer vegetation and topsoil stripping proved to be an effective method of restoring relatively weed-free habitat for Floyds Grass to recolonise. Maintenance, however, was still necessary to remove low numbers of exotics and thin out native tree and shrub regeneration.

The low level of mortality recorded was probably due to water and heat stress as the receival sites were relatively exposed and long periods of hot dry weather have occurred during the monitoring program.

2.4.7 Koala Bells (*Artanema fimbriatum*)

The survival rate of Koala Bells at Receival Site 7 was 76% after six months, 63% after one year, 25% after two years, 13% after three years, and 6% after four years. Most transplants flowered and produced seed in year 1. A fairly rapid decline was recorded in year 2, similar to the pattern of survival recorded for this species on the NH2U translocation project. Only one plant has survived to year 4.

The survival of propagated Koala Bells at Receival Site 9b, however, has increased from 57% in spring 2017 to 86% in Spring 2018 due to recruitment. The small plants observed appeared to be seedling recruits. Ecos Environmental has translocated this species on other highway upgrade projects including NH2U, Oxley Highway (Pt Macquarie), but this is the first instance recorded of recruitment following translocation. Koala Bells is a short-lived ephemeral and like other such species prefers disturbed areas where there is abundant light and minimal competition from other plant species. These environmental conditions were likely created at Receival Site 9b when the topsoil was stripped, enabling introduced Koala Bells to recruit successfully.

Of the 12 individuals alive at Receival Site 9b in spring 2018, 10 were flowering, suggesting that recruitment may continue at this site.

Koala Bells generally flowers and sets seed in the first six months after transplanting in Spring or Summer, then it gradually dies back in Autumn and Winter. Most plants die completely but a few reshoot the following Spring in the second or even third year. This appears to be the species natural life cycle rather than a response induced by translocation. In the bush, Koala Bells can appear suddenly on disturbed sites such as roadsides, then disappear the following year. Some populations have been observed persisting for more than one year, so longevity can apparently vary depending on site conditions, but overall Koala Bells is a relatively short-lived species. Observations on translocated plants indicate that for plants that survive into the second year, regrowth occurs from adventitious shoots produced from persistent lateral roots.

Fertiliser addition during translocation appears to speed up the life cycle, causing plants to flower and seed prolifically then die out in the first year, presumably leaving behind dormant seed in the soil. Fertilisers were not applied to Koala Bells on WC2NH so this factor did not influence results.

Corrective action because of low survival rate is not appropriate or warranted, as Koala Bells is a naturally short-lived species. Most plants are annual or biennial, which is why they die out quickly. Translocation goals were achieved by plants growing to reproductive maturity and seeding their receival sites. If the right disturbance occurs in future, chances are it will reappear from dormant seed in the soil formed as a result of translocation. Note that Koala Bells is a nationally rare (ROTAP – Rare or Threatened Australian Plants) species, but not a listed threatened species under environmental legislation.

2.5 Performance Assessment

Performance criteria were met (Table 9) and therefore no corrective actions are required.

Table 9: Performance criteria for Threatened Translocation Areas monitoring.

Performance criteria	Yes/No
1. All recorded directly impacted individuals were translocated.	Yes
2. At least 60% of transplant and enhancement individuals are surviving after the first year, 50% after five years and 40% after eight years.	Yes – survival rate between 67% and 100% in year 4 (excluding Koala Bells but this species is a short-lived ephemeral that persists in the soil seedbank)
3. At the end of the monitoring program at least 50% of surviving individuals have a Condition Class of 3.	Not applicable yet

2.6 Evaluation of Methods and Cost-effectiveness

The translocation methods applied for the WC2NH threatened flora translocation achieved relatively high survival rates for all species after four years (>60%) for all threatened species except the annual/biennial species Koala Bells (reasons explained above). The general approach to translocation was based on the ANPC guidelines for the translocation of threatened plants in Australia (ANPC 2004). Methods were developed for WC2NH taking into consideration the results of previous translocation projects involving the subject

threatened species, including the NH2U, Bonville and S2W threatened flora translocation projects.

Methods were applied that aimed to achieve a satisfactory translocation outcome while keeping costs to a reasonable level. A full evaluation of the costs of the project would require an analysis of input to the threatened flora translocation project by Ecos Environmental, Geolink and Pacifico which is beyond the scope of this report.

2.7 Work Plan for Year 5 (December 2018 – December 2019)

Table 10: Work plan for Threatened Translocation Areas for the period of December 2018 – December 2019.

Task	**Time**
Monitoring	
Second yearly operation phase monitoring	November 2019 (to coincide with flowering of Slender Marsdenia and Rusty Plum)
Reporting	
Second yearly operation phase monitoring report	November-December 2019

3 In-Situ Threatened Flora Populations

3.1 Methods

The In-situ Threatened Flora Populations component of the TFMP comprises the following threatened plant species:

- Maundia (*Maundia triglochinoides*)
- Rusty Plum (*Niemeyera whitei*)
- Slender Marsdenia (*Marsdenia longiloba*)
- Spider Orchid (*Dendrobium melaleucaphilum*)
- Woolls' Tylophora (*Tylophora woollsii*).

Individuals of these threatened species were located and tagged before clearing and construction of the WC2NH section of the Pacific Highway began. All individuals occurred within the project boundary but outside the clearing limit (Figures 5-9) and have remained in-situ during the pre-construction, construction and operation phases of the upgrade.

GeoLINK conducted pre-construction and construction monitoring of the in-situ threatened species between January 2015 and October 2017. The following identification and condition data were recorded for each in-situ plant:

- Genus and species
- Plant identification number
- Overall plant condition scored on scale between 0 and 5 (see Tables 2-4)
- Presence of flowers and/or fruit
- Any new growth
- Any recruitment

- Any weed infestations or other impacts.

See *Warrell Creek to Nambucca Heads Monitoring of In-situ Threatened Flora (Annual Report – Spring 2017)* (GeoLINK 2017) for more information.

Andrew Benwell and Jeremy Benwell-Clarke of Ecos Environmental conducted the first yearly operation phase monitoring of the in-situ threatened species on 7 and 8 November 2018. All tagged plants were located and the same condition data as recorded by GeoLINK were collected. Additionally, Ecos Environmental recorded the height of each individual to assess plant growth throughout the monitoring program.

