Warrell Creek to Nambucca Heads

Giant Barred Frog Monitoring Report
Summer Year One - Operational Phase

Roads and Maritime Services | March 2019

THIS PAGE LEFT INTENTIONALLY BLANK

Document Review

Date	Version	Status	Sent to	Represent	Delivered Format	Dispatched By
14/3/19	1	Draft	S. Hardiman	RMS	MSW	D. Rohweder

Document Distribution

Date	Version	Status	Sent to	Represent	Delivered Format	Dispatched By
26/3/19	2	Final	S. Hardiman	RMS	PDF & MSW	D. Rohweder

Project team:

Dr D. Rohweder (project management, report writing)
Mr N. Priest (field survey, project management)
N. Makings (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**

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 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.

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 6
2.4 Habitat assessment 6
2.5 Water quality 9
3. Results and discussion 9
3.1 Frog survey 9
3.2 Habitat 11
3.2.1 Upper Warrell creek 11
3.2.2 Butchers Creek 11
3.3 Water quality 11
4. References 13
Appendix A – Weather conditions 14
Appendix B – Habitat data 15

List of tables

Table 1: Giant barred frogs captured during the summer 2018/19 survey at Upper Warrell Creek. NR = not recorded 10

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). *Laboratory error, not regarded as accurate measurement. 12

List of figures

Figure 1: Location of giant barred frog sample sites in relation to the WC2NH alignment. 4

Figure 2: Daily rainfall recorded at the WC2NH northern compound in February and early March 2019..... 5

Figure 3: Survey zones within the Upper Warrell creek sample site and location of spring 2018 and summer 2018/19 giant barred frog records..... 7

Figure 4: Survey zones within the Butchers Creek giant barred frog sample site. 8

List of plates

Plate 1: Male (left) and female giant barred frogs recorded at Upper Warrell Creek during the summer 2018/19 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 summer year 1 operational phase giant barred frog (*Mixophyes iteratus*) 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 summer 2018/19 giant barred frog survey more detailed analysis on 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 June 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).

Measures proposed to manage impacts on giant barred frogs included: population monitoring, pre-clearing surveys, temporary frog fencing during construction, clearing supervision, dewatering procedures (tadpole surveys) and permanent frog exclusion fence. Population monitoring was recommended to occasional 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 occasional 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.

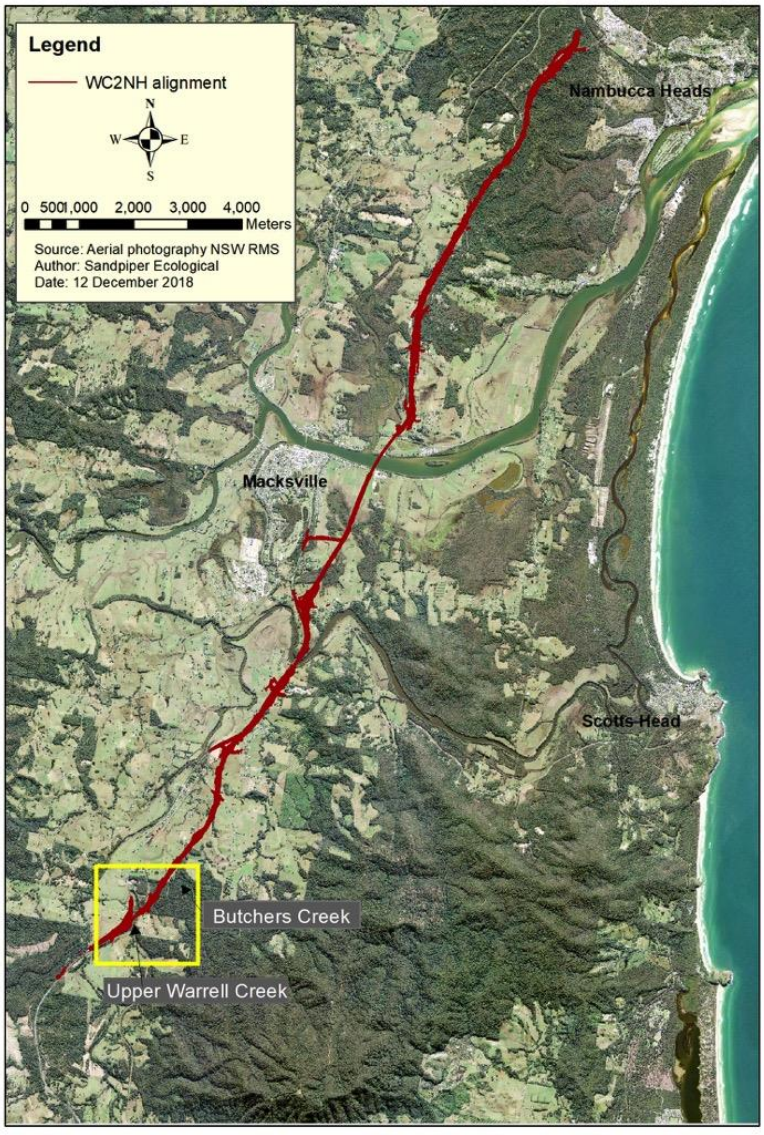

Figure 1: Location of giant barred frog sample sites in relation to the WC2NH alignment.

