



Green-thighed Frog Monitoring 2019/2020

Habitat Protection and Breeding Ponds

Frederickton to Eungai Pacific Highway Upgrade

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Cover photograph: Green-thighed Frog located at Collombatti Reference Site during 2020 monitoring (left) (Photo: M. Stanton) and Collombatti reference site (right).

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Executive Summary

Context

This report documents the third and final round of Green-thighed Frog monitoring undertaken as part of the Frederickton to Eungai Ecological Monitoring Program (EMP, RMS 2016), required for the Frederickton to Eungai (F2E) Pacific Highway Upgrade Project (the Project). The Green-thighed Frog (*Litoria brevipalmata*) was one threatened species identified as requiring mitigation and monitoring throughout the course of the Project's construction and operational period. This report details the final of three monitoring events required at constructed compensatory habitat breeding sites (Green-thighed Frog Breeding Ponds). Transport for NSW (TfNSW) is required to manage and monitor the effectiveness of biodiversity mitigation measures implemented as part of the Project. The Green-thighed Frog Breeding Pond monitoring has been undertaken at 20 constructed breeding ponds and one area of adjacent habitat (at five sites).

Aims

The aims of this report are to summarise the methods and results of the 2020 monitoring and determine if Green-thighed Frogs are using the purpose-built compensatory breeding habitat and persisting in known breeding habitat, and thus determine whether the Project is meeting the performance indicators for the species. Corrective actions are also to be recommended where required.

Methods

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

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

Key results

The key results are as follows:

- Stage 1 surveys were undertaken on the 10th February 2020, after rainfall that was deemed suitable by the Project Ecologist: 24 hour rainfall between 30.4-37.8 millimetres; cumulative rainfall over 72 hours between 96.4-195.8 millimetres.
- Stage 2 surveys were undertaken on the 18 and 19 March 2020, 37 and 38 days after Stage 1 surveys.

- Two Green-thighed Frogs were observed and approximately another three were heard calling at the Collombatti reference site.
- No Green-thighed Frogs or their tadpoles were recorded during Stage 1 or Stage 2 surveys at any of the constructed pond sites.
- Stage 1 pond depths at Sites 1 and 2E varied between 30 – 40 cm, Sites 2W and 3E each had one pond holding 10 cm of water while the remaining four ponds were dry and Site 3W pond depth varied between 0 - 2cm.
- At least nine of the 20 selected ponds did not retain water for the minimum period specified in the EMP, and additional constructed ponds at Site 3(E&W) were not selected as monitoring ponds as none were found to hold water during Stage 2 surveys.

Conclusions

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

Management implications

A number of identified potential problems and contingency measures presented in the EMP (RMS 2016) are considered relevant due to the absence of Green-thighed Frogs from monitoring sites and the constructed ponds not holding water for sufficient time after rain. Due to these outcomes, recommendations for further surveys of peripheral habitat to establish the ongoing persistence/existence of natural breeding sites of the species were developed in consultation with and endorsed by the NSW Environment Protection Authority (EPA) and TfNSW.

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1. Introduction

1.1 Context

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

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

1.1.1 Legal status

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

1.1.2 Monitoring framework

The EMP states the following regarding Habitat Protection – Green-thighed Frog Breeding Sites monitoring:

“Monitoring will only be undertaken if construction works extend into the identified known Green-thighed Frog breeding sites”. This condition was triggered at the Hills Lane breeding site in summer 2015 and monitoring of this site was undertaken on two occasions and reported on as follows:

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

This report does not include results in relation to Green-thighed Frog Breeding Sites monitoring as monitoring at the Hills Lane breeding site was completed in 2018. No Green-thighed Frogs were recorded during either monitoring event at the Hills Lane breeding site. Prior to 2017, Green-thighed Frog activity at the site has not been monitored since 2005 (RMS 2016). As such it was not possible to conclude that the lack of records of Green-thighed Frogs from the Hills Lane site was directly due to the backfilling of the adjacent dam that occurred in summer 2015. However, it was recommended in Niche (2018) that TfNSW pursue discussions with the NSW Environment Protection Authority (EPA) to determine appropriate measures for continued monitoring and any corrective actions needed. As outcomes in relation to Hills Lane have not been reached, the recommendation for ongoing consultation with EPA has been carried forward into this report.

The EMP states the following regarding monitoring for the Green-thighed Frog Breeding Ponds:

“Monitoring will be undertaken on three occasions commencing in 2015 with each event at least 10-12 months apart but ultimately dependant on rainfall.”

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

summer 2016/2017 and again in summer 2017/2018. Rainfall for the 2018/2019 period did not meet the trigger and therefore, the final monitoring event was undertaken in summer 2019/2020.

The 2020 monitoring represents the final of three Green-thighed Frog Breeding Ponds monitoring events. To date, these monitoring events have been undertaken and reported on as follows:

- *Summer (March) 2017*: Niche (2017)
- *Summer (March) 2018*: Niche (2018)
- *Summer (February) 2020*: current report.

This report therefore presents the final results for the Green-thighed Frog Breeding Ponds monitoring program.

1.1.3 Baseline data

Breeding sites

In relation to Habitat Protection – Green-thighed Frog Breeding Sites, the EMP refers to a number of suitable breeding sites within and adjacent to the Project. However, monitoring at these sites was to be undertaken only if construction works extended into any of these identified breeding sites. This became relevant for a single site in summer 2015, where back filling of a dam approximately 20-40 metres from the Hills Lane breeding site (Hills Lane drainage line) triggered the need for monitoring of this site. The Hills Lane site was successfully used as a breeding site in 2005 (RMS 2016). The Hills Lane breeding site was monitored on two occasions, in 2017 and 2018 and no Green-thighed Frogs were recorded during either monitoring event.

