Appendix 3

2018 Abel Underground Coal Mine Dam Monitoring and Management Survey

(No. of pages including blank pages = 62)

This page has intentionally been left blank

KLEINFELDER
Bright People. Right Solutions.

2018 Abel Underground Coal Mine Dam Monitoring and Management Survey

Yancoal Australia Pty Ltd

Abel Underground Coal Mine, Beresfield, NSW

Black Hill and Stockrington, NSW

22 February 2019

This page has intentionally been left blank

2018 Abel Underground Coal Mine Dam Monitoring and Management Survey

Abel Underground Coal Mine, Beresfield, NSW

Black Hill and Stockrington, NSW

Kleinfelder Document Number: NCA19R91071
Project No: 20192332

Prepared for:

YANCOAL AUSTRALIA PTY LTD
1132 JOHN RENSHAW DR
BLACK HILL NSW 2322

Document Control:

Version	Description	Date	Author	Quality Review	External Review
1.0	Draft for external review	13 February 2019	Mark Dean	Kristy Peters	Colin Driscoll (Hunter Eco)
1.1	Final draft to client	22 February 2019			
2.0	Final to client				

Kleinfelder Australia Pty Ltd
95 Mitchell Road
Cardiff NSW 2285
Phone: (02) 4949 5200
Fax: 1300 881 035

ABN: 23 146 082 500

This page has intentionally been left blank

EXECUTIVE SUMMARY

Donaldson Coal Pty Ltd (now part of Yancoal Australia Pty Ltd) commenced operating Abel Underground Coalmine at Beresfield in the lower Hunter Valley, New South Wales, during 2008. To comply with part of the conditions of consent a Flora and Fauna Management Plan was prepared (Ecobiological 2007). This identified the need to establish a Surface Ecological Monitoring Plan (SEMP), comprised of several different monitoring programs. This Dam Monitoring and Management Plan (DMMP) is one of the monitoring programs. The mine is currently in a state of care and maintenance, with no coal extraction at this time. Should the mine re-open in the future, the seams that would be mined are located under the rural residential and forested areas at Black Hill.

In 2008, baseline ecological data was recorded at 156 dams in the Abel underground mine area (Ecobiological 2008). As well, assessment of the habitat value of dam sites for threatened fauna and flora was undertaken so that future monitoring could target dams which exhibited habitat that may potentially support target threatened species. This report builds on the baseline information collected in previous surveys regarding the occurrence of threatened and non-threatened species at the targeted dams.

Over time, the number of participants (land holders) with surveyed dams has declined due to a range of factors including lack of interest and changing ownership. In 2018, only 36 dams were surveyed for amphibians out of a possible 65 dams surveyed in 2008, only one out of the four dams were surveyed for Blue-billed Duck, and only 30 dams out of the original 87 were surveyed for Maundia triglochinoides*.*

Species diversity and composition data for frogs, in addition to abundance for water-dependent bird species, were recorded at each of the targeted dams for the 2018 survey. These data provide a means of measurement and evaluation of potential subsidence impacts at each of the dams over time. The data collected over the last 11 years will enable evaluation of potential subsidence impacts in the future.

Mining operations commenced in 2008 and ceased in April 2016. Several dams are located above previously active areas where subsidence has been detected at two of the surveyed dams. Given that mining operations have ceased and sufficient baseline data has been collected, assessment of changes to ecological conditions will be examined. Impacts of

weather conditions, landholder clearing, stock, invasive species and mining operations will be considered when analysing changes to species diversity and abundance within dams.

No frog species listed as threatened under State or Commonwealth legislation were recorded during field surveys. A total of nine species of frog were detected across all dams during 2018 surveys. There has been a general pattern of decline in total species recorded since 2011 with a small increase in 2018 from the previous four years. There is a negative correlation between the mean number of frog species per dam and average temperature in the three months preceding the survey. However, no correlation between total rainfall during these months and number of frog species recorded was found. Temperature, or some other factor, and not rainfall, is possibly the limiting factor for frog diversity in the area.