2. Methodology

2.1 Timing and weather conditions

The summer 2018/19 giant barred frog survey was conducted on 25 and 26 February 2019. The rainfall trigger of 10mm in a 24hr period measured at the WC2NH north compound project weather station was achieved on 22 February 2019 (Figure 2). Light rain occasional during the survey. Water level was low at both sample sites, and Butchers Creek was reduced to isolated pools. Summer 2018/19 was characterised by above average temperatures and below average rainfall. Conditions during the survey were suitable for surveying frogs with temperatures over 19^0C, relative humidity >80% and light wind (Table A1, Appendix A).

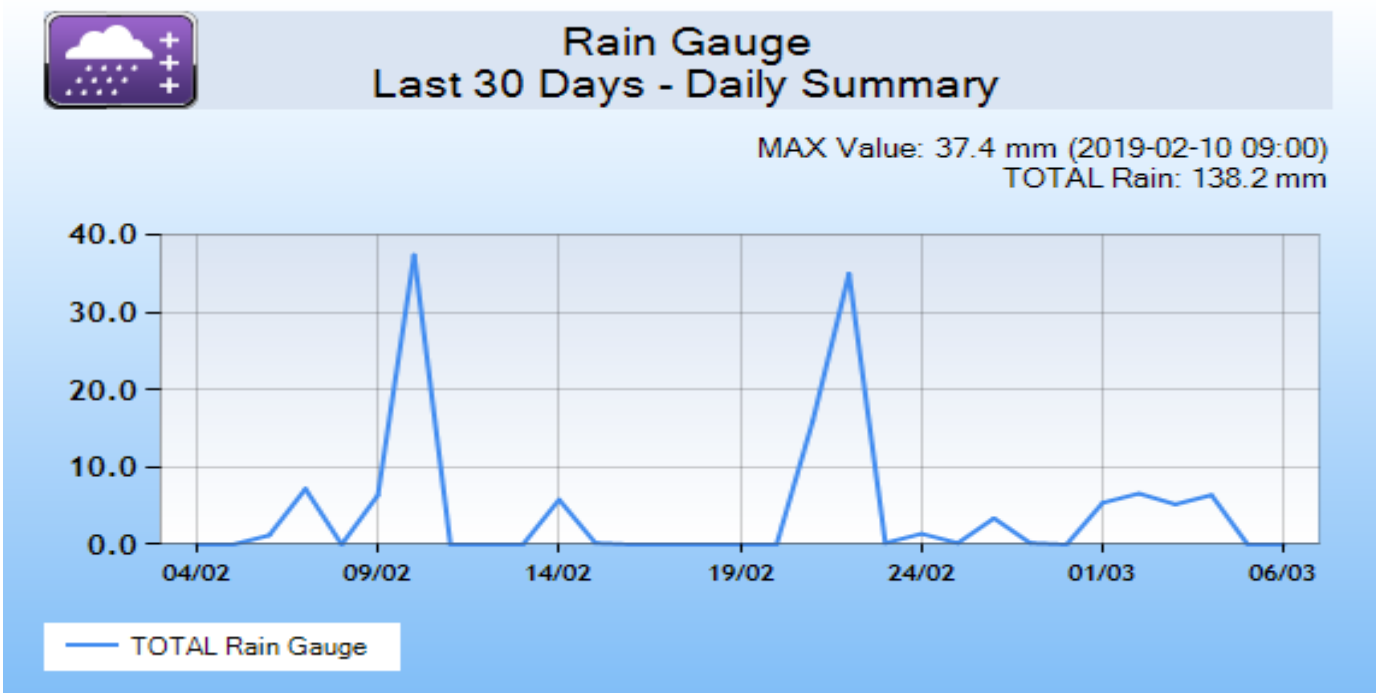

Figure 2: Daily rainfall recorded at the WC2NH northern compound in February and early March 2019.

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 200 lumen spotlight and slowly traversed the riparian zone searching for frogs and 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. Distance from the stream edge measured to the nearest 0.1m.
    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 (2014b);
        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.

2.3 Tadpole survey

Tadpole surveys were not required during the summer monitoring event.

2.4 Habitat assessment

Key habitat components in each survey zone are required to be sampled annually (i.e. once/year). Habitat sampling was conducted during the summer 2018/19 sample period. An ecologist conducted a meandering traverse of each zone at each site, including both banks. Habitat data recorded in each zone at each site included:

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).

Figure 3: Survey zones within the Upper Warrell creek sample site and location of spring 2018 and summer 2018/19 giant barred frog records.