Breeding ponds

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

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

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

1.1.4 Purpose of this report

This report complies with the monitoring requirements described within the EMP and details the findings obtained from the final of three monitoring events completed for the Green-thighed Frog Breeding Ponds.

The aim of this report is to summarise the methods and results of the 2019/2020 monitoring, provide an overall discussion of all monitoring events and determine if performance measures have been met, as per the EMP.

1.2 Performance Measures

As specified in the EMP, the performance indicators of success for the Green-thighed Frog Breeding Ponds are as follows:

- Continued presence of Green-thighed Frog at Sites 1, 2 and 3
- Green-thighed Frogs calling from the edge of the constructed ponds
- The presence of tadpoles, juveniles or metamorphs during follow up surveys.

Signs of the mitigation being unsuccessful are as follows:

- Absence of Green-thighed Frogs from the area
- Ponds not holding water for a sufficient time to enable tadpoles to reach metamorphosis
- Ponds holding water for too long and representing unsuitable habitat (i.e. permanent versus ephemeral).

1.3 Monitoring Timing

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

The current monitoring took place in February 2020, 23 months after the previous monitoring event and represents the final monitoring event for the constructed breeding ponds.

1.4 Reporting

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

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

All reports prepared under the EMP will be submitted to the NSW Department of Planning, Industry and Environment (DPIE) and the NSW EPA.

1.5 Limitations

The following limitations to the monitoring procedure were encountered:

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

2. Methods

2.1 Monitoring Sites

Green-thighed Frog Breeding Ponds were established as compensatory habitat within the areas identified in the baseline surveys (RMS 2016). The site locations are shown in Figure 1, with details provided in Table 1. Individual constructed breeding ponds are shown in Figure 2, Figure 3 and Figure 4. The Collombatti site was used as the reference site.

Table 1: Monitoring sites

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

2.2 Survey Method

The survey method described within the EMP was employed for all surveys and is provided below.

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

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

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

a) Stage 1 – Determining Presence and Breeding Activity

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

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

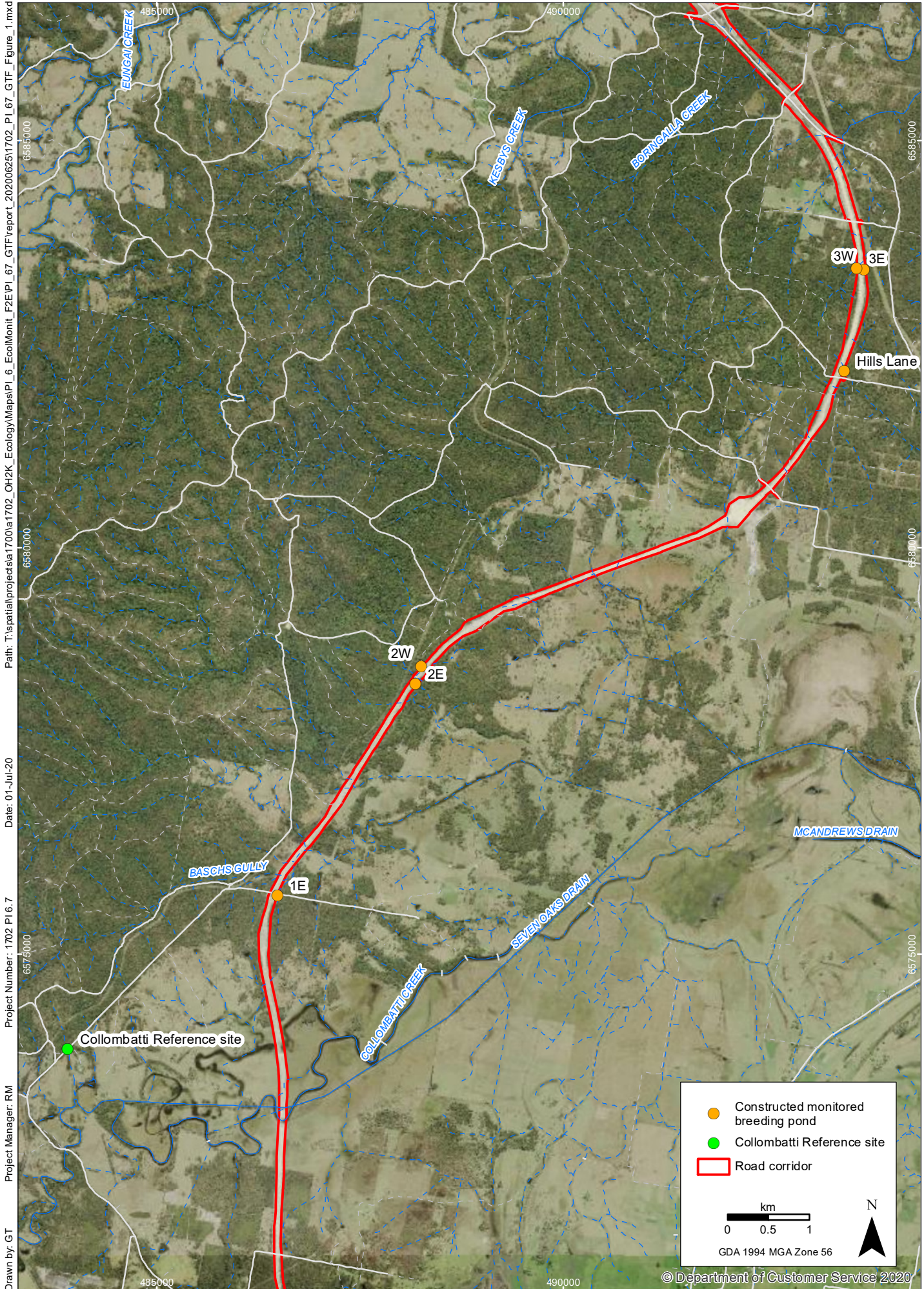
b) Stage 2 – Determining the Success of the Breeding Event