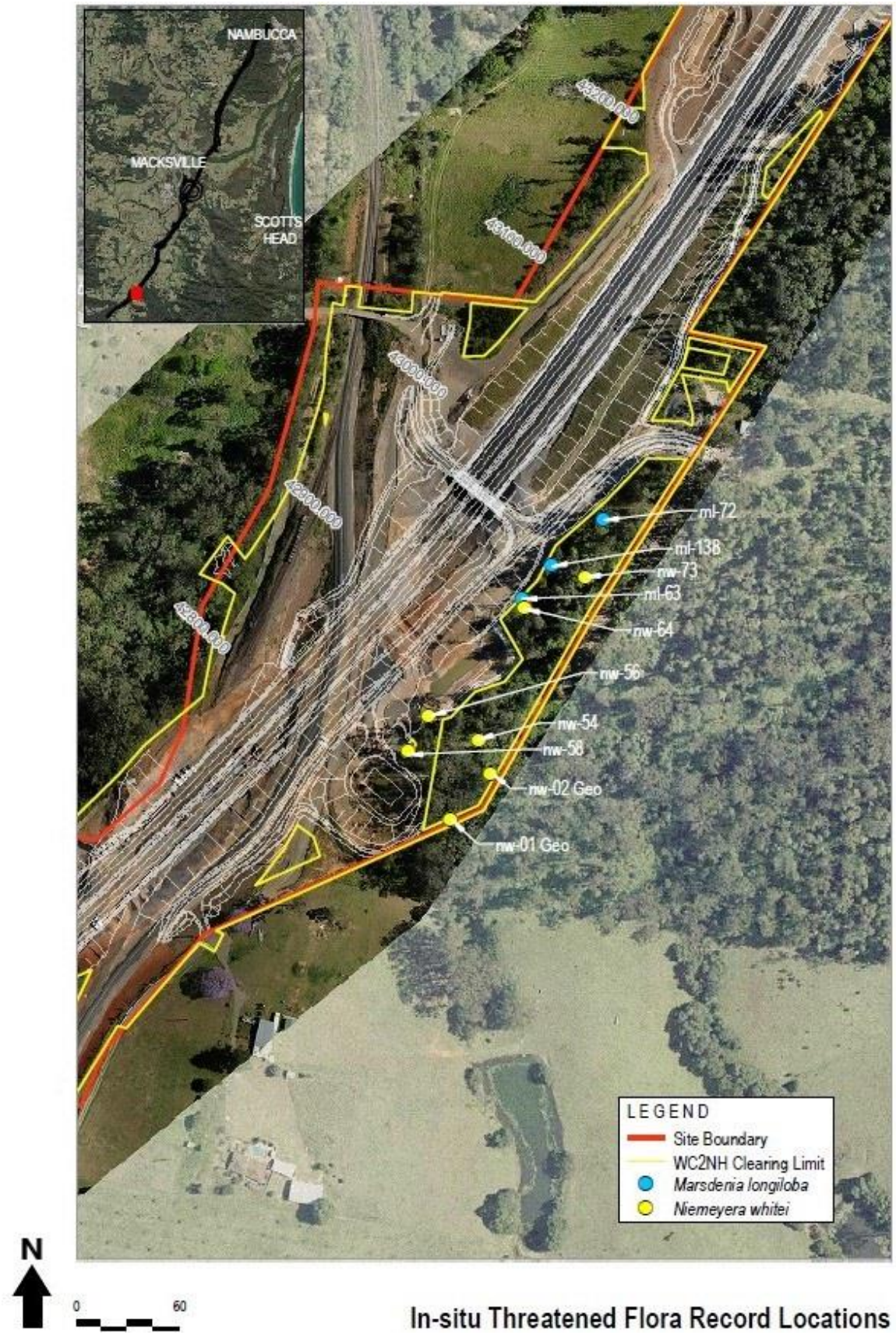


Figure 5: In-situ Slender Marsdenia and Rusty Plum at Cockburns Lane, WC2NH. Map sourced from GeoLINK (2017).

Figure 6: Maundia population at Nambucca Floodplain, WC2NH. Map sourced from GeoLINK (2017).

Figure 7: In-situ Slender Marsdenia, WC2NH. Map sourced from GeoLINK (2017).

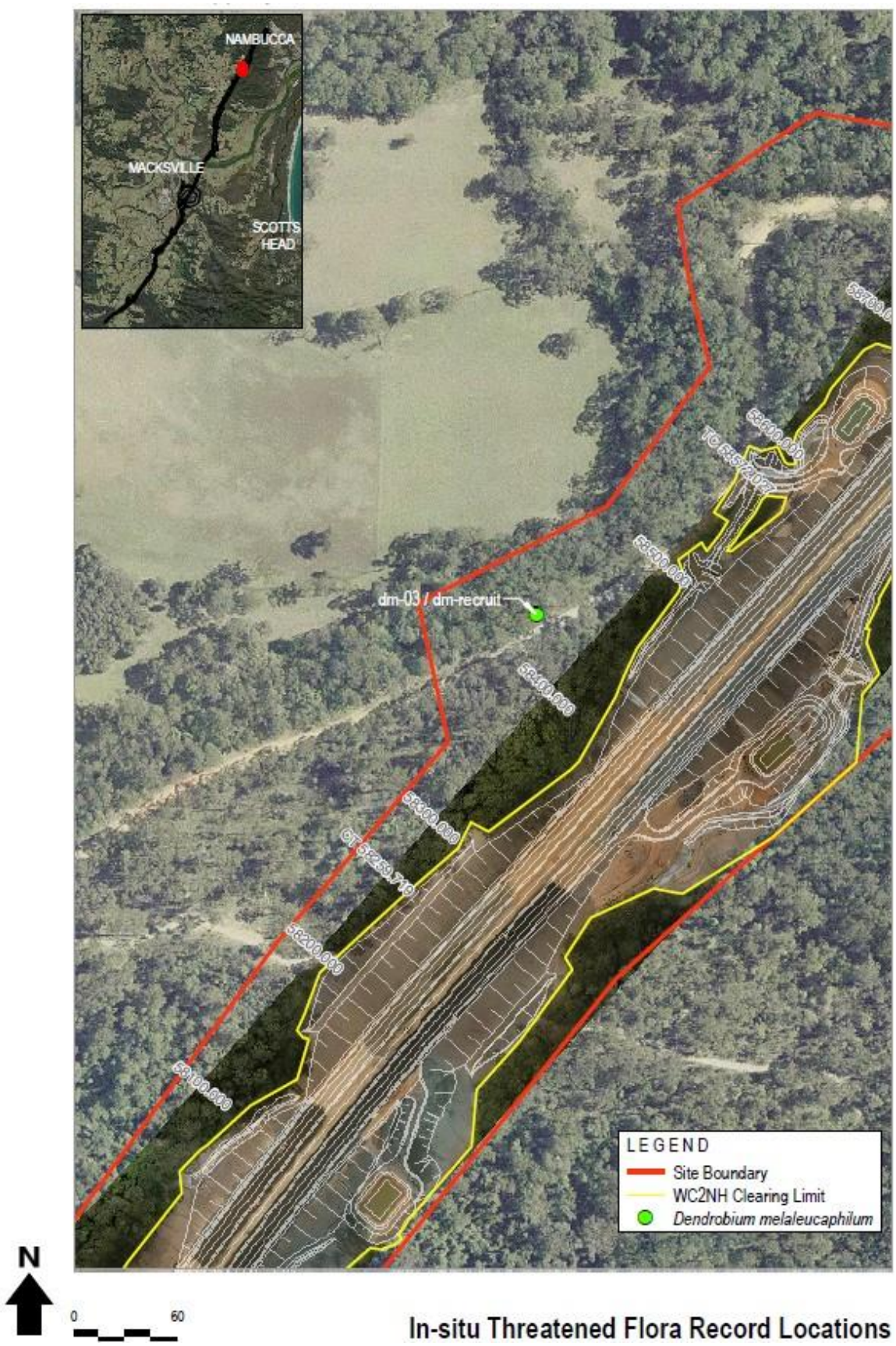


Figure 8: In-situ Spider Orchid, WC2NH. Map sourced from GeoLINK (2017).