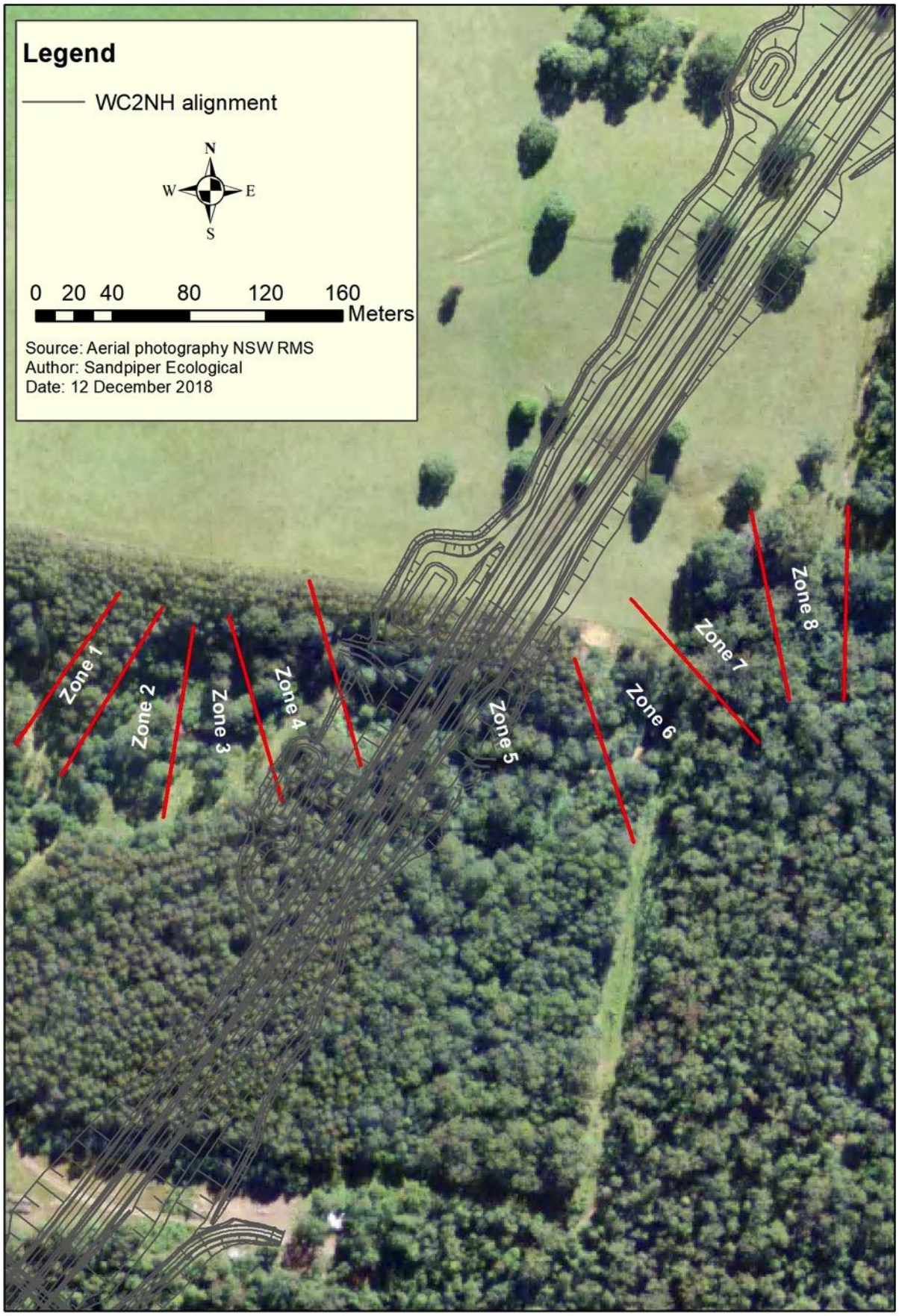

Figure 4: Survey zones within the Butchers Creek giant barred frog sample site.

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. Two samples were collected at each site and placed immediately into an esky. One sample was sealed immediately after collection for dissolved oxygen analysis. 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 12 person hours were spent conducting nocturnal frog surveys, 9 hours and 24 minutes at Upper Warrell Creek and 2 hours and 46 minutes at Butchers Creek. No giant barred frogs were recorded at Butchers Creek. Four adult giant barred frogs, three males and one female, were recorded at Upper Warrell Creek (Table 1; Plate 1). Three of these were recaptures and the fourth individual could not be captured. That individual was heard calling from the opposite side of Warrell Creek but could not be relocated when ecologists sampled the south bank.

The three captured frogs were all recaptures (Table 1). Frog #3 was originally captured on 6 November 2017, whilst frog #3 and 4 were both captured in February 2018. Frog #4 was captured at a similar location to Frog #1, which was captured during the spring 2018 survey (Sandpiper Ecological 2018). Both individuals had very similar S-V length, although Frog #1 was 32grams heavy, a result attributed to its gravid state. It is possible that frogs #1 and 4 are the same individual.

All captured frogs were situated on the north bank downstream of the alignment, and the calling male was on the south bank also downstream of the alignment (Figure 2). Distance from the waters edge ranged from 1.1 to 8.3m. Male frogs were between 1.1 and 1.3m from the waters edge. Two individuals were recorded amongst clumps of grass and one was initially observed on top of leaf litter.