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

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

2.3 Analysis

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



Green-thighed Frog constructed breeding pond location
Pacific Highway Upgrade Frederickton to Eungai

FIGURE 1

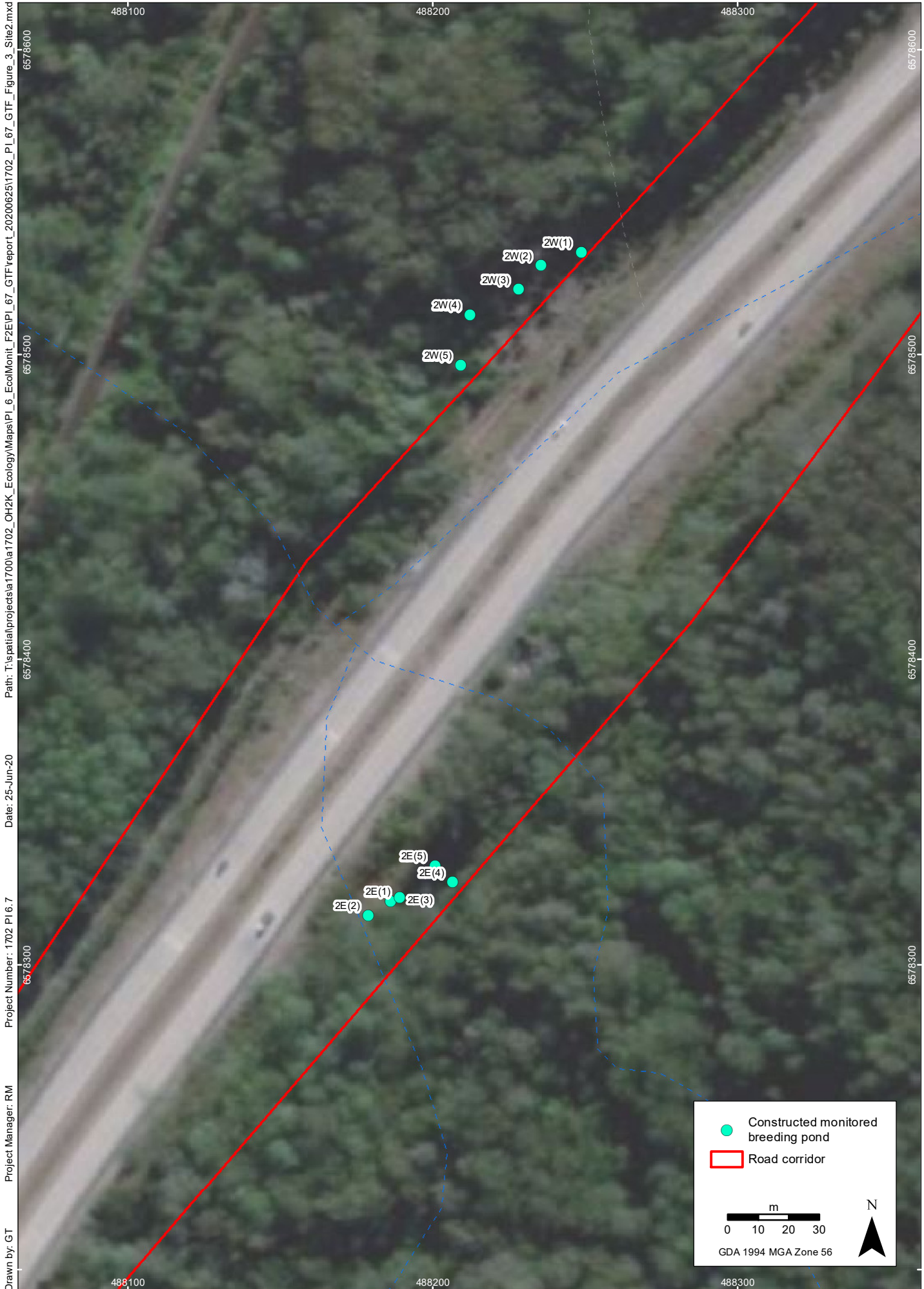
Imagery: (c) LPI 2014-09-18



Green-thighed Frog constructed breeding ponds - Site 1E
Pacific Highway Upgrade Frederickton to Eungai

FIGURE 2

Imagery: (c) DigitalGlobe 2019



Path: T:\spatial\project\1700\1702_OH2K_Ecology\Maps\PI_6_EcolMonit_F2E\PI_67_GTF\report_20200625\1702_PL67_GTF_Figure_3_Site2.mxd
 Date: 25-Jun-20
 Project Number: 1702 PI 6.7
 Project Manager: RM
 Drawn by: GT

Green-thighed Frog constructed breeding ponds - Site 2
 Pacific Highway Upgrade Frederickton to Eungai



FIGURE 3
 Imagery: (c) DigitalGlobe 2019



Green-thighed Frog constructed breeding ponds - Site 3
Pacific Highway Upgrade Frederickton to Eungai

FIGURE 4

Imagery: (c) DigitalGlobe 2019

3. Results

Field data from Stage 1 and Stage 2 monitoring are provided in Annex 1 and photo monitoring in Annex 2.