Figure 9: In-situ Slender Marsdenia, WC2NH. Map sourced from GeoLINK (2017).

3.2 Results

3.2.1 Maundia (Maundia triglochinoides)

The population of Maundia at the Nambucca Floodplain is in a patch about 50 m by 20 m, with the long edge running parallel to the highway. The plant community canopy height reaches 10-13 m and is dominated by *Melaleuca quinquenervia*. When Ecos Environmental visited the site in November 2018, the water depth was about 10 cm. Crown cover (%) of Maundia in the 50 m by 20 m patch was 40% (Table 11), which is an increase from spring 2017 when GeoLINK last monitored the population. In November 2018 Ecos Environmental also observed flowers on some plants, new growth on some plants and signs of recent recruitment. No evidence of disturbance to the population was observed.

See Appendix 2 for photos of the in-situ threatened plant species in November 2018.

3.2.2 Spider Orchid (Dendrobium melaleucaphilum)

The mature and recently recruited Spider Orchid plants were in healthy condition in November 2018. The mature plant appeared to have recently flowered – most likely earlier in spring that year – but no fruit were observed. The number of pseudobulbs of the mature plant had increased since spring 2017 (Table 12). The overall condition of the recruit remained the same since last year (condition score of 3).

3.2.3 Rusty Plum (*Niemeyera whitei*)

All seven Rusty Plum individuals in-situ at Cockburns Lane were in healthy condition in November 2018 (Table 13). Two individuals were fruiting – nw-73 and nw-64. Six fruits were observed on the former and 3 fruits were observed on the latter. These two individuals were flowering in spring 2017 but not fruit were observed (GeoLINK 2017).

No fruit were observed on the other 5 in-situ plants in November 2018 but they all appeared to be healthy and received a condition score of 4.

In spring 2016, nw-56 appeared to be suffering from construction-related edge effects as its leaves had turned yellow and become stunted (GeoLINK 2017). For this reason supplementary watering was carried out by Pacifico in 2016 and 2017, which appeared to have been beneficial as the health and growth of nw-56 improved. nw-56 was also in good condition in spring 2018, suggesting that it is no longer suffering from edge effects.

The habitat condition at Cockburns Lane in November 2018 was generally good. Lantana was scattered throughout the site, which did not appear to be having any negative effects on Rusty Plum or Slender Marsdenia (also occurs at site, see below), but could threaten their health and survival in the future if it were to further invade the site.

3.2.4 Slender Marsdenia (*Marsdenia longiloba*)

The monitoring program includes five in-situ Slender Marsdenia individuals across three sites (Table 14). Monitoring Slender Marsdenia through time can be difficult as plants often die back and reshoot and new stems emerge from underground rhizomes away from old stems, making it appear that plants have changed location. This is most likely part of Slender Marsdenia's natural life cycle rather than a response to human-related disturbances.

The survival rate of the in-situ Slender Marsdenia was 62% at the finish of clearing (October 2015) and 60% at the end of years 1-3 (GeoLINK 2017). In November 2018, Slender

Marsdenia was actively growing (i.e. green stem and leaves) in all five in-situ locations, suggesting plants had died back in the previous years but were still alive as stem bulbs underground. In most locations there was more than one stem and so height and plant condition was recorded for the largest stem. The height (of the largest stem) of individuals ranged from 8 to 300 cm and their condition score ranged from 2 to 4 (Table 14).

In November 2018, the in-situ location consisted of a clonal patch of about 10 stems growing around the base of a large *Eucalyptus microcorys* tree. The largest stem was 100 cm and most stems had new growth. There were additional Slender Marsdenia plants immediately adjacent to this in-situ location which could have been included in GeoLINK's count of 23 stems in 2017. The number of stems appears to have increased at this location since 2015 but as no flowering or fruiting has been recorded, recruitment is mostly likely by asexual means (i.e. production of stems from underground rhizomes).

Two small stems about 2 m apart were recorded there in November 2018, both with new shoots. In 2015, stem height was 40 cm and increased to 50 cm in 2017. Die back appears to have occurred after 2017 as stem height was only 8 cm in November 2018.

Specimens ml-72, ml-138 and ml-63 occur at Cockburns Lane (same site as in-situ Rusty Plum). In November 2018, stem heights for ml-72, ml-138 and ml-63 were 40 cm, 90 cm and 300 cm, respectively. The height of ml-63 (300 cm) increased substantially since spring 2017 when it was 120 cm.

Table 11: In-situ threatened flora monitoring results for Maundia (*Maundia triglochinoides*). PC (pre-construction) 2015 and Spr (spring) 2017 data recorded by GeoLINK, Spr 2018 data recorded by Ecos Environmental.

Maundia (*Maundia triglochinoides*)																
Population	Cover-Abundance and (Condition Class Score)			Flower/ Fruit Present			New Growth			Recruitment			Damage/ Disturbance			Site Conditions
	PC 2015	Spr 2017	Spr 2018	PC 2015	Spr 2017	Spr 2018	PC 2015	Spr 2017	Spr 2018	PC 2015	Spr 2017	Spr 2018	PC 2015	Spr 2017	Spr 2018	
Nambucca Floodplain	10-20% (3)	10-20% (3)	40% (5)	N	N	Y	N	Y	Y	N	Y	Y	N	N	N	Canopy height 10-13 m with *Melaleuca quinquenervia* dominant species; ground stratum 100% crown cover; water depth 10 cm; few exotics.

Table 12: In-situ threatened flora monitoring results for Spider Orchid (*Dendrobium melaleucaphilum*). PC (pre-construction) 2015 and Spr (spring) 2017 data recorded by GeoLINK, Spr 2018 data recorded by Ecos Environmental. Y = yes, N = no.

Plant ID #	Length of longest pseudobulb (cm)			Leaf Condition			Number of pseudobulbs with leaves			New Growth			Recruitment			Damage/ Disturbance			Site Conditions	GeoLINK notes (PC 2015-Spr 2017)	Ecos Environmental notes (Spr 2018)
	PC 2015	Spr 2017	Spr 2018	PC 2015	Spr 2017	Spr 2018	PC 2015	Spr 2017	Spr 2018	PC 2015	Spr 2017	Spr 2018	PC 2015	Spr 2017	Spr 2018	PC 2015	Spr 2017	Spr 2018			
3	30	40	35	2	4	5	6	20	50+	Y	Y	N	N	N	N	N	N	N	Canopy height 25 m and crown cover approx 90% comprised of Eucalyptus spp.	Very healthy with signs of increased flowering activity.	Appears to have flowered prolifically recently
DM Recruit	-	10	12	-	3	3	-	-	4	-	Y	N	-	N	N	-	N	N		This new recruit was first observed during Spring 2016.	