Table 1: Giant barred frogs captured during the summer 2018/19 survey at Upper Warrell Creek. NR = not recorded

Upper Warrell Creek	Frog 3	Frog 4	Frog 5	Frog 6
Date	26/2/19	26/2/19	26/2/19	26/2/19
Zone	4	5	6	7
Creek side	N	N	N	S
GPS location	489322, 6594426	489354, 6594451	489364, 6594543	489318, 6594556
Distance from stream edge (nearest 0.1m)	1.1m	8.3m	1.3m	NR
Position in micro-habitat*	Amongst grass	On leaf litter	Among clumps of Grass, some leaf litter on tributary	
Sex*	M - calling	F	M- calling	M-calling
Age*	Adult	Adult	Adult	Adult
S/V length	83.8	101.5	74.8	
Weight	85g	141g	76g	
Breeding condition*	Moderate		Moderate-dark	
Microchip ID (new or re-capture)	Recapture: 00077E8FEF	Recapture: 00078ABBF2	Recapture: 00078ABB9B	
Original date of capture	6/11/2017	5/2/2018	7/2/2018	
Recapture dates			17/10/2018	

*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.

Plate 1: Male (left) and female giant barred frogs recorded at Upper Warrell Creek during the summer 2018/19 survey.

3.2 Habitat

3.2.1 Upper Warrell creek

Habitat at Upper Warrell Creek ranged from grassland/pasture 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 and grazed riparian forest. Whilst some areas appear rarely used by cattle there is evidence of disturbance (i.e. clearing, weed infestation) throughout the study area. Vegetation does not extend beyond the creek bank/riparian zone. The width of riparian vegetation ranged from nil to 40m. Leaf litter cover ranged from high (>75%) in areas with an intact riparian zone to low (<10%) 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 zone 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. The bank profile is characterised by a vertical face (<1m) at the waters edge and then a steep slope that ranged from 5 to 40m in length. Undercuts were recorded at the waters edge in several locations.

Weeping lilly pilly (*Waterhousia floribunda*) and flooded gum (*Eucalyptus grandis*) dominated the overstorey and mat rush (*Lomandra longifolia*) dominated the ground layer. Mat rush occurred in small clumps along the entire waters edge. Leaf litter depth, in areas of intact riparian forest, ranged from 40 to 100mm deep and total vegetation cover from 50 to 90%. Vegetation cover remained high in cleared areas due to dense grass cover.

3.2.2 Butchers Creek

Habitat at Butchers Creek varied substantially across the study area (Appendix B). During summer, the creek bed was dry except for a single pool in Zone 2. Habitat west of the alignment was highly degraded with recent clearing to the creek bank. The dominant riparian species was camphor laurel (Cinnamomum camphora) with some small-leaved privet (spp), callicoma (*Callicoma serratifolia*) and red ash (*Alphitonia excelsa*). Habitat east of the alignment was characterised by wet sclerophyll forest that extended well beyond the riparian zone. The creek bed consisted of rock and gravel with a steep bank and gravel bars. Leaf litter cover on the creek bank varied from 25 to 80% and ground vegetation cover from 10 to 60%. Despite the degree of fragmentation total vegetation cover was high, with only one of 16 sample sites receiving a cover score less than 40%. Habitat at Butchers Creek did not contain the moist microclimate that is typical of many giant barred frog habitats, which coupled with the ephemeral stream flow makes the site largely unsuitable for giant barred frogs.

3.3 Water quality

Most water quality parameters were within the ANZECC trigger values for freshwater ecosystems in south eastern Australia (Table 2). Exceptions were pH at Butchers Creek, and total Phosphorus at upper Warrell Creek. The low dissolved oxygen levels recorded at both sites are attributed to a laboratory error and is not regarded as accurate. Turbidity was below the ANZECC threshold at both sites a result attributed to the low water and absence of recent runoff. The lower nitrogen value recorded in summer 18/19 than spring 2018 is also attributed to less runoff. Both nitrogen and phosphorus values exceeded thresholds during the 2017/18 sample period (Geolink 2018).

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). *Laboratory error, not regarded as accurate measurement.

Parameter	Warrell Creek	Butchers Creek	ANZECC/ARMCANZ Trigger value for freshwater (95% species level of protection)
Temperature (^{0}C)	25	25	
pH	6.59	6.12	6.5-8.0
Conductivity (us/cm)	292	179	125-2200
Dissolved oxygen (mg/L O_2)	3.5*	6.7*	9-10.5
Total Suspended Solids (mg/L)	3	1	
Turbidity (NTU)	3.4	1.5	6-50
Total Phosphorus (mg/L P)	0.03	0.01	0.025
Total Nitrogen (mg/L N)	0.29	0.10	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)	<100	<100	ID
C29-C36 Fraction (µg/L or ppb)	<50	<50	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)	<200	<200	ID
C34-C40 Fraction (µg/L or ppb)	<100	<100	ID
Sum C10-C36 Fraction (µg/L or ppb)	<100	<100	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 (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.

Geolink (2018). *Annual report – WC2NH giant barred frog population monitoring 2017/2018 – year 3*. 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.