3.1 Frog Fence Monitoring

Frog fence monitoring is undertaken as part of the Fauna Underpass and Associated Fauna Fencing Monitoring program for the Project. Extensive grass growth over frog fences was an issue identified during surveys in several locations. These issues are detailed and discussed within the Fauna Underpass and Associated Fauna Fencing Monitoring report (Niche 2020).

3.2 Breeding Ponds Stage 1 – Determining Presence and Breeding Activity

3.2.1 Conditions

Suitable rainfall, as specified within the EMP, did not occur until February 2020, almost two years after the previous trigger and monitoring event (March 2018). Stage 1 surveys were undertaken on the 10th February 2020 when the rainfall was deemed suitable by the Project Ecologist. Rainfall and temperatures during Stage 1 surveys for relevant weather stations are provided in Table 2. Air temperatures during surveys, as displayed within the Bureau of Meteorology (BOM) App for the ‘current location’, ranged from 19.0°C to 20.3°C.

Table 2: Rainfall and temperatures for 10th February 2020

BOM Weather Station	24hr rainfall (mm)	72hr rainfall (mm)	Min temperature °C	Max. temperature °C
Port Macquarie Airport AWS #60139	30.4	195.8	14.8	20.3
Kempsey Airport AWS #59007	37.8	96.4	13.2	17.4

3.2.2 Nocturnal active searches

Green-thighed Frogs were heard calling and observed at the Collombatti reference site during Stage 1 surveys; two individuals were observed and approximately three additional individuals were heard calling. No Green-thighed Frogs were observed or heard calling at any of the constructed ponds or within adjacent habitat.

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

3.2.3 Pond depth at Stage 1

Pond depth varied greatly between ponds and the Collombatti reference site during Stage 1 surveys due to the volume of rain and subsequent flooding of some sites. Table 3 provides the Stage 1 and Stage 2 water levels in the constructed ponds. Water depth of the ponds can be summarised as follows:

- Collombatti reference site: depths ranging from 40 to greater than 50 centimetres (cm)
- Site 1E: 30 to 40 cm
- Site 2W: ponds were dry except for pond 2 with a depth of 10 cm
- Site 2E: 35 to 40 cm
- Site 3W: 0 to 2 cm.
- Site 3E: ponds were dry except for pond 3 with a depth of 10 cm

3.2.4 Vegetation structure and other observations

While the surrounding habitat at Site 1E is considered to be suitable Green-thighed Frog habitat, the vegetation immediately surrounding the ponds consisted of dense invasive grass species. Site 2E represents suitable frog habitat with a young emerging canopy surrounding the ponds and suitable adjacent habitat. Ponds at Sites 2W and 3(E&W) are more exposed (little to no canopy cover) and quite distant from surrounding habitat. At Site 3(E&W) dense perennial grasses surrounded the ponds and *Allocasuarina* sp. saplings were observed growing in the middle of some ponds. It is possible that invasive grass growth at many ponds is too dense and possibly not suitable for Green-thighed Frogs, a species that requires leaf litter for foraging (OEH 2018) and a more open low ground vegetation (Hero *et al.* 2004) such as ferns and mat rushes. Site photos are provided in Annex 2.

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

Stage 2 surveys were undertaken on the 18 and 19 March 2020, 37 and 38 days after the Stage 1 surveys.

3.3.1 Active searches and dip-netting

A number of tadpoles were caught at the Collombatti reference site, Site 1E (ponds 1, 2 and 4) and Site 2E (ponds 1 and 5). The majority of ponds were dry at Site 2W, Site 3E and Site 3W and the single ponds with water at Site 2W and 3E did not contain tadpoles.

Tadpoles were identified as either Peron's Tree Frog, Tyler's Tree Frog, Striped Marsh Frog or *Crinia* spp. Unidentified specimens were not Green-thighed Frog tadpoles.

3.3.2 Predatory fish and invertebrates

A number of predatory fish and invertebrates were identified at the Collombatti reference site, Site 1E and Site 2E. These included *Gambusia* (*Gambusia holbrooki*), mayfly larvae, Firetail Gudgeon (*Hypseleotris gali*) and various insect species. Predator presence is summarised as follows:

- Site 1E: three constructed ponds had either predatory fish or invertebrates
- Site 2W: no predators recorded (only one pond with water)
- Site 2E: one of five ponds with one predator type
- Site 3W: no predators detected (ponds dry)
- Site 3E: no predators recorded (only one pond with water).

3.3.3 Pond depth at Stage 2

Table 3 provides the Stage 1 and Stage 2 water levels in the constructed ponds. According to the EMP (Table 3-5) ponds should have a maximum depth of 400 mm and hold water for up to 60 - 80 days. Stage 2 surveys were undertaken 37 and 38 days after Stage 1 surveys (required by the EMP to be undertaken 30 - 50 days after Stage 1). Water levels during Stage 2 surveys were as follows:

- Collombatti reference site: 30 - 60 cm.
- Site 1E: all four constructed ponds held water (20 - 40 cm).
- Site 2W: one of the five constructed ponds held water (10 cm).
- Site 2E: all five constructed ponds held water (28 - 45 cm).
- Site 3W: all three selected constructed ponds were dry. All additional constructed ponds were dry.
- Site 3E: one of three selected constructed ponds held water (10 cm). All additional constructed ponds were dry.