Table 13: In-situ threatened flora monitoring results for Rusty Plum (*Niemeyera whitei*). PC (pre-construction) 2015 and Spr (spring) 2017 data recorded by GeoLINK, Spr 2018 data recorded by Ecos Environmental. Y = yes, N = no.

Plant ID #	Height (cm)			Leaf Condition			Flower/ Fruit Present			New Growth			Recruitment			Damage/ Disturbance			Site Conditions
	PC 2015	Spr 2017	Spr 2018	PC 2015	Spr 2017	Spr 2018	PC 2015	Spr 2017	Spr 2018	PC 2015	Spr 2017	Spr 2018	PC 2015	Spr 2017	Spr 2018	PC 2015	Spr 2017	Spr 2018	
NW58	700	750	800	5	4	4	N	N	N	Y	Y	Y	N	N	N	N	N	N	Canopy height 20 m with crown cover 70%; some medium to large patches of Lantana scattered throught site.
NW56	100	130	120	5	3	4	N	N	N	Y	Y	Y	N	N	N	N	N	N	
NW73	600	650	700	5	5	5	N	Y	Y	Y	Y	N	N	N	N	N	N	N	
NW54	400	500	600	5	5	4	N	N	N	Y	Y	N	N	N	N	N	N	N	
NW64	500	650	800	5	5	5	N	Y	Y	Y	Y	N	N	N	N	N	N	N	
NW01-Geo	-	450	450	-	5	4	-	N	N	-	Y	N	-	N	N	-	N	N	
NW02-Geo	-	500	500	-	5	4	-	N	N	-	Y	N	-	N	N	-	N	N	

Table 14: In-situ threatened flora monitoring results for Slender Marsdenia (*Marsdenia longiloba*). PC (pre-construction) 2015 and Spr (spring) 2017 data recorded by GeoLINK, Spr 2018 data recorded by Ecos Environmental. Y = yes, N = no

Plant ID #	Height (cm)			Leaf Condition			Flower/ Fruit Present			New Growth			Recruitment			Damage/ Disturbance			Site Conditions	GeoLINK notes (PC 2015-Spr 2017)	Ecos Environmental notes (Spr 2018)
	PC 2015	Spr 2017	Spr 2018	PC 2015	Spr 2017	Spr 2018	PC 2015	Spr 2017	Spr 2018	PC 2015	Spr 2017	Spr 2018	PC 2015	Spr 2017	Spr 2018	PC 2015	Spr 2017	Spr 2018			
ML93	5	5 - 60	100	3	1 - 4	2	N	N	N	N	Y	Y	N	Y	N	N	N	N	Canopy height 20 m; crown cover 100% with Eucalyptus microcorys dominant species.	15 live plants now within 1 m radius of subject plant. All range from 2 – 4 in condition class. Some plants recorded during spring 2016 have died back however new recruits have also been recorded and are now at a count of 23 flagged individual plants.	Clonal patch of about 10 stems around base of Eucalyptus microcorys.
ML132	40	50	8	3	3	2	N	N	N	Y	Y	Y	N	Y	N	N	N	N	Canopy height 25 m; crown cover 80%	During Spring 2016 partially natural die back was recorded. The plant recorded during spring 2017 is fresh, green with new growth indicating possibly a new plant to the one previously recorded.	Prostrate; another stem 2 m away, which was tagged with flagging tape
ML72	5	100	40	2	1	2	N	N	N	N	N	N	N	N	N	N	N	N	Canopy height 20 m; crown cover 70%	Natural die back of the stem, possibly live stem bulb. No obvious signs of construction related impacts.	
Ml138	5	230	90	2	4	3	N	N	N	N	Y	Y	N	N	N	N	N	N		Tall plant with mature leaves some yellowing.	

ML63	10	120	300	2	1	4	N	N	N	N	N	Y	N	N	N	N	N	N	Natural die back of the stem, possibly live stem bulb. No obvious signs of construction related impacts.	

3.3 Conclusion

The survival rate of in-situ plants at the end of Year 4 (spring 2018) was 100% for all four threatened species (Table15). For Slender Marsdenia, survival rate increased from previous years, indicating that plants appeared dead but stems later reshot from underground rhizomes.

One hundred percent of plants were in good condition (class 3 or >) for all species except Slender Marsdenia (40% in good condition). This species, however, regularly dies back and reshoots meaning the condition of plants (as defined by above ground characteristics) will fluctuate considerably.

No signs of construction-related impacts were observed in spring 2018 and the monitoring results meet the performance criteria – *survival rate at the end of Years 4-8 is >70%* and *of surviving plants at end of each year >75% are in good condition (class 3 or >)* – and therefore no corrective actions are required. Note that >75% of in-situ Slender Marsdenia plants do not have a class score of 3 or > but this is not of concern for reasons described above.

Table 15: Performance measures for In-situ Threatened Flora Populations monitoring.

Species	Survival rate at finish of clearing (October 2015/ Spring 2015) is 100%, no accidental damage due to clearing	Survival rate at end of Years 1-3 is >80%	Survival rate at end of Year 4 (2018)	Survival rate at the end of Years 4-8 is >70%	Of surviving plants at end of each year >75% are in good condition (class 3 or >)			
					Year 1 - 2015	Year 2 - 2016	Year 3 - 2017	Year 4 - 2018
Spider Orchid (*Dendrobium melaleucaphilum*)	Yes - 100% survival No accidental damage due to clearing	Yes - 100% survival	Yes - 100%	Not applicable yet	Yes - 100% in good condition	Yes - 100% in good condition, with new recruit. recorded also in good condition (score 3)	Yes - 100% (including new recruit) in good condition (Score 4)	Yes - 100% with one plant reproductive
Maundia (*Maundia triglochinoides*)	Yes - 100% survival No accidental damage due to clearing	Yes - 83% survival	Yes - 100%	Not applicable yet	Yes - 100% in good condition (score 4)	Yes - 100% in good condition (score 5)	Yes - 100% of visible plants in good condition (score 3)	Yes - 100% with some plants reproductive
Rusty Plum (*Niemeyera whitei*)	Yes - 100% survival No accidental damage due to clearing	Yes - 100% survival	Yes - 100%	Not applicable yet	Yes - 100% in good condition (score 4 - 5)	Yes - 80% in good condition (score 2 - 5)	Yes - 100% in good condition (score 3 - 5)	Yes - 100% with some plants reproductive
Slender Marsdenia (*Marsdenia longiloba*)	No - 62% of plants were recorded as living But no construction related impacts were recorded	No - 60%	Yes - 100%	Not applicable yet	No - 62% (5 of 8 records) recorded scores 0 - 3	Yes - 100% (5 of 5 records) recorded scores 3 - 4	No - 60% (3 of 5 records) recorded scores 1 - 4	No - 40% in good condition

4 Slender Marsdenia and Woolls' Tylophora Habitat Condition

4.1 Methodology

This component of the TFMP aims to monitor Slender Marsdenia and Woolls' Tylophora habitat within the indirect impact zone – i.e. within 10 m of the edge of clearing – for potential edge effects and declines in habitat condition. The study design involves ten permanent plots along the edge of clearing in known Slender Marsdenia and Woolls' Tylophora habitat (Figures 10-12). Each plot is 10 m * 20 m with the long axis parallel to the edge of clearing. Within each plot, the following vegetation and landscape attributes are measured:

- Native vegetation structure (according to Native Vegetation Interim Type Standard)
- Level of weed incursion (measured by summing the abundance of all exotic species)
- Microclimate class (Table 16).