The Blue-billed Duck was not detected during 2018 surveys. A total of 63 bird species, including 23 waterbirds and 40 woodland/forest birds have been recorded between 2008 and 2018 across all of the dams surveyed. The 2018 surveys detected three species (2 waterbirds and 1 woodland/forest bird) across the one dam. Waterbird diversity and abundance has been relatively constant over the survey years. The abundance and diversity of woodland/forest bird species has fluctuated more widely, however, results in 2018 were below the averages across all survey years. These results were however only based on the survey of one dam (due to access restrictions).

No individuals of the threatened plant, Maundia triglochinoides *were identified. However* Eichhornia crassipes *(water hyacinth), a Weed of National Significance listed under the* Biosecurity Act 2015 *was identified in 11 dams. Other weed species detected included:* Cortaderia selloana (*Pampas Grass*) *– one dam;* Rubus fruticosus spp. agg. (*Blackberry) – 24 dams*; Lantana camara (*Lantana) – 26 dams.*

Monitoring will continue until one year after mining has passed the Long Gully and Blue Gum Creek catchments. The information and management recommendations from these and other surface monitoring studies will then be available to inform best practice measures to be incorporated into the Subsidence Management Plan (SMP).

Surveys of water quality, water level, conditions and habitat suitability assessment at each dam, particularly those which have not yet been undermined are strongly recommended. These data will be important for differentiating mining impacts from other factors that effect the composition and abundance of frog and water bird species at the target dams.

Contents

Tables

Figures

Appendices

1. INTRODUCTION

Donaldson Coal Pty Ltd (now owned by Yancoal Australia Pty Ltd) commenced operations at Abel Underground Mine in 2008. The mine is currently in a state of care and maintenance (since April 2016), with no coal extraction currently. Should the mine re-open in the future, the seams that would be mined are located under the rural residential and forested areas at Black Hill. Mine access and associated surface infrastructure are located within the existing Donaldson Coal mine open cut void at Beresfield, approximately 23 kilometres north-west of Newcastle, with transfer of coal to the existing Bloomfield Coal Handling and Preparation Plant (CHPP) to the north for coal washing and rail transport to the Port of Newcastle.

Underground coal mining is often associated with adverse environmental impacts because of subsidence (Bell *et al*. 2000, Sidle *et al*. 2000). Subsidence can cause loss of productive land, damage to underground pipelines and above-ground structures, decreased stability of slopes and escarpments, contamination of groundwater by acid drainage and dewatering of streams and groundwater supplies (Sidle *et al*. 2000). Of these, one of the major environmental concerns arising from the Abel mine is the effect of subsidence on local and regional hydrology. Surface and sub-surface cracking associated with mining subsidence can alter and create preferential flow paths, thus causing dewatering and rerouting of surface water and groundwater (Sidle *et al*. 2000). Alterations in channel and drainage morphology may also affect channel erosion, sediment delivery, and routing in streams and riparian habitat.

Associated with development approval for the Abel coalmine were a number of conditions of consent. These conditions included a requirement for the preparation of a Flora and Fauna Management Plan (F & FMP) which was prepared by Ecobiological (2007). The F & FMP, which forms part of a comprehensive Environmental Management System for the Abel mine, sets out a strategy to monitor the effectiveness of the conservation measures proposed in the Environmental Assessment (EA) Statement of Commitments for the overall operation of the mine.

Part of this strategy was to establish a Surface Ecological Monitoring Plan (SEMP) to monitor the effectiveness of the conservation measures proposed in the EA to mitigate against subsidence impacts on three distinct habitat areas; farm dams that form a belt across the mine site; subtropical rainforest areas of Long Gully Creek; and Pambalong Nature Reserve. The SEMP outlines a monitoring program for each of these areas by which baseline and

subsequent monitoring data are to be gathered to inform future management. This report builds upon the baseline report for the Dam Monitoring and Management Program (DMMP) which forms part of the overall SEMP.

The Dam Monitoring and Management Plan (DMMP) gathered data for 156 dams in 2008, all of which are located above the Abel underground mining area. In 2009, the number of dams identified for longer-term monitoring was reduced to 84, following assessment of their habitat suitability for the threatened Green and Golden Bell Frog (*Litoria aurea*), Green-thighed Frog (*Litoria brevipalmata*), Blue-billed Duck (*Oxyura australis*) and the aquatic plant *Maundia triglochinoides*. Preferred habitat of each species is detailed in **Appendix 1**.