Minimum water retention period – 60 days

The EMP states that ponds are to support water for up to 60 - 80 days, however Stage 2 surveys are required to be undertaken 30 - 50 days after Stage 1 surveys. Stage 2 surveys were undertaken 37 and 38 days after Stage 1 surveys. As such, survey timing precludes a definitive statement as to whether or not ponds still contained water at 60 or 80 days (and additional surveys to determine this are out of the scope of this monitoring program).

Stage 2 water depth was impacted by rainfall immediately prior to surveys. Port Macquarie Airport Weather Station recorded 26.4 mm of rainfall in the 24 hours prior to surveys. Despite this rainfall, all ponds at Site 3W (three selected and all additional), all but one pond (3E(3)) at Site 3E (selected and additional) and four of five ponds at Site 2W, were dry.

It can therefore be deduced that of the 24 required ponds, at least 13 (nine selected ponds and four additional required ponds at Site 3) did not retain water for the minimum period of 60 days specified in the EMP. It should be noted that Green-thighed Frog monitoring for the Oxley Highway to Kempsey section of the Pacific Highway Upgrade specifies that the water minimum retention period should depend on site exposure, i.e. ponds at sunny exposed sites should hold surface water for between 30 - 40 days, and between 50 - 60 days at shaded locations (Lewis 2013). As mentioned above, Sites 2W and 3 are exposed and lack canopy cover and therefore could be considered as sunny exposed sites. Metamorphosis may occur within 28 days (Lewis 2013) and field records show metamorphosis occurring at an exposed site within 40 days (Lemckert *et al.* 2006). Nevertheless, taking these additional details into account, while it is not possible to state if the ponds that were dry at day 37 and 38 were dry at day 30, it is considered unlikely (in particular noting the fact that many were dry during Stage 1 surveys) that all ponds at Site 2W and Site 3 will hold water for the minimum period required for the successful breeding of the Green-thighed Frog.

Maximum water retention period

Given that Stage 2 surveys were undertaken 37 and 38 days after Stage 1 surveys it is not possible to state the duration of water retention in the ponds. In addition, as water retention is dependent not only on pond permeability but on weather conditions and local rainfall, it is difficult to draw conclusions regarding the likelihood of ponds to dry out. Research has shown that an extended hydroperiod is unlikely to impact the breeding of this species, as long as the pond is ephemeral (Lemckert *et al.* 2006, and Lemckert *pers. comm.*). Therefore, water retention within ponds somewhat beyond the preferred hydroperiod is not considered as important to the survival of this species as the retention of water for long enough to allow metamorphosis to occur.

Table 3: Pond water retention

Site	Site condition	Pond	Stage 1 depth (cm)	Stage 2 depth (cm)	Minimum water retention (60 to 80 days)
1E	Moderately exposed with surrounding sclerophyll forest.	1	35	40	Unknown
		2	40	40	Unknown
		3	30	30	Unknown
		4	35	31	Unknown
		5- adjacent habitat	30	20	Not applicable
2W	Sunny exposed. Vegetation	1	0	0	No
		2	10	10	Unknown
		3	0	0	No

Site	Site condition	Pond	Stage 1 depth (cm)	Stage 2 depth (cm)	Minimum water retention (60 to 80 days)
	adjacent to west.	4	0	0	No
		5	0	0	No
2E	Moderately exposed with surrounding shrub growth.	1	35	35	Unknown
		2	40	40	Unknown
		3	30	45	Unknown
		4	35	28	Unknown
		5	35	32	Unknown
3W	Sunny exposed. Vegetation adjacent to west.	1	0-2	0	No
		2	0-2	0	No
		3	0-2	0	No
3E	Sunny exposed. Vegetation adjacent to east.	3	10	10	Unknown
		4	0	0	No
		5	0	0	No

3.4 Breeding Ponds Cumulative Results

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

Table 4: Cumulative monitoring results

Site (pond)	2016/2017			2017/2018			2019/2020		
	# GTF	# GTF Tadpoles	MRP met? (checked at 43 days)	# GTF	#GTF Tadpoles	MRP met? (checked at 35 days)	# GTF	# GTF Tadpoles	MRP met? (checked at 37 days)
Ref	1	0		0	0		4	0	
1E(1)	0	0	Unknown	0	0	Unknown	0	0	Unknown
1E(2)	0	0	Unknown	0	0	Unknown	0	0	Unknown
1E(3)	0	0	No	0	0	Unknown	0	0	Unknown
1E(4)	0	0	No	0	0	Unknown	0	0	Unknown
2W(1)	0	0	No	0	0	No	0	0	No
2W(2)	0	0	Unknown	0	0	Unknown	0	0	Unknown
2W(3)	0	0	Unknown	0	0	Unknown	0	0	No
2W(4)	0	0	No	0	0	No	0	0	No
2W(5)	0	0	No	0	0	Unknown	0	0	No
2E(1)	nm	nm	nm	0	0	Unknown	0	0	Unknown
2E(2)	nm	nm	nm	0	0	Unknown	0	0	Unknown
2E(3)	nm	nm	nm	0	0	Unknown	0	0	Unknown
2E(4)	nm	nm	nm	0	0	Unknown	0	0	Unknown