The plots were established by GeoLINK on 26 November 2015 around the time that clearing operations in the northern zone of the project were being completed. The plots were again monitored by GeoLINK during autumn and spring 2016 and spring 2017. See GeoLINK (2017) for more information.

On 7 and 8 November 2018, Andrew Benwell and Jeremy Benwell-Clarke of Ecos Environmental carried out the first yearly operation phase monitoring of the ten plots. The plots were located and data on the above parameters were collected. Native vegetation structure was measured according to Roads and Maritime Services (2018) which states that: "Structure consists of the height, crown cover and dominant species in each vegetation layer and will be recorded according to the current OEH vegetation standard (Native Vegetation Interim Type Standard –http://www.environment.nsw.gov.au/research/VISplot.htm)."- p27.

Ecos Environmental was sent GeoLINK (2017) after the data were collected and when it was read it became apparent that GeoLINK measured native vegetation structure slightly different to the Interim Type Standard. Specifically, overall crown cover was estimated for each stratum rather than individually for the three most dominant species. As Ecos Environmental followed the Interim Type Standard as per Roads and Maritime Services (2018), our vegetation structure data had to be compared qualitatively rather than quantitatively with GeoLINK's data. Appendix 4 includes GeoLINK (2017) data on vegetation structure.

Table 16: Microclimate exposure classes for Slender Marsdenia and Woolls' Tylophora habitat.

Microclimate Class (less exposed to more exposed)	**Microclimate Type**
1	Sheltered aspect (e.g. south) and vegetation understorey slightly more open and exposed than before clearing.
2	Sheltered aspect (e.g. south) and vegetation understorey moderately more open and exposed than before clearing.
3	Sheltered aspect (e.g. south) and vegetation understorey much more open and exposed than before clearing.
4	Exposed aspect (e.g. east, north and west) and vegetation understorey slightly more open and exposed than before clearing.
5	Exposed aspect (e.g. east, north and west) and vegetation understorey moderately more open and exposed than before clearing.
6	Exposed aspect (e.g. east, north and west) and vegetation understorey much more open and exposed than before clearing.

Figure 10: Slender Marsdenia and Woolls' Tylophora Habitat monitoring quadrats 5, 6, 7 and 8, WC2NH. Map sourced from GeoLINK (2017).

Figure 11: Slender Marsdenia and Woolls' Tylophora Habitat monitoring quadrats 9 and 10, WC2NH. Map sourced from GeoLINK (2017).

Figure 12: Slender Marsdenia and Woolls' Tylophora Habitat monitoring quadrats 1, 2, 3 and 4, WC2NH. Map sourced from GeoLINK (2017).

4.2 Results

Comparing (qualitatively) the vegetation structure data recorded by Ecos Enviromental (Table 18) with that recorded by GeoLINK (Appendix 4), no major changes in vegetation structure could be inferred.

It appears that since spring 2017 the level of weed incursion has increased in some plots but decreased in others (Table 17). All changes, however, are minor with weed crown cover remaining far below the performance measure threshold of 25% at the end of year 4.

The data also indicate that the microclimate of some plots in spring 2018 differs from previous years. Specifically, that plots 6, 7, 8, 9 and 10 became more exposed. The data, however, should be interpreted cautiously as it were collected by two different observers – GeoLINK from 2015-2017 and Ecos Environmental in 2018 – and therefore likely reflects observer variability. In the field, Ecos Environmental was of the impression that the vegetation understorey of plots was either moderately or much more exposed than before clearing. Consequently, no plots were assigned a microclimate class of 1 or 4 (for different aspects but both meaning only slightly more exposed than before clearing). GeoLINK, on the other hand, assigned plots 6, 7, 8, 9 and 10 either a 1 or 4 depending on their aspect.

See Appendix 3 for photos of each Slender Marsdenia and Woolls' Tylophora habitat condition plot in 2018.

Table 17: Weed level and microclimate class of Slender Marsdenia and Woolls' Tylophora habitat plots.

Plot	Weed Level (% crown cover)	Microclimate Class
1	Lantana	
Spring 15 (GeoLINK)	<5%	5
Autumn 16 (GeoLINK)	5	5
Spring 16 (GeoLINK)	5	5
Spring 17 (GeoLINK)	5	5
Spring 18 (Ecos)	<5%	5
2	Lantana, Whisky Grass	
Spring 15 (GeoLINK)	<5%	5
Autumn 16 (GeoLINK)	5	5
Spring 16 (GeoLINK)	10	5
Spring 17 (GeoLINK)	10	5
Spring 18 (Ecos)	2	5
3	Lantana	
Spring 15 (GeoLINK)	<5%	1
Autumn 16 (GeoLINK)	<5%	1
Spring 16 (GeoLINK)	<5%	1
Spring 17 (GeoLINK)	<5%	1
Spring 18 (Ecos)	0	2
4	Lantana	
Spring 15 (GeoLINK)	0	2
Autumn 16 (GeoLINK)	0	2
Spring 16 (GeoLINK)	0	2

Plot	Weed Level (% crown cover)	Microclimate Class
Spring 17 (GeoLINK)	0	2
Spring 18 (Ecos)	<5%	2
5	Lantana, Setaria	
Spring 15 (GeoLINK)	<5%	5
Autumn 16 (GeoLINK)	<5%	5
Spring 16 (GeoLINK)	<5%	5
Spring 17 (GeoLINK)	<5%	5
Spring 18 (Ecos)	<5%	5
6	Lantana	
Spring 15 (GeoLINK)	5	4
Autumn 16 (GeoLINK)	5	4
Spring 16 (GeoLINK)	5	4
Spring 17 (GeoLINK)	5	4
Spring 18 (Ecos)	<5%	5
7	Broad-leaved Paspalum	
Spring 15 (GeoLINK)	0	1
Autumn 16 (GeoLINK)	0	1
Spring 16 (GeoLINK)	0	1
Spring 17 (GeoLINK)	0	1
Spring 18 (Ecos)	<5%	2
8	Lantana	
Spring 15 (GeoLINK)	5	1
Autumn 16 (GeoLINK)	5	1
Spring 16 (GeoLINK)	7	1
Spring 17 (GeoLINK)	5	1
Spring 18 (Ecos)	1	2
9	Lantana, Broad-leaved Paspalum, Coastal Morning Glory	
Spring 15 (GeoLINK)	5	1
Autumn 16 (GeoLINK)	5	1
Spring 16 (GeoLINK)	<5%	1
Spring 17 (GeoLINK)	<5%	1
Spring 18 (Ecos)	3	2
10	Lantana, Billygoat Weed	
Spring 15 (GeoLINK)	<5%	4
Autumn 16 (GeoLINK)	<5%	4
Spring 16 (GeoLINK)	<5%	4
Spring 17 (GeoLINK)	<5%	4
Spring 18 (Ecos)	2	5

Table 18: Vegetation structure of ten Slender Marsdenia and Woolls' Tylophora habitat monitoring plots, WC2NH. Data recorded November 2018 by Ecos Environmental.