Sandpiper Ecological (2018). Warrell Creek to Nambucca Heads interim giant barred frog monitoring report – spring year one operational phase. Report prepared for NSW Roads and Maritime Services

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	25/2/19	Start	2007	Nil	1.6mm	52.8mm	112	98.1	24.6	21.9	0
		Finish	2130	Light shower				88.6	22.2	20	0
Warrell Creek	25/2/19	Start	2140	Nil				91.8	21	20.1	1
		Finish	2255	Moderate				100	21.4	20.4	1
Warrell Creek	26/2/19	Start	1958	Nil	1.0mm	53.8mm	113.8	80.9	22.7	19.1	0
		Finish	2325	Nil				92.8	19.2	17.9	0

Appendix B – Habitat data

Table B1: Habitat data collected in 21 zones at Upper Warrell Creek

Zone	Bank	Land use (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	N	Agriculture	Riparian	Rare snags & logs, knotweed & mat rush at waters edge, water lily	20-25	1-2m	No	Unknown	Water lily
	S	Agriculture	Riparian	Rare snags & logs, knotweed & mat rush at waters edge, water lily	20-25	1-2m	No	Unknown	Water lily
2	N	Agriculture	Riparian	Rare snags & logs, knotweed & mat rush at waters edge, water lily	20-25	1-2m	No	Unknown	Water lily
	S	Agriculture	Riparian	Rare snags & logs, knotweed & mat rush at waters edge, water lily	20-25	1-2m	No	Unknown	Water lily
3	N	Agriculture	Riparian	Rare snags & logs, knotweed & mat rush at waters edge, water lily	20-25	1-2m	No	Unknown	Water lily
	S	Agriculture	Riparian	Rare snags & logs, knotweed & mat rush at waters edge, water lily	20-25	1-2m	No	Unknown	Water lily
4	N	Agriculture	Riparian	Rare snags & logs, knotweed & mat rush at waters edge, water lily	20-25	1-2m	No	Unknown	Water lily
	S	Agriculture	Riparian	Rare snags & logs, knotweed & mat rush at waters edge, water lily	20-25	1-2m	No	Unknown	Water lily
5	N	Agriculture	Riparian	Snags, mat rush at waters edge, water lily, undercut bank	20	1-2m	No	Unknown	Water lily, occasional
	S	Agriculture	Riparian	Snags, mat rush at waters edge, water lily, undercut bank	20	1-2m	No	Unknown	Water lily, occasional
6	N	Road reserve	Riparian	Logs, snags, water lily, mat rush at waters edge	15	1-2m	No	Unknown	Water lily
	S	Agriculture	Riparian	Logs, snags, water lily, mat rush at waters edge	15	1-2m	No	Unknown	Water lily
7	N	Road reserve	Riparian	Logs, snags, water lily, mat rush at waters edge	15	1-2m	No	Unknown	Water lily
	S	Agriculture	Riparian	Logs, snags, water lily, mat rush at waters edge	15	1-2m	No	Unknown	Water lily
8	N	Road reserve	Grassland	Boulders, logs, waterlily, juncus, schoenoplectus	8	1m	Yes	Silt& gravel	Water lily, water primrose
	S	Road reserve	Grassland/ riparian	Boulders, logs, waterlily, juncus, schoenoplectus	8	1m	Yes	Silt& gravel	Water lily, water primrose
9	N	Road reserve	Riparian/cleared	Boulders, logs, waterlily, juncus, schoenoplectus	8	1m	Yes	Silt& gravel	Water lily, water primrose
	S	Road reserve	Grassland/ riparian	Boulders, logs, waterlily, juncus, schoenoplectus	8	1m	Yes	Silt& gravel	Water lily, water primrose
10	N	Agriculture	Riparian	Occasional logs & snags	15	1-2m	Yes	Unknown	Water lily, water primrose
	S	Road reserve	Grassland	Occasional logs & snags	15	1-2m	Yes	Unknown	Water lily, water primrose
11	N	Agriculture	Riparian	Snags, logs, aquatic vegetation	12	1-2m	No	Unknown	Water lily
	S	Road reserve	Grassland	Snags, logs, aquatic vegetation	12	1-2m	No	Unknown	Water lily
12	E	Agriculture	Riparian	Occasional logs, water lily, snags	15	1-2m	No	Unknown	Water lily