Site (pond)	2016/2017			2017/2018			2019/2020		
	# GTF	# GTF Tadpoles	MRP met? (checked at 43 days)	# GTF	#GTF Tadpoles	MRP met? (checked at 35 days)	# GTF	# GTF Tadpoles	MRP met? (checked at 37 days)
2E(5)	nm	nm	nm	0	0	Unknown	0	0	Unknown
3W(1)	0	0	No	0	0	No	0	0	No
3W(2)	0	0	No	0	0	No	0	0	No
3W(3)	0	0	No	0	0	No	0	0	No
3E(3)	0	0	No	0	0	Unknown	0	0	Unknown
3E(4)	0	0	Unknown	0	0	Unknown	0	0	No
3E(5)	0	0	Unknown	0	0	Unknown	0	0	No

Bold = did not meet minimum water retention period; MRP = minimum water retention period of 60 days; Unknown = water present during Stage 2 but unknown if retained to 60 days due to survey limitations; No = pond dry at Stage 2 survey; nm = not monitored as ponds not complete.

4. Discussion

4.1 Performance Measures

Given that this report represents the results of the final monitoring period for the Green-thighed Frog, a discussion of the cumulative monitoring results in relation to the performance measures detailed in the EMP is provided in Table 5 and Table 6.

Table 5: Performance indicators of success

Performance indicators of success	Outcome
Continued presence of Green-thighed Frog at Sites 1, 2 and 3 and Hills Lane breeding site.	This performance indicator has not been met. Green-thighed Frogs have not been observed at any of the sites containing constructed ponds, nor at Hills Lane.
Green-thighed Frogs calling from the edge of the constructed ponds.	This performance indicator has not been met. Green-thighed Frogs have not been heard calling at any of the sites containing constructed ponds.
The presence of tadpoles, juveniles or metamorphs during follow up surveys.	This performance indicator has not been met. Green-thighed Frog tadpoles, juveniles or metamorphs have not been observed during follow up surveys.

Table 6: Signs of the mitigation being unsuccessful

Performance indicators of unsuccessful mitigation	Outcome
Absence of Green-thighed Frogs from the area.	This indicator of unsuccessful mitigation has been met. Green-thighed frogs have not been detected in the area of constructed ponds.
Absence of Green-thighed Frogs from the area that cannot be attributed to environmental factors.	This indicator of unsuccessful mitigation has been met. As surveys have not been undertaken at the monitoring sites since 2005 it is not possible to make conclusive statements attributing the absence of Green-thighed Frogs from the monitoring sites to the Project. However, given that in two of the three monitoring periods (2017 and 2020) Green-thighed Frogs were detected at the Collombatti reference site and during one monitoring period at an Oxley Highway to Kempsey Pacific Highway Upgrade breeding pond (2018) while not being recorded at the constructed breeding ponds, it can be inferred that the species is not using the constructed ponds for breeding and that the ponds as mitigation for this species have failed.
Ponds not holding water for a sufficient time to enable tadpoles to reach metamorphosis.	This indicator of unsuccessful mitigation has been met consistently for two ponds at Site 2W (1 and 4), for all ponds at Site 3W (selected and additional) and all additional ponds at Site 3E. According to the EMP ponds should have a maximum depth of 400 mm and hold water for up to 60 - 80 days. Only eight ponds have consistently retained water until Stage 2 surveys.
Ponds holding water for too long and representing unsuitable habitat (i.e. permanent versus ephemeral).	This performance indicator of unsuccessful mitigation cannot be assessed due to survey limitations. Given that Stage 2 surveys must be undertaken between 30 - 50 days after Stage 1 surveys it is not possible to comment on the permanent versus ephemeral nature of the ponds.

5. Recommendations

5.1 Contingency Measures

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

Table 7: Contingency Measures

Potential Problem	Contingency Measure proposed in EMP	Discussion of proposed measure
Green-thighed Frog Breeding Ponds		
Ponds not used by Green-thighed frog	Survey adjacent areas to confirm frogs remain in area. Review/modify ponds to improve potential site suitability problems	Green-thighed Frogs have not been recorded at the constructed ponds. This contingency measure is considered relevant.
Ponds not holding water long enough to enable breeding to succeed	Review/modify ponds either by placing a semi permeable layer or further excavation	The EMP specified construction of 24 suitable ponds, however only eight ponds have consistently retained water until Stage 2 surveys. This contingency measure is considered relevant.
Ponds holding water for too long encouraging competition from non-target frog fauna	Improve drainage	This problem cannot be assessed due to survey limitations. However, research has shown that an extended hydroperiod is unlikely to impact the breeding of this species, as long as the pond is ephemeral. The relevance of this contingency measure cannot be determined.
Exotic fish species recorded in breeding ponds	Modify pond to ensure it dries out	Exotic fish species have been detected in constructed ponds at site 1E (ponds 1, 2, 3 and 4), 2E (pond 4) during the monitoring program. This contingency measure is considered relevant.

5.2 Recommendations

Green-thighed Frogs have not been recorded at the constructed breeding ponds during monitoring periods where they were recorded at either the Collombatti reference site (2016/2017 and 2019/2020) or an Oxley Highway to Kempsey Pacific Highway Upgrade constructed breeding pond (2017/2018, 2019/2020). Due to these outcomes, recommendations for further surveys of peripheral habitat to establish the ongoing persistence/existence of natural breeding sites of the species were developed in consultation with and endorsed by the NSW Environment Protection Authority (EPA) and TfNSW. Table 8 summarises the performance measures that have not been met to date and the endorsed recommendations.