Over time, the number of participants (land holders) with surveyed dams has declined due to a range of factors including lack of interest and changing ownership. Sixty-four (64) dams with suitable Green and Golden Bell Frog habitat were surveyed for this species in 2008 and 2009, 61 dams in 2010 and 2011, 65 in 2012 and 2013, 49 in 2014 and 2015, 44 in 2016, 42 in 2017 and 36 in 2018. Thus, fluctuations of surveyed dams are largely a result of private landholders declining access to their land.

Eighty-seven (87) dams were originally assessed as containing suitable habitat for the aquatic plant *M. triglochinoides*, but with knowledge gained from past surveys this number has been reduced to 82; only 30 dams were surveyed in 2018 due to landholder restrictions.

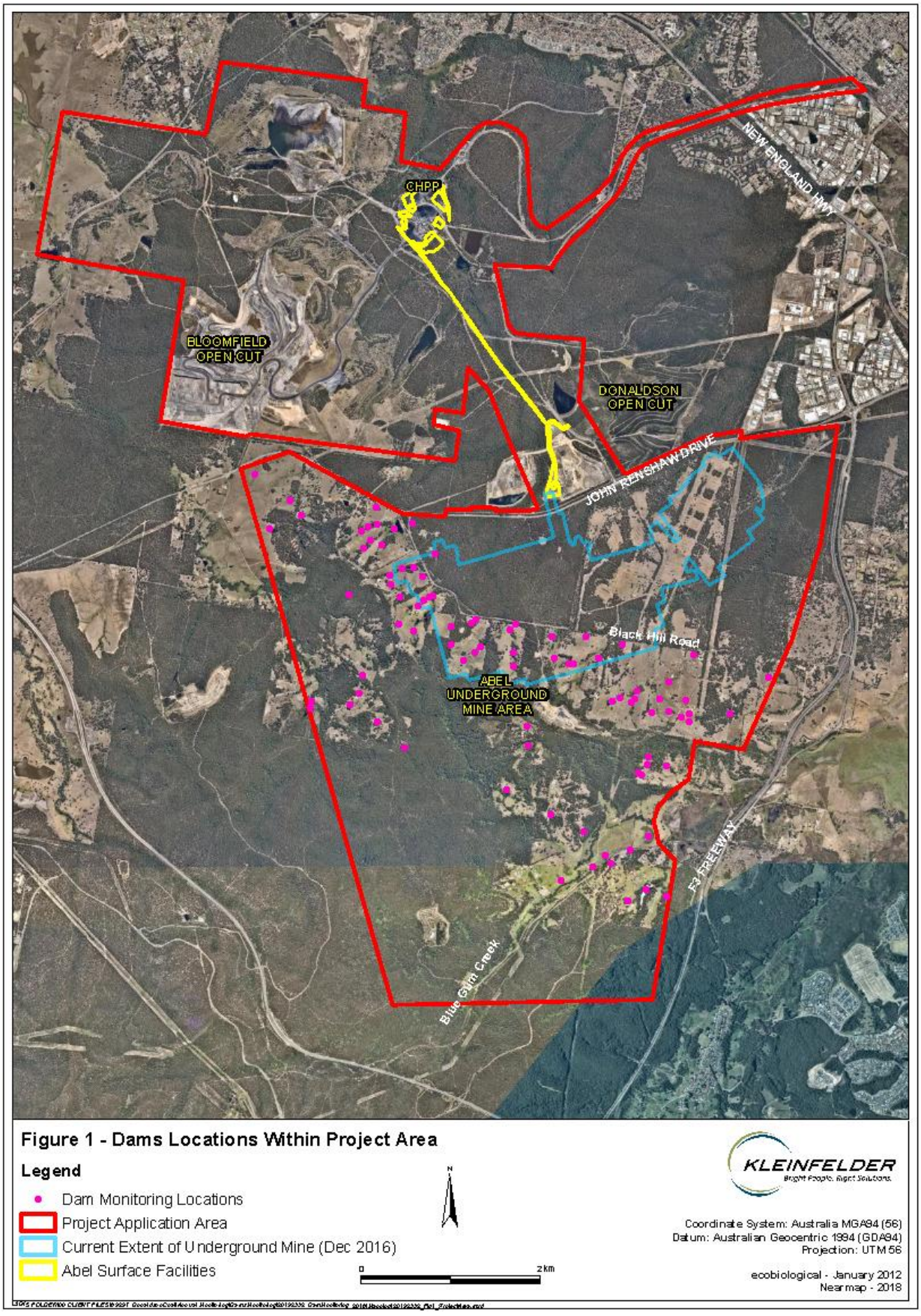
Species diversity, abundance and composition data for water-dependent bird species at four of the dams containing preferred habitat have historically been recorded since 2008, however only one dam was surveyed in 2018 due to lack of access. These data provide a means of measurement and evaluation of potential subsidence impacts at each of the dams over time to later be incorporated into the SMP.