Zone	Bank	Land use (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
	W	Road reserve	Riparian	Occasional logs, water lily, snags	15	1-2m	No	Unknown	Water lily
13	E	Agriculture	Riparian	Occasional logs, water lily, snags	13	1-2m	No	Unknown	Water lily
	W	Road reserve	Riparian	Occasional logs, water lily, snags	13	1-2m	No	Unknown	Water lily
14	E	Agriculture	Grassland	Occasional logs, water lily (capensis & indica), elodea	13	1m	No	Unknown	Water lily
	W	Road reserve	Riparian	Occasional logs, water lily (capensis & indica), elodea	13	1m	No	Unknown	Water lily
15	E	Agriculture	Grassland	Occasional logs, clumps of mat rush, water lily, knot weed	11	Unknown	No	Unknown	Water lily
	W	Road reserve	Riparian	Occasional logs, clumps of mat rush, water lily	11	Unknown	No	Unknown	Water lily
16	E	Agriculture	Grassland	Occasional logs, clumps of mat rush, water lily, knot weed	11	Unknown	No	Unknown	Water lily
	W	Road reserve	Riparian	Occasional logs, clumps of mat rush, water lily	11	Unknown	No	Unknown	Water lily
17	E	Agriculture	Grassland	Occasional logs, clumps of mat rush, water lily	11	Unknown	No	Unknown	Water lily
	W	Road reserve	Riparian	Occasional logs, clumps of mat rush, water lily	11	Unknown	No	Unknown	Water lily
18	E	Agriculture	Riparian	Occasional logs; grass to water level	5	Unknown	No	Unknown	Water lily
	W	Road reserve	Riparian	Occasional logs; grass to water level	5	Unknown	No	Unknown	Water lily
19	E	Agriculture	Riparian	Occasional logs; grass to water level	9	Unknown	No	Unknown	Water lily
	W	Road reserve	Grassland	Occasional logs; grass to water level	9	Unknown	No	Unknown	Water lily
20	E	Agriculture	Riparian	Occasional logs; grass to water level	9	Unknown	No	Unknown	Water lily
	W	Road reserve	Grassland	Occasional logs; grass to water level	9	Unknown	No	Unknown	Water lily
21	E	Agriculture	Riparian	Occasional logs; grass to water level	9	Unknown	No	Unknown	Water lily
	W	Road reserve	Grassland	Occasional logs; grass to water level	9	Unknown	No	Unknown	Water lily

Table B2: Habitat data collected in 21 zones at Upper Warrell Creek

Zone	Bank	Stream bank characteristics	Bank profile	Bank vegetation cover (%)	Groundcover composition (% of vegt, litter, rock, bare earth)	Depth of leaf litter
1	N	Intact riparian zone 25m, waterhousia, flooded gum, mat rush at waters edge, lantana,	Steep 20m	65	Mat rush, lantana, shrubs	40-50mm
	S	Intact riparian zone 12m wide, waterhousia, flooded gum, camphor laurel, mat rush at waters edge,	Undercuts, vertical 0.5m, steep 4m, moderate 5m	80	Mat rush, fishbone fern, vines	75-100mm
2	N	Intact riparian zone 25m, waterhousia, flooded gum, mat rush at waters edge, lantana,	Steep 20m	65	Mat rush, lantana, shrubs	40-50mm
	S	Intact riparian zone 12m wide, waterhousia, flooded gum, camphor laurel, mat rush at waters edge,	Undercuts, vertical 0.5m, steep 4m, moderate 5m	80	Mat rush, fishbone fern, vines	75-100mm
3	N	Intact riparian zone 25m, waterhousia, flooded gum, mat rush at waters edge, lantana,	Steep 20m	65	Mat rush, Carex, BL paspalum	40-50mm
	S	Intact riparian zone 12m wide, waterhousia, flooded gum, camphor laurel, mat rush at waters edge,	Undercuts, vertical 0.5m, steep 4m, moderate 5m	80	Mat rush, fishbone fern, vines	75-100mm
4	N	Immediate bank cleared - BL paspalum & igloo grass within 15m of bank, riparian on slope, waterhousia, flooded gum 40m, dense ground cover on immediate bank	Flat for 20m, Steve 40m	25	BL paspalum, pigeon grass, occasional mat rush	50mm
	S	Intact riparian zone 12m wide, waterhousia, flooded gum, camphor laurel, mat rush at waters edge,	Undercuts, vertical 0.5m, steep 4m, moderate 5m	80	Mat rush, fishbone fern, vines	75-100mm
5	N	Riparian 40m incl side channel, waterhousia, mat rush, BL paspalum, SL privet, dense shrub & ground layer	Vertical 2m, moderate 20m	60	Mat rush, BL paspalum, lantana	40mm
	S	Intact riparian zone 15m wide from water to top of bank, waterhousia, some lantana, mat rush at waters edge	Vertical 0.5m, steep 13m	55	Mat rush, shrubs, lantana,	100mm
6	N	Riparian 40m incl side channel, waterhousia, mat rush, BL paspalum, SL privet, dense shrub & ground layer	Vertical 2m, moderate 20m	60	Mat rush, BL paspalum, lantana	40mm
	S	Established riparian zone 13m, waterhousia, good litter cover	Vertical 0.75m, steep 12m	70	Leaf litter, mat rush at waters edge, occasional vines & low shrubs	30mm
7	N	Established riparian zone 13m, waterhousia, good litter cover	Vertical 0.75m, steep 12m	70	Leaf litter, mat rush at waters edge, occasional vines & low shrubs	30mm
	S	Established riparian zone 13m, waterhousia, good litter cover	Vertical 0.75m, steep 12m	70	Leaf litter, mat rush at waters edge, occasional vines & low shrubs	30mm
8	N	Scour protection, immediate bank is flat, occasional boulders, gravel, sedges, to waters edge	Flat 20m	35	Knotweed, Schoenoplectus, juncus, cyperus spp, Carex	<10mm
	S	Scour protection, immediate bank is flat, occasional boulders, gravel, sedges, to waters edge	Flat 20m	35	Knotweed, Schoenoplectus, juncus, cyperus spp, Carex	<10mm
9	N	Scour protection, flat bank profile under bridge, 20m riparian zone, waterhousia, mat rush at waters edge,	Flat beneath bridge, moderate 20m	55	Mat rush, low shrubs	50mm
	S	Scour protection, immediate bank is flat, occasional boulders, gravel, sedges, to waters edge	Flat 20m	35	Knotweed, Schoenoplectus, juncus, cyperus spp, Carex	<10mm
10	N	Established riparian zone 25m, waterhousia, flooded gum, mat rush at waters edge, established mid storey	Vertical 1m, moderate 15m, steep 10m	80	Mat rush, BL paspalum, shrubs	40mm
	S	Scour protection (under bridge), knot weed, pigeon grass, occasional waterhousia	Vertical 1.5m, mod slope 3m	90	Knot weed, pigeon grass, BL paspalum	20mm
11	N	Established riparian zone 25m, waterhousia, flooded gum, mat rush at waters edge, established mid storey	Vertical 1m, moderate 15m, steep 10m	80	Mat rush, BL paspalum, shrubs	40mm
	S	Cleared grassland, pigeon grass, and knotweed to waters edge, sparse Schoenoplectus mucronatus.	Flat 3m, vertical 1m	95	Pigeon grass, knot weed	20mm