Table 8: Signs of the mitigation being unsuccessful and recommendations

Problem encountered	Proposed contingency measure (EMP)	Recommendations developed in consultation with and endorsed by TfNSW and EPA.
Absence of Green-thighed Frogs from the area.	Survey adjacent areas to confirm frogs remain in area. Review/modify ponds to improve potential site suitability problems.	Compensatory habitat for the Green-thighed Frog has been provided for within the offset strategy for the Project. Offset areas were assessed and considered to provide suitable habitat for this species. As such, the intent of the constructed frog ponds was not to provide compensation for lost habitat but to provide artificial habitat to act as an experimental mitigation for this species (Parsons Brinckerhoff 2006): "A suggested mitigation measure to account for the loss of potential breeding habitat is the creation of artificial breeding ponds adjacent to the new road. Such breeding ponds have not been constructed or trialled previously, Although such ponds have been suggested on other sections of the Pacific Highway where the species occurs, they have not as yet been constructed or trialled. As such the creation of frog breeding ponds should be considered experimental." (Parsons Brinckerhoff 2007).
Ponds not holding water for a sufficient time to enable tadpoles to reach metamorphosis.	The corrective action for this would involve a review and if deemed necessary, modification of the ponds by placing a semi permeable layer or further excavation.	Given the experimental nature of the ponds, it was not the intent that the ponds act as an indicator of successful mitigation for this species. Adaptive management/monitoring was highlighted as necessary to determine their effectiveness.
Exotic fish species recorded in breeding ponds	Modify pond to ensure it dries out	Given the lack of success of constructed ponds to date it is recommended that surveys of peripheral habitat be undertaken to establish the ongoing persistence/existence of natural breeding sites of the species by undertaking extended habitat and frog surveys. This would be achieved via the following:
Dense exotic grasses within/surrounding ponds	Not proposed	<ul style="list-style-type: none"> • A review of background and baseline data was undertaken to gain a better understanding of the baseline survey areas and observations. • Baseline data and review of satellite imagery has been used to inform the key areas for extended surveys (where property access is possible) to demonstrate ongoing presence/existing natural breeding sites in proximity to the Project. • Reconnaissance surveys have been completed to ground truth aerial data/mark access tracks and waypoint locations that are considered to contain suitable habitat. Photos/waypoints regarding habitat suitability of the peripheral (accessible) habitat were taken and limitations of the search area have been determined. • Areas flagged during the baseline data review and reconnaissance surveys as suitable for extended surveys were chosen based on safe access during heavy rain/flooding and are primarily located in areas/along access tracks that were surveyed during baseline surveys. • A water level check in the days/week prior to a predicted trigger event would be undertaken to determine existing water levels. Noting that 50% capacity would be considered adequate levels to assume flooding during a trigger event. • Stage 1 Field surveys of peripheral habitat identified during the above reconnaissance surveys –two teams of 2x ecologists over two nights once the trigger rainfall has occurred. Noting surveys shall aim to be undertaken when the sites/peripheral habitat are under flood conditions, with ongoing precipitation, i.e. a trigger rainfall event in isolation as per EMP may not

Problem encountered	Proposed contingency measure (EMP)	Recommendations developed in consultation with and endorsed by TfNSW and EPA.
		<p>provide suitable conditions, hence preceding rainfall and water levels would be taken into consideration with the trigger rainfall.</p> <ul style="list-style-type: none"> • Stage 2 Field surveys to be undertaken 30 days after Stage 1 field surveys • Dip netting would be undertaken at constructed frog ponds only • During Stage 2 Field surveys, record water depth of constructed ponds and natural ponds/depressions within peripheral habitat where (i) frogs observed during Stage1 field surveys and (ii) within any other sites (depressions) observed during Stage 1 surveys and deemed suitable by qualified ecologist as high potential breeding sites. <p>Following the outcomes of Stage 1 and 2 surveys:</p> <ul style="list-style-type: none"> • Where the species is recorded within the defined peripheral habitat and/or existence of natural breeding sites is confirmed, no further work would be undertaken on the constructed ponds. • Where peripheral habitat surveys do not detect the species and/or habitat is not deemed suitable, further discussions with EPA would be undertaken.

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Annex 1. 2019/2020 monitoring results

Table 9: Stage 1 field data

Site	Time	Air temp (°C)	Humidity	Wind	Cloud cover %	Pond	Water depth (cm)	GTF Calling (<10 m from pond)	# GTF (<10 m from pond)	GTF calling (10-100 m from pond)	# GTF (10-100 m from pond)	Habitat notes	Notes	Other species
Reference	9:04 PM	20.3	93	0	80 - 100	Collombatti	40 - 50	Yes at least 3 different locations	2	Na	Na	GTF calling 10-15 m from road edge	Active along with numerous other frogs	Striped Marsh Frog, Tyler's Tree Frog, Graceful Tree Frog, Bleating Tree Frog, <i>Crinia</i> sp., Dusky Toadlet, Great Barred Frog
1	9:49 PM	20.3	95	0	90	1	35	0	0	0	0		Overgrown with Palm Grass (<i>Setaria palmifolia</i>), lacking overstorey	Striped Marsh Frog, Dusky Toadlet
						2	40	0	0	0	0			
						3	30	0	0	0	0			
						4	35	0	0	0	0			
						5	30	0	0	0	0			
2W	10:39 PM	19.3	95	0	90	1	0	0	0	0	0		Pond overgrown with <i>Allocastraria</i> saplings	
						2	10	0	0	0	0			Dusky Toadlet
						3	0	0	0	0	0			Green Tree Frog
						4	0	0	0	0	0		Pond overgrown with <i>Allocastraria</i> saplings	
						5	0	0	0	0	0		Pond overgrown with <i>Allocastraria</i> saplings	
2E	11:02 PM	19.3	95	0	90	1	35	0	0	0	0			<i>Crinia</i> sp. and Striped Marsh Frog
						2	40	0	0	0	0			Dwarf Tree Frog
						3	30	0	0	0	0			
						4	35	0	0	0	0			
						5	35	0	0	0	0			
3W	11:46 PM	19	95	0	100	1	0-2	0	0	0	0		Overgrown with exotic grasses	Red-backed Toadlet in distance
						2	0-2	0	0	0	0			