2. LOCATION

The Abel Underground Mine is located within Newcastle, Cessnock and Maitland local government areas (LGAs). The majority of the underground mine and surface infrastructure area is within the Cessnock LGA.

The location of the underground mine area, surface facilities and the current extent of the underground mine are shown in **Figure 1**. The underground mine area is bounded on the eastern side by the M1 Freeway; the western and southern sides by a tract of forest that extends south to the Central Coast and beyond to Hornsby and to the northern side by existing open cut coal mining activities within the Donaldson and Bloomfield mine leases.

The Abel underground mine area is approximately 2750 ha and consists of low undulating forested hills with patches of cleared land for 110 rural/residential properties. Approximately 175 farm dams are located above the underground mining area, scattered across these various properties. Large areas of land are owned by Donaldson Coal, Coal and Allied (Rio Tinto) and the Catholic Diocese of Maitland and Newcastle. Black Hill Public School, various local roads and other infrastructure are located in the area.


CHPP
BLOOMFIELD OPEN CUT
DONALDSON OPEN CUT
NEW ENGLAND HWY
JOHN RENSHAW DRIVE
Black Hill Road
ABEL UNDERGROUND MINE AREA
F3 FREEWAY
Blue Gum Creek
Figure 1 - Dams Locations Within Project Area
Legend
Dam Monitoring Locations
Project Application Area
Current Extent of Underground Mine (Dec 2016)
Abel Surface Facilities
N
0
2km
KLEINFELDER
Bright People. Right Solutions.
Coordinate System: Australia MGA94 (56)
Datum: Australian Geocentric 1994 (GDA94)
Projection: UTM 56
ecobiological - January 2012
Nearmap - 2018

3. OBJECTIVES

The Abel EA submission notes that the 175 dams located above the underground mining area are vulnerable to subsidence impacts such as cracking or tilting with significant water loss as a result. The DMMP aims to develop a set of data for 87 of these dams (**Appendix 2**) focusing on sensitive flora and fauna (targeting threatened species), species diversity, composition and abundance to inform the SMP. **Figure 2** shows the location of the accessible and inaccessible dams across the mine area in 2018 including the extent of underground mining. Dam access is subject to the ability to contact landholders prior to survey dates and obtain permission. Dam numbers and habitat suitability for specific threatened species are listed in **Appendix 2**.