Stratum	Dominant species	Cover (% crown cover)	For the entire		
Plot 1					
Upper	*Eucalyptus grandis*	10	Upper stratum Height to crown (m) min-mode-max		
Upper	*Syncarpia glomulifera*	15			
Upper			20	20	30
Mid	*Lophostemon confertus*	20	Mid stratum Height to crown (m) min-mode-max		
Mid	*Cissus hypoglauca*	65			
Mid	*Acacia binervata*	15	4	5	10
Lower	*Blechnum cartilagineum*	30	Lower stratum Height to crown (m) min-mode-max		
Lower	*Dodonaea triquetra*	10			
Lower	*Cordyline stricta*	10	0.5	2	4
Plot 2					
Upper	*Syncarpia glomulifera*	40	Upper stratum Height to crown (m) min-mode-max		
Upper	*Eucalyptus microcorys*	20			
Upper	*Allocasurina torolosa*	10	15	24	28
Mid	*Cissus hypoglauca*	40	Mid stratum Height to crown (m) min-mode-max		
Mid	*Calicoma seratifolia*	15			
Mid	*Trochocarpa laurina*	15	2	8	15
Lower	*Blechnum cartilagineum*	15	Lower stratum Height to crown (m) min-mode-max		
Lower	*Morinda jasminoides*	20			
Lower	*Cryptocarya rigida*	30	0.5	1	2
Plot 3					
Upper	*Syncarpia glomulifera*	15	Upper stratum Height to crown (m) min mode max		
Upper	*Eucalyptus grandis*	30			
Upper	*Eucalyptus ancophila*	10	28	28	30
Mid	*Schizomeria ovata*	10	Mid stratum Height to crown (m) min mode max		
Mid	*Callicoma seratofolia*	30			
Mid	*Cissus hypoglauca*	30	4	5	12
Lower	*Blechnum cartilagineum*	30	Lower stratum Height to crown (m) min mode max		
Lower	*Livistonia australis*	30			
Lower	*Ripognum forcetianum*	15	0.5	1	3
Plot 4					
Upper	*Eucalyptus grandis*	30	Upper stratum Height to crown (m) min mode max		
Upper	*Eucalyptus pilularis*	10			
Upper			20	30	30
Mid	*Livistonia australis*	5	Mid stratum Height to crown (m) min mode max		
Mid	*Alphitonia excelsa*	20			
Mid	*Synoum glandulosum*	10	4	5	15
Lower	*Cissus hypoglauca*	50	Lower stratum Height to crown (m) min mode max		
Lower	*Gahnia sieberana*	15			
Lower	*Lepidosperma laterale*	5	0.5	1	2

Stratum	Dominant species	Cover (% crown cover)	For the entire		
Plot 5					
Upper	*Syncarpia glomulifera*	40	Upper stratum Height to crown (m) min mode max		
Upper	*Glochidion ferdinandii*	10			
Upper	*Gmelina leichhardtii*	10	15	18	20
Mid	*Livistonia australis*	15	Mid stratum Height to crown (m) min mode max		
Mid	*Guioa semiglauca*	25			
Mid	*Cissus hypoglauca*	20	7	10	12
Lower	*Cordyline stricta*	20	Lower stratum Height to crown (m) min mode max		
Lower	*Gahnia aspera*	15			
Lower	*Lomandra longifolia*	10	0.8	1	1.5
Plot 6					
Upper	*Eucalyptus pilularis*	40	Upper stratum Height to crown (m) min mode max		
Upper	*Lophostemon confertus*	20			
Upper	*Eucalyptus microcorys*	20	15	22	27
Mid	*Trochocarpa laurina*	15	Mid stratum Height to crown (m) min mode max		
Mid	*Acacia melanoxylum*	15			
Mid	*Tabernaemontana pandacaqui*	20	5	8	12
Lower	*Cordyline stricta*	20	Lower stratum Height to crown (m) min mode max		
Lower	*Livistonia australis*	20			
Lower	*Blechnum cartilagineum*	10	0.5	1	2
Plot 7					
Upper	*Eucalyptus microcorys*	80	Upper stratum Height to crown (m) min mode max		
Upper	*Eucalyptus grandis*	10			
Upper			14	20	22
Mid	*Leptospermum polygalifium*	35	Mid stratum Height to crown (m) min mode max		
Mid	*Archirhodomyrtus beckleri*	10			
Mid	*Glochidion ferdinandi*	10	1.5	3	5
Lower	*Calochlaena dubia*	75	Lower stratum Height to crown (m) min mode max		
Lower	*Lomandra longifolia*	5			
Lower	*Blechnum cartilagineum*	5	0.5	0.7	1
Plot 8					
Upper	*Eucalyptus grandis*	70	Upper stratum Height to crown (m) min mode max		
Upper					
Upper			30	24	18
Mid	*Cissus hypoglauca*	20	Mid stratum Height to crown (m) min mode max		
Mid	*Rubus moluccanus*	20			
Mid	*Guioa semiglauca*	20	12	8	7
Lower	*Blechnum cartilagineum*	25	Lower stratum Height to crown (m) min mode max		
Lower	*Oplismenus imbecilis*	20			
Lower	*Morinda jasminoides*	15	2	1	0.3
Plot 9					

Stratum	Dominant species	Cover (% crown cover)	For the entire		
Upper	*Eucalyptus grandis*	15	Upper stratum Height to crown (m) min mode max		
Upper	*Corymbia intermedia*	30			
Upper	*Eucalyptus microcorys*	10	14	25	32
Mid	*Cryptocarya rigida*	30	Mid stratum Height to crown (m) min mode max		
Mid	*Livistonia australis*	15			
Mid	*Synoum glandulosum*	10	1.5	2.5	7
Lower	*Gahnia siberana*	5	Lower stratum Height to crown (m) min mode max		
Lower	*Lastreopsis* sp.	25			
Lower	*Cordyline stricta*	2	0.1	0.5	1
Plot 10					
Upper	*Eucalyptus grandis*	70	Upper stratum Height to crown (m) min mode max		
Upper					
Upper			20	25	28
Mid	*Melaleuca stypeloides*	10	Mid stratum Height to crown (m) min mode max		
Mid	*Lophostemon confertus*	10			
Mid	*Cissus antarctica*	20	2	8	10
Lower	*Morinda jasminoides*	40	Lower stratum Height to crown (m) min mode max		
Lower	*Opplismenus imbecilis*	40			
Lower	*Cissus antarctica*	20	0.3	1.2	2

4.3 Conclusion

The monitoring plot data suggest that to date there have been no declines in Woolls' Tylophora and Slender Marsdenia habitat condition along the edge of clearing.