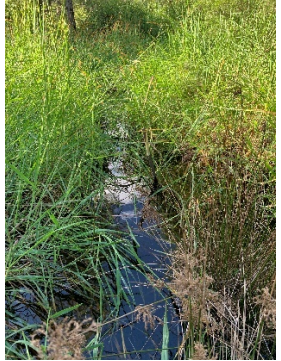



Site	Time	Air temp (°C)	Humidity	Wind	Cloud cover %	Pond	Water depth (cm)	GTF Calling (<10 m from pond)	# GTF (<10 m from pond)	GTF calling (10-100 m from pond)	# GTF (10-100 m from pond)	Habitat notes	Notes	Other species
						3	0-2	0	0	0	0			
						4	0-2	0	0	0	0			
						5	0-2	0	0	0	0			
3E	11:56 PM	19	95	0	100	1	0	0	0	0	0		Overgrown with exotic grasses	
						2	0	0	0	0	0			
						3	10	0	0	0	0			Eastern Dwarf Tree Frog, Great Barred Frog in creek
						4	0	0	0	0	0			
						5	0	0	0	0	0			












Table 10: Stage 2 field data



Site	Pond	Depth (cm)	# GTF (juv)	# of tadpoles	Tadpoles identified	Presence of fish	Predatory invertebrates	Comments
Reference	Collombatti	40-60	0	10	Striped Marsh Frog	Y	Y	Firetail Gudgeon and mayfly larvae
1E	1	40	0	1	Striped Marsh Frog	Y		Gambusia, Gudgeon
	2	40	0	2	Striped Marsh Frog, <i>Crinia</i> sp.			
	3	30	0	0			Y	Insects
	4	31	0	1	Unknown sp. (confirmed not GTF)	Y	Y	Gambusia and water spider
	Adjacent habitat	20	0	0				Adjacent habitat
2W	1	0	0	0				
	2	10	0	0				
	3	0	0	0				
	4	0	0	0				
	5	0	0	0				
2E	1	35	0	1	Unknown sp. (confirmed not GTF)			
	2	40	0	0				
	3	45	0	0			Y	Insects
	4	28	0	0				
	5	32	0	15	<i>Litoria peronii/tyleri</i>			
3W	1	0	0	0				Ponds difficult to locate in grass
	2	0	0	0				
	3	0	0	0				
	Ponds further south	All dry						
3E	Extra ponds	All dry	0	0				Ponds overgrown with grass difficult to locate
	3	10	0	0				
	4	0	0	0				
	5	0	0	0				








Annex 2. Photo monitoring

Table 11: Individual pond photo monitoring

Site	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5
1E 2017					
1E 2018					
1E 2020					

Site	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5
2W 2017					
2W 2018					
2W 2020					

Site	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5
2E 2018					
2E 2020					
3W 2017				Suitable pond not available	Suitable pond not available

Site	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5
3W 2018				Suitable pond not available	Suitable pond not available
3W 2020		Unable to locate in grass	Unable to locate in grass	Suitable pond not available	Suitable pond not available
3E 2017	Suitable pond not available	Suitable pond not available			






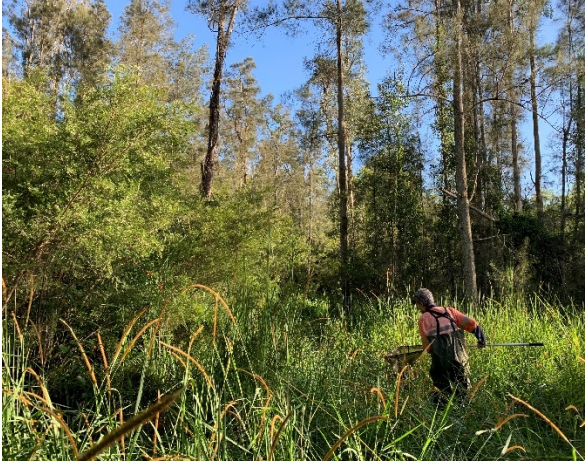














Site	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5
3E 2018	Suitable pond not available	Suitable pond not available			
3E 2020	Suitable pond not available	Suitable pond not available			Unable to locate in grass

Table 12: Site photo monitoring

Site ID	2017	2018	2020
Collombati Reference			
Site 1			

Site ID	2017	2018	2020
Site 2W			
Site 2E	NA		

Site ID	2017	2018	2020
Site 3W			
Site 3(1-2)E			

Site ID	2017	2018	2020
Site 3(3-5)E			

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