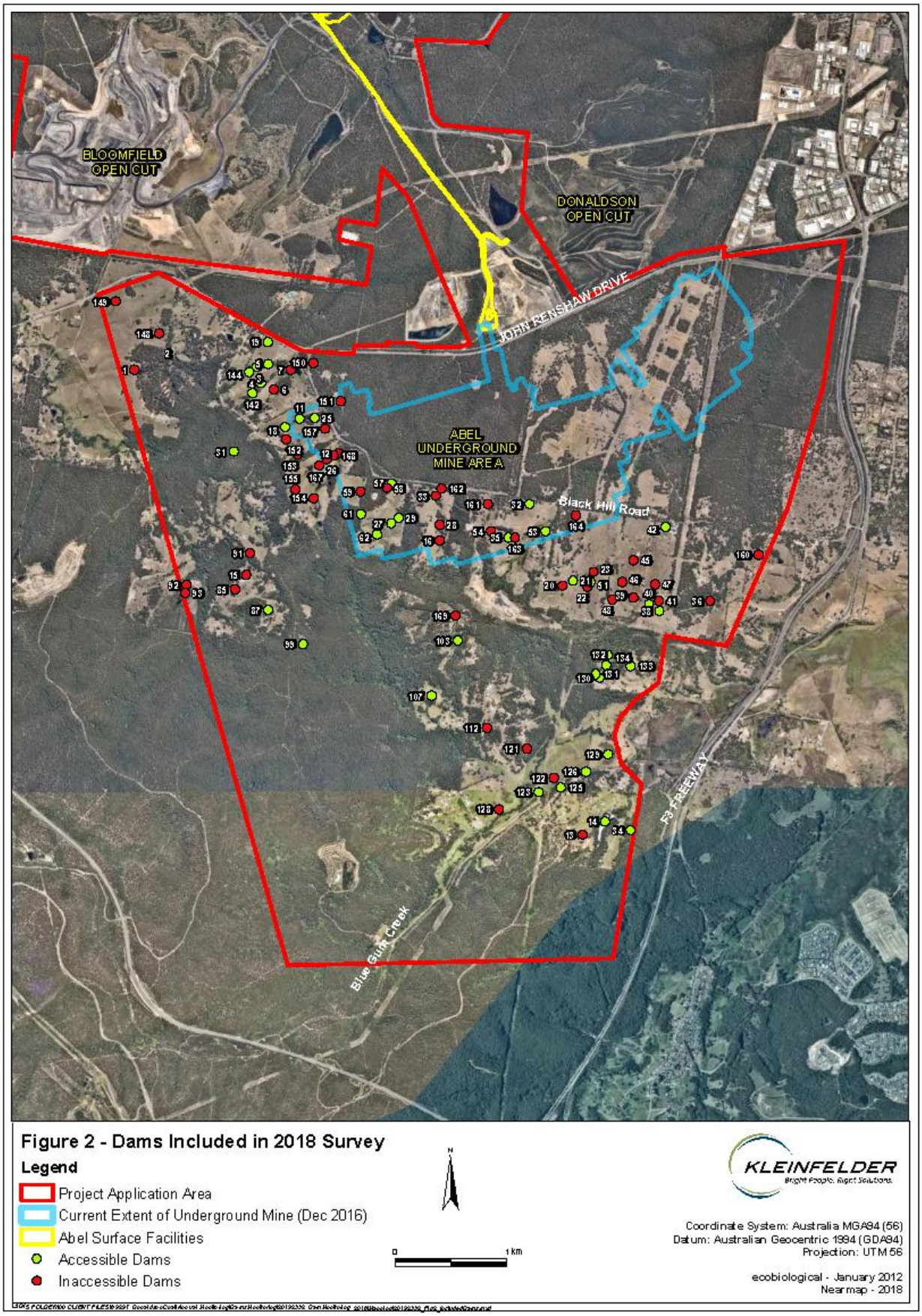
Table 1 sets out the target threatened species, appropriate methods and monitoring times as outlined in the F & FMP.

Table 1: Species targeted by the Dam Monitoring and Management Plan.

Scientific name	Common Name	Method	No. of Dams	Monitoring Period
Litoria aurea	Green and Golden Bell Frog	Call playback and targeted search	65	Warm nights during or after rain (October – February)
Litoria brevipalmata	Green-thighed Frog	Targeted search	3	Warm nights after heavy rain (October – February)
Oxyura australis	Blue-billed Duck	Targeted search	4	Summer
Maundia triglochinoides	-	Targeted search	87	Late spring to early autumn

Table 2: Species targeted by the Dam Monitoring and Management Plan in 2018

Scientific name	Common Name	Method	No. of Dams	Monitoring Period
Litoria aurea	Green and Golden Bell Frog	Call playback and targeted search	35	Warm nights during or after rain (October – February)
Litoria brevipalmata	Green-thighed Frog	Targeted search	1	Warm nights after heavy rain (October – February)
Oxyura australis	Blue-billed Duck	Targeted search	1	Summer
Maundia triglochinoides	-	Targeted search	30	Late spring to early autumn