Ecos Environmental, applying the method specified by RMS (2018), assigned different microclimate exposure scores for some plots than GeoLINK, which most likely reflects observer variability rather than physical changes. Plot crown-cover of exotic species at the end of year 4 – which ranged from 0 to 3% – was far below the performance threshold of 25% and vegetation structured appeared to have remained the same since year 3. Therefore, no corrective actions are required (Table 19).

Table 19: Performance measures for Slender Marsdenia and Woolls' Tylophora Habitat Condition monitoring.

Performance measure	**Yes/No – comments**
Plot crown-cover of exotic species is no more than 25% at the end of Years-2 to 8.	Yes – plot crown cover of exotic species at the end of year 4 is 0-3%
Baseline vegetation structure (height and crown cover) remains the same or increases in height and crown cover at the end of each year compared to the previous year.	Yes – qualitative assessment of vegetation structure data revealed no major decreases in height and crown cover at the end of year 4 compared to year 3
There is no increase in the microclimate exposure class (e.g. 1 to 2, or 4 to 5) compared to the previous year.	No – the plots 6 and 10 increased from a microclimate exposure score of 4 to 5 and plots 6-9 increased from 2 to 1, but this most likely reflects observer variability rather than physical changes.

5 References

ANPC (2004). *Guidelines for the Translocation of Threatened Plants in Australia* (2nd Edition). Australian Network for Plant Conservation.

Ecos Environmental (2016a). *Nambucca Heads to Urunga Threatened Flora Translocation Project – Annual Monitoring Report Year-3*. Report prepared for Lend Lease Infrastructure.

Ecos Environmental (2016b). *Warrell Creek to Nambucca Heads Upgrade of the Pacific Highway Threatened Flora Translocation Project Annual Monitoring Report – Year 1*. Report prepared for Pacifico.

Ecos Environmental (2017). *Warrell Creek to Nambucca Heads Upgrade of the Pacific Highway Threatened Flora Translocation Project Annual Monitoring Report – Year 2*. Report prepared for Pacifico.

Ecos Environmental (2018). *Warrell Creek to Nambucca Heads Upgrade of the Pacific Highway Threatened Flora Translocation Project Annual Monitoring Report – Year 3*. Report prepared for Pacifico.

GeoLINK (2017). *Warrell Creek to Nambucca Heads Monitoring of In-situ Threatened Flora (Annual Report – Spring 2017)*.

NSW Roads and Maritime Service and Ecos Environmental (2016). Warrell *Creek to Urunga Upgrade Threatened Flora Management Plan* (Version 5 July 2-016). (http://www.rms.nsw.gov.au/documents/projects/northern-nsw/warrell-creek-tonambucca-heads/management-plan-threatened-flora.pdf).

Primack, R. B. (1996). *Lessons from ecological theory: dispersal, establishment and population structure*. In D.A. Falk, C.I. Millar and M. Olwell (eds) Restoring Biodiversity pp. 208-234. Island Press, Washington.

Roads and Maritime Services (2018). *Warrell Creek to Nambucca Heads Operational Ecological and Water Quality Monitoring Brief*.

Shapcott, A, Lamont, R, O'Connor, K, James, H and Benwell, A. (2016). *How is genetic variability in the endangered rainforest vine Marsdenia longiloba (Benth:*Slender Marsdenia*) distributed at different geographic scales?* Botanical Journal of the Linnaen Society.

Appendix 1: Photos of Threatened Flora Translocations, WC2NH, Nov 2018

Plate 1: Floyds Grass receival site (9), Area 1 (direct transplanted). Dense ground cover of Ottochloa and Floyds Grass in SE corner. November 2018

Plate 2: Floyds Grass receival site (9), Area 1. View over site looking south. November 2018

Plate 3: Floyds Grass receival site (9), Area 2 (population enhancement). Shade awning still in place due to greater sun exposure. November 2018

Plate 4: Floyds Grass receival site (9), Area 2. Close up of Floyds Grass patch. November 2018

Plate 5: Translocated Koala Bells in Floyds Grass receival site 9, Area 2. Plant no. 4. November 2018

Plate 6: Translocated Koala Bells in Floyds Grass receival site 9, Area 2. Plant no. 6. November 2018

Plate 7: Slender Marsdenia receival site 5a. Open highway corridor on right hand side.

Plate 8: Slender Marsdenia receival site 1 Cockburns Lane, plant no. 4. November 2018

Plate 9: Slender Marsdenia receival site 1 Cockburns Lane, plant no. 6. November 2018

Plate 10: Slender Marsdenia receival site 7a, plant no. 1. November 2018

Plate 11: Slender Marsdenia receival site 7a, plant no. 2. November 2018

Plate 12: Slender Marsdenia receival site 7a, plant no. 3. November 2018

Plate 13: Slender Marsdenia receival site 7a, plant no. 4. November 2018

Plate 14: Slender Marsdenia receival site 8a. Photo taken from track next to highway. Nov. 2018

Plate 15: Slender Marsdenia receival site 8a, plant no. 3. November 2018

Plate 16: Slender Marsdenia receival site 8a, plant no. 4. November 2018

Plate 17: Slender Marsdenia receival site 8a, plant no. 13. November 2018

Plate 18: Slender Marsdenia receival site 8c. November 2018

Plate 19: Slender Marsdenia receival site 8c, plant no. 3. November 2018

Plate 20: Slender Marsdenia receival site 8c, plant no. 21. November 2018

Plate 21: Slender Marsdenia receival site 8c, plant no. 22. November 2018

Plate 22: Rusty Plum seedlings at the direct seeding area adjacent to receival site 7a. Nov 2018

Plate 23: Spider Orchid receival site adjacent to receival site 7a, plant no. 1 November 2018

Plate 24: Translocated Rusty Plum, Receival Site 1 Cockburns Lane, plant no. 2, 1 November 2018

Plate 25: Translocated Rusty Plum, Receival Site 1 Cockburns Lane, close-up of stem regrowth off trunk of plant no. 2, 1 November 2018

Appendix 2: Photos of in-situ threatened plant species, WC2NH, November 2018

Plate 1. In-situ Slender Marsdenia, monitoring ID ml-132, November 2018.

Plate 2. In-situ Slender Marsdenia, monitoring ID ml-138, November 2018. Not that it is growing on *Rhodamnia rubescens*, which was recently listed as Critically Endangered under the BC Act 2016.

Plate 3. In-situ Rusty Plum, monitoring ID nw-732, November 2018.

Plate 4. Fruit of nw-732, November 2018.

Plate 5. In-situ Rusty Plum, monitoring ID nw-64, November 2018.