Zone	Bank	Stream bank characteristics	Bank profile	Bank vegetation cover (%)	Groundcover composition (% of vegt, litter, rock, bare earth)	Depth of leaf litter
12	E	Established riparian zone 25m, waterhousia, flooded gum, mat rush at waters edge, established mid storey	Vertical 1m, moderate 15m, steep 10m	80	Mat rush, BL paspalum, shrubs	50mm
	W	Fragmented riparian/grassland, waterhousia, pigeon grass, knotweed & mat rush at waters edge	Vertical 1m, steep 2.5m	50	Pigeon grass, mat rush, knotweed to waters edge	50mm
13	E	Established riparian zone 35m, waterhousia, flooded gum, mat rush at waters edge, established mid storey	Vertical 1m, moderate 15m, steep 10m	80	Mat rush, BL paspalum, shrubs	50
	W	Riparian 7m wide, waterhousia, wattles, mat rush & knot weed on bank, fallen logs, woody debris	Vertical 1m, steep 2m	75	Knotweed, mat rush, basket grass, BL paspalum	75mm
14	E	Cleared grassland, knotweed to water level	Steep 0.5m	40	Knotweed	Nil
	W	Riparian 7m wide, waterhousia, wattles, mat rush & knot weed on bank, fallen logs, woody debris	Vertical 1m, steep 2m	75%	Knotweed, mat rush, basket grass, BL paspalum	75mm
15	E	Cleared grassland, knotweed to water level	Vertical 1m	55	Pasture grass, knot weed	Nil
	W	Riparian, waterhousia, camphor, mat rush at water level (clumps)	Vertical 1m, moderate 2.5m	70	Mat rush, BL paspalum	75mm
16	E	Cleared grassland, knotweed to water level	Vertical 1m	55	Pasture grass, knot weed	Nil
	W	Riparian, waterhousia, mat rush at water level	Steep 4m	75	Mat rush, BL paspalum, lantana	50
17	E	Cleared, grassland	Vertical 1m	60	Pasture grass, knot weed	Nil
	W	8m riparian zone, waterhousia	Steep 4m	65	Mat rush, low shrubs	50mm
18	E	Fragmented, grazed, half cleared, waterhousia, camphor	Moderate slope 2m	40	Knot weed, pigeon grass	10mm
	W	Fragmented riparian, waterhousia, camphor, pigeon grass & knot weed on immediate bank	Steep, with back channel	90	Knot weed, pigeon grass	20mm
19	E	Fragmented riparian vegt, waterhousia, flooded gum, grazed, cleared u/S	Sloping, moderate	70	Sparse mat rush, BL paspalum	10mm
	W	Cleared grassland, dense pigeon grass	Steep, with back channel	90	Pigeon grass	10mm
20	E	Fragmented riparian vegt, waterhousia, flooded gum, grazed, cleared u/S	Sloping, moderate	70	Sparse mat rush, BL paspalum	10mm
	W	Cleared grassland, dense pigeon grass	Steep, with back channel	90	Pigeon grass	10mm
21	E	Fragmented riparian vegt, waterhousia, grazed, cleared u/S	Sloping, moderate	70	Sparse mat rush, BL paspalum	10mm
	W	Cleared grassland, dense pigeon grass	Steep, with back channel	90	Pigeon grass	10mm