BLOOMFIELD OPEN CUT
DONALDSON OPEN CUT
JOHN RENSHAW DRIVE
ABEL UNDERGROUND MINE AREA
Black Hill Road
F3 FREEWAY
Blue Gum Creek
Figure 2 - Dams Included in 2018 Survey
Legend
Project Application Area
Current Extent of Underground Mine (Dec 2016)
Abel Surface Facilities
Accessible Dams
Inaccessible Dams
N
0
1 km
KLEINFELDER
Bright People. Right Solutions.
Coordinate System: Australia MGA94 (56)
Datum: Australian Geocentric 1994 (GDA94)
Projection: UTM 56
ecobiological - January 2012
Nearmap - 2018

4. METHODS

4.1 AMPHIBIANS

4.1.1 Green and Golden Bell Frog (*Litoria aurea*)

Sixty-four (64) dams with suitable Green and Golden Bell Frog habitat were surveyed for in 2008 and 2009, 61 dams in 2010 and 2011, 65 in 2012 and 2013, 50 in 2014, 49 in 2015, 44 in 2016, 42 in 2017 and 36 in 2018. Fluctuations of surveyed dams are a result of inability to contact private landholders to gain permission to access their land or landholders declining access.

Surveys were conducted on 12, 13, 17 and 18 December 2018. Although numbers of available dams had dropped since 2013, the 36 dams surveyed in 2018 were located above or adjacent to where underground mining occurred. Mining ceased in April 2016. As such, the dams surveyed were suitably representative of the total dams present and provided the best practicable opportunity of detecting the Green and Golden Bell Frog.

Targeted habitat surveys and call playback surveys were conducted throughout the survey period. At each dam an initial two-minute quiet listening period was carried out to see if any Green and Golden Bell Frogs were calling and to record any other common species heard. This was followed by 10 minutes of call playback and 10 minutes of habitat searching. During call playback, pre-recorded calls of the Green and Golden Bell Frog were broadcast over a megaphone to attempt to illicit a response from any males that may have been present.

The call playback period consisted of 1 minute of playing the calls followed by 20 seconds of quiet listening, repeated until the 10-minute period was complete. The habitat searches consisted of searching suitable habitat with the aid of a head-torch to locate any adults or juveniles. All other frog species observed were also recorded.

Weather conditions during the survey period are described in **Table 3**.

4.1.2 Green-thighed Frog (*Litoria brevipalmata*)

Three (3) dams were deemed potentially suitable for the Green-thighed Frog, however only one dam (Dam 87) was accessible in 2018 (surveyed on 13/12/18). Access could not be gained for Dam 1 or 151.

Surveys are required to be completed after heavy rainfall during the breeding season (November- February) (DECC 2009). A total of 8.2 mm of rain fell in the five days prior to the survey being conducted and a further 82.2 mm during the survey period. Weather conditions during the survey period are provided in **Table 3**.

Quiet listening and a habitat search were carried out for the Green-thighed Frog at Dam 87. The species only calls on a small number of nights (usually <5) in any given season and only after significant rainfall (usually 70 mm). It does not readily respond to call playback. The habitat search consisted of searching suitable habitat with the aid of a head-torch to locate any adults or juveniles.

4.2 BIRDS

4.2.1 Blue-billed Duck (*Oxyura australis*)

One dam (Dam 14) was surveyed for the Blue-billed Duck on 19 December 2018. Originally only four dams were considered to have suitable habitat for the Blue-billed Duck. The surveyed dams were chosen based on their size (with only large dams usually being inhabited by the species), the amount of deep, open water and the amount of fringing aquatic vegetation present. Dam 14 is predominantly open water with small reeds and aquatic vegetation around the fringes.

Targeted surveys for the Blue-billed Duck involved a 20-minute walking transect along the edge of each of the selected dams. This time enabled the inspection of the entire surface area of each dam for the target species. The surveys were carried out during favourable conditions. Individual counts of all other waterbird and woodland/forest species observed utilising the surface of the water body or foraging either within the vegetated margins or aerially foraging over each dam was also recorded.