Plate 6. In-situ Spider Orchid, monitoring ID dm-03, November 2018.

Plate 7. Maundia population at Nambucca River Floodplain, November 2018.

Appendix 3: Photos of Slender Marsdenia and Woolls' Tylophora habitat condition monitoring plots, Nov 2018

Plate 1. Slender Marsdenia and Woolls' Tylophora habitat condition monitoring plot 1, south-west corner, November 2018.

Plate 2. Slender Marsdenia and Woolls' Tylophora habitat condition monitoring plot 2, south-west corner, November 2018.

Plate 3. Slender Marsdenia and Woolls' Tylophora habitat condition monitoring plot 3, north-east corner, November 2018.

Plate 4. Slender Marsdenia and Woolls' Tylophora habitat condition monitoring plot 4, north-east corner, November 2018.

Plate 5. Slender Marsdenia and Woolls' Tylophora habitat condition monitoring plot 5, south-west corner, November 2018.

Plate 6. Slender Marsdenia and Woolls' Tylophora habitat condition monitoring plot 6, south-west corner, November 2018.

Plate 7. Slender Marsdenia and Woolls' Tylophora habitat condition monitoring plot 7, south-west corner, November 2018.

Plate 8. Slender Marsdenia and Woolls' Tylophora habitat condition monitoring plot 9, north-east corner, November 2018.

Plate 9. Slender Marsdenia and Woolls' Tylophora habitat condition monitoring plot 10, south-west corner, November 2018.

Appendix 4: Vegetation structure of Slender Marsdenia and Woolls' Tylophora habitat monitoring quadrats Recorded BY GeoLINK (2017)

Quadrat	*Vegetation Structure (dominant species, height, cover)*			*Weed Level*	*Microclimate Class*
	Canopy	*Mid-storey*	*Ground cover*		
1	**Flooded Gum, Swamp Turpentine – 25m**	**Red Ash, Brush Box, Swamp Turpentine, Rosewood – 3-8m**	**Gristle Fern, Water Vine, Mat-rush, Native Jasmine – 0.5m**	**Lantana**	
Spring 15	5%	50%	40%	<5%	5
Autumn 16	5%	50%	40%	5%	5
Spring 16	5%	45%	45%	5%	5
Spring 17	5%	60%	45%	5%	5
2	**Swamp Turpentine, Forest Oak, Tallowwood – 20m**	**Black Wattle, Red Ash, Brush Box, Rosewood – 3-6m**	**Gristle Fern, Palm Lily, Mat-rush, Native Jasmine – 0.5m**	**Lantana**	
Spring 15	15%	60%	10%	<5%	5
Autumn 16	15%	65%	15%	5%	5
Spring 16	15%	65%	15%	10%	5
Spring 17	15%	65%	20%	10%	5
3	**Swamp Turpentine, Flooded Gum, Ironbark – 22m**	**Rosewood, Red Ash, Black Wattle, Cabbage Palm – 2-10m**	**Gristle Fern, Mat-rush, Native Jasmine – 0.5m**	**Lantana**	
Spring 15	5%	70%	10%	<5%	1
Autumn 16	5%	70%	10%	<5%	1
Spring 16	5%	70%	10%	<5%	1
Spring 17	10%	70%	30%	<5%	1
4	**Flooded Gum, White Mahogany, Swamp Turpentine – 25m**	**Red Ash, Forest Oak, Cabbage Palm, Rosewood -3-8m**	**Water Vine, Palm Lily, Saw-sedge, Gristle Fern – 0.5m**	**No weeds**	
Spring 15	5%	10%	30%	-	2
Autumn 16	5%	10%	30%	-	2
Spring 16	5%	10%	35%	-	2
Spring 17	5%	10%	45%	-	2
5	**Ironbark, Brush Box, Tallowwood, Swamp Turpentine – 28m**	**Forest Oak, Swamp Turpentine, Cabbage Palm, Palm Lily – 3-8m**	**Mat-rush, Gristle Fern, Palm Lily. Regrowth shrub species Cheese Tree and Banana Bush – 0.5m**	**Lantana**	
Spring 15	50%	15%	15%	<5%	5
Autumn 16	50%	20%	15%	<5%	5
Spring 16	50%	20%	15%	<5%	5
Spring 17	55%	25%	25%	<5%	5
6	**White Mahogany, Brush Box, Paperbark – 20m**	**Black Wattle, Cabbage Palm, Palm Lily, Geebung – 3-8m**	**Mat-rush, Gristle Fern, Palm Lily <1m**	**Lantana**	
Spring 15	50%	40%	30%	5%	4
Autumn 16	50%	40%	30%	5%	4
Spring 16	50%	40%	35%	5%	4
Spring 17	55%	50%	35%	5%	4
7	**Tallowwood – 20m**	**Red Ash, Rosewood, Acacia sp, Leptospermum sp – 2-8m**	**Gristle Fern, Bracken Fern, Mat-rush – 0.5m**	**No weeds**	
Spring 15	10%	25%	50%	-	1
Autumn 16	10%	25%	50%	-	1

Quadrat	*Vegetation Structure (dominant species, height, cover)*			*Weed Level*	*Microclimate Class*
	Canopy	*Mid-storey*	*Ground cover*		
Spring 16	10%	25%	50%	-	1
Spring 17	15%	25%	50%	-	1
8	**Paperbark, Brush Box, White Mahogany – 18m**	**Cheese Tree, Rosewood, Geebung, Lilly Pilly – 2-8m**	**Gristle Fern, Mat-rush, Bracken Fern, Water Vine, Palm Lily – 0.5m**	**Lantana**	**1**
Spring 15	40%	40%	25%	5%	1
Autumn 16	40%	40%	30%	5%	1
Spring 16	40%	40%	30%	7%	1
Spring 17	40%	40%	35%	5%	1
9	**Tallowwood, Swamp Turpentine, Flooded Gum – 28m**	**Palm Lily, Paperbark, Cabbage Palm, Acacia sp., Cheese Tree – 2-8m**	**Saw-sedge, Jasmine, Gristle Fern, Mat-rush - <0.5m**	**Lantana, Broad-leaved Paspalum**	
Spring 15	40%	30%	25%	5%	1
Autumn 16	40%	30%	25%	5%	1
Spring 16	40%	30%	30%	<5%	1
Spring 17	45%	30%	40%	<5%	1
10	**Flooded Gum – 30m**	**Sandpaper Fig, Red Ash 6-8m**	**Jasmine, Bracken Fern – 0.5m (5%)**	**Lantana <5%**	
Spring 15	5%	30%	5%	<5%	4
Autumn 16	5%	30%	10%	<5%	4
Spring 16	5%	30%	20%	<5%	4
Spring 17	10%	30%	25%	<5%	4

13 22 13

Customer feedback
Roads and Maritime
Locked Bag 928,
North Sydney NSW 2059

April 2019

rms.nsw.gov.au

13 22 13

Customer feedback
Roads and Maritime
Locked Bag 928,
North Sydney NSW 2059

March 2018