Table B3: Habitat data collected in 8 zones at Butchers Creek

Zone	Bank	Land use (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	N	Agriculture	Camphor forest	Pool/riffle with rocks	3	Nil	Nil	Rock 50%; litter 25%; vegt 25%	Mat rush
	S	Agriculture	Shrubs and	Pool/riffle with rocks	3	Nil	Nil	Rock 50%; litter 25%; vegt 25%	Mat rush
2	N	Agriculture	Grassland	Pool rifle with rocks	3.5	Nil	Nil	Rock 25%; litter 40%; grass 40%	Grass
	S	Agriculture	Wet sclerophyll	Pool rifle with rocks	3.5	Nil	Nil	Rock 25%; litter 40%; grass 40%	Grass
3	N	Agriculture	Wet sclerophyll	Pool/riffle with rocks	3	Nil	Nil	Rock 30%; litter 60%; silt 20%	Mat rush
	S	Agriculture	Disturbed grassland	Pool/riffle with rocks	3	Nil	Nil	Rock 30%; litter 60%; silt 20%	Mat rush
4	N	Agriculture	Wet sclerophyll	Pool/riffle with rocks	4.5	Nil	Nil	Rock 70%; gravel 10%; silt 10%; organic 10%	Nil
	S	Agriculture	Disturbed grassland	Pool/riffle with rocks	4.5	Nil	Nil	Rock 70%; gravel 10%; silt 10%; organic 10%	Nil
5	N	Conservation	Wet sclerophyll	Pool/ riffle with rocks	6	Nil	Nil	Rock 60%; litter 40%	Nil
	S	Conservation	Wet sclerophyll	Pool/ riffle with rocks	6	Nil	Nil	Rock 60%; litter 40%	Nil
6	N	Conservation	Wet sclerophyll	Pool/ riffle with rocks	6	Nil	Nil	Rock 60%; litter 40%	Nil
	S	Conservation	Wet sclerophyll	Pool/ riffle with rocks	6	Nil	Nil	Rock 60%; litter 40%	Nil
7	N	Conservation	Wet sclerophyll	Pool/ riffle with rocks	5	Nil	Nil	Rock 60%; litter 40%	Nil
	S	Conservation	Wet sclerophyll	Pool/ riffle with rocks	5	Nil	Nil	Rock 60%; litter 40%	Nil
8	N	Agriculture	Wet sclerophyll	Pool/ riffle with rocks	6-7	Nil	Nil	Rock 60%; litter 40%	Nil
	S	Conservation	Wet sclerophyll	Pool/ riffle with rocks	6-7	Nil	Nil	Rock 60%; litter 40%	Nil

Table B4: Habitat data collected in 8 zones at Butchers Creek

Zone	Bank	Stream bank characteristics	Bank profile	Bank vegetation cover (%)	Groundcover composition	Depth of leaf litter
1	N	Camphor, mat rush, lantana, privet, degraded	Vertical 1.25m	60	Mat rush, carex, lantana	25mm
	S	Mat rush, Lilly pilly, privet, Brown kurrajong degraded	Steep slope 2m	60	Mat rush, BL paspalum, regrowth shrubs	<10mm
2	N	No o/S, grass & lantana	Vertical 1m	90	Pigeon grass, lantana	20mm
	S	2m wide, camphor, flooded gum, red ash, degraded	Vertical 2m	60	Mat rush, lantana, BL paspalum	20mm
3	N	3m wide, camphor, lantana, privet, highly degraded	Vertical 1.5m	60	Gahnia, mat rush, ferns, BL paspalum	50mm
	S	2m wide riparian zone, catacomb, lantana, degraded	Vertical 1.5m	40	Mat rush, gahnia, lantana, ferns	25mm
4	N	5m wide riparian zone, clumps of mat rush & gahnia, degraded	Vertical 2m	75	Gahnia, mat rush, ferns, BL paspalum	50mm
	S	2m wide riparian zone, Callicoma, lantana, degraded	Vertical 2m	10	BL paspalum	25mm
5	N	Rocky substrate, dense cover of lantana, mat rush, BL paspalum	Sloping - steep	90	Mat rush, lantana, BL paspalum	30-50mm
	S	Intact riparian zone, water vine, lantana, flooded gum, camphor laurel	Steep	80	Mat rush, lantana, BL paspalum	50-100mm
6	N	5-10m riparian, flooded gum, camphor laurel, dense midstorey	Steep	75	Occasional mat rush & ferns	30-50mm
	S	20m + riparian, various midstorey rainforest species	Moderate slope	80	Occasional mat rush & ferns	30-50mm
7	N	5-10m riparian, flooded gum, camphor laurel, dense midstorey	Steep slope	80	Very sparse, low shrubs	50-75mm
	S	20m + riparian, various midstorey rainforest species	Steep slope	80	Very sparse, low shrubs, mat rush	50-75
8	N	5-10m riparian, flooded gum, blackbutt, camphor laurel, dense midstorey	Vertical 7m	70	Very sparse, low shrubs	<20mm
	S	20m + riparian, various midstorey rainforest species, camphor laurel	Variable	80	Mat rush, lantana, BL paspalum, saw-sedge	30-50mm

rms.nsw.gov.au

13 22 13

Customer feedback
Roads and Maritime
Locked Bag 928,
North Sydney NSW 2059

March 2019