4.2.2 Weather Conditions during Fauna Survey Period

Table 3: Weather during the fauna survey period (Maitland Airport AWS 061428)

Weather	Date				
	12/12/2018	13/12/2018	17/12/2018	18/12/2018	19/12/2018
Temp. Min. (°C)	17.1	19.2	18.8	20.1	21.7
Temp Max. (°C)	25.1	32.3	32.1	31.6	28.6
Relative Humidity (%) 9am	100	85	75	87	90
Relative Humidity (%) 3pm	81	61	55	67	67
Rain	5.4	1.2	1.2	0	0
Max wind gust (km/hr)	30	76	37	31	-
Wind direction	E	WNW	SE	E	-

4.3 FLORA

4.3.1 Maundia triglochinoides

Eighty-seven (87) dams were originally assessed as containing suitable habitat for the aquatic plant *M. triglochinoides*, but with knowledge gained from past surveys this number has been reduced to 82 dams, with 30 dams surveyed with permission of owners in 2018. Searches were conducted on 19 December 2018. Surveys were undertaken by completely circumnavigating the edges of the dams on foot (where physically possible) ensuring that all water edge environments were searched. The surveys were conducted in December to coincide with the flowering time of *M. triglochinoides* as it is difficult to detect and distinguish from closely related species during the non-flowering period.

5. RESULTS

5.1 AMPHIBIANS

No Green and Golden Bell Frogs were detected at any of the 36 dams surveyed. No frog species listed as threatened under State or Commonwealth legislation were recorded during field surveys.

A total of nine species of frog were detected across all dams during 2018 surveys (**Figure 3**). All nine species are considered common in the region and are known to breed in dams and ponds. There has been a general pattern of decline in total species recorded since 2011 with a small increase recorded in 2018.

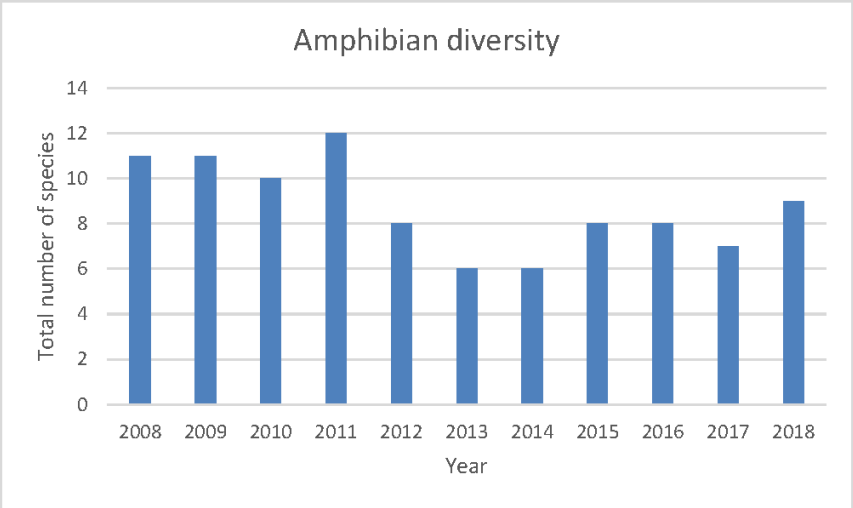


Figure 3: **Total number of species detected across all dams each year.**

Figure 4 shows the frequency distribution of numbers of frog species found at each dam. The distribution of frog diversity is seen to fluctuate throughout the years with the years 2008 – 2012 showing the widest distributions. The distributions of frog diversity in 2014, 2015, 2016 and 2017 are negatively skewed, with most dams containing 1 – 3 species. Compared to 2017, the 2018 results indicated an increase in frog species numbers at 18 dams, 12 dams had no change in species number and four showed a decrease. It should be noted that some dams had their fringe vegetation removed by landowners and also some dams showed signs of herbicide use for weeds which may have affected frog species.

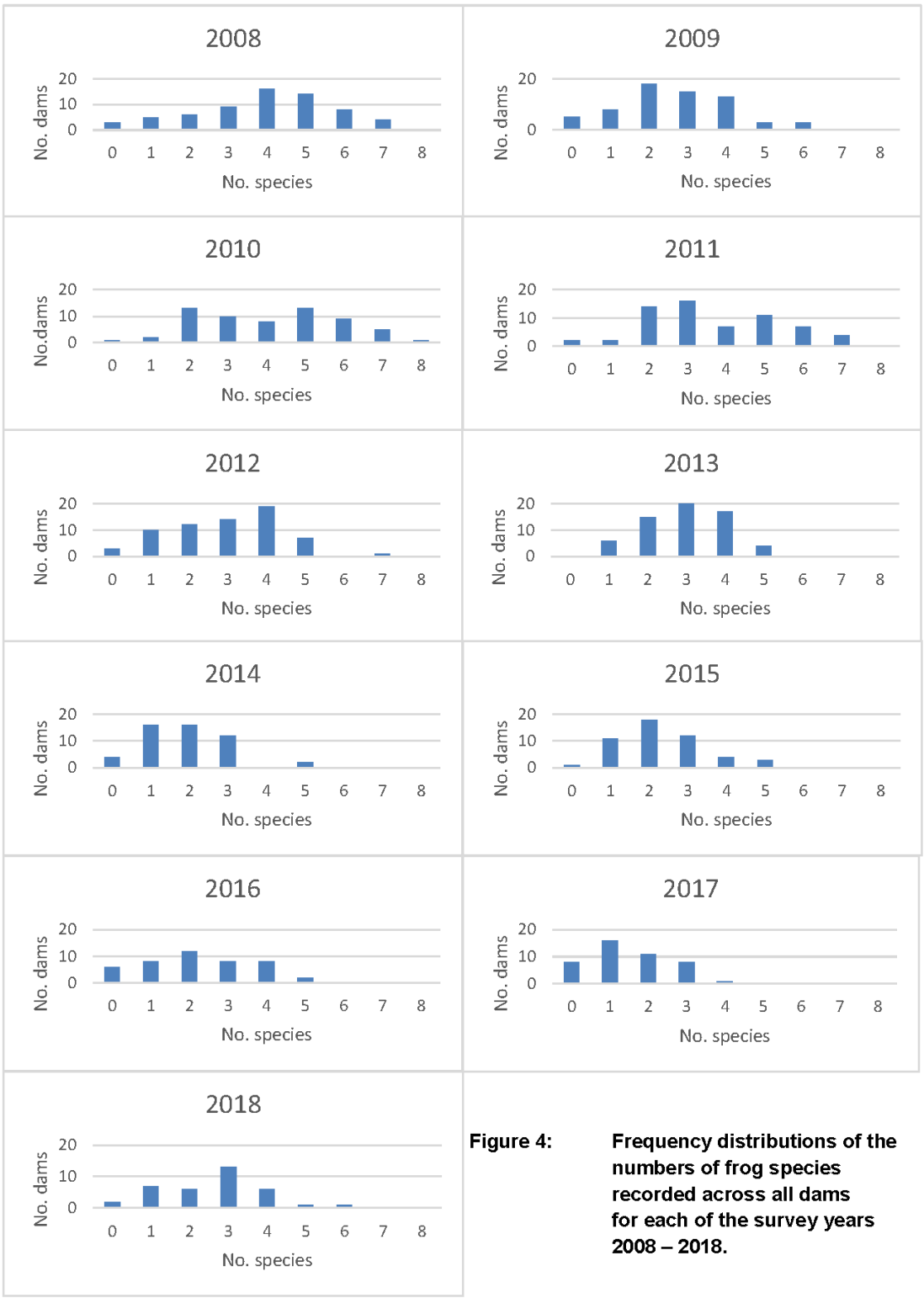


Figure 4: **Frequency distributions of the numbers of frog species recorded across all dams for each of the survey years 2008 – 2018.**

When observed over all survey years, there is a strong negative correlation (R^2 = -0.52) between the mean number of frog species per dam and average temperature in the three months preceding the survey (**Figure 5**). The highest mean number of frog species was observed in 2010, when the average temperature from October to December was 25.3°C; conversely, the lowest mean number of frog species detected was in 2014, 2015, 2016 and 2017 when average temperatures for October to December were around 28°C. In 2018 the average temperature was 27.6°C with an average of 2.53 frog species per dam which is higher than the preceding four years.

There was, however, no correlation found between mean number of frog species per dam and the total rainfall during the three months preceding the surveys (**Figure 6**). The three years that recorded the highest mean number of frog species per dam, 2008, 2010 and 2011, all received over 250 mm of rain in the three months preceding the surveys. Prior to surveys in 2018, 282.4 mm of rain was recorded. The 2018 survey recorded the highest average of 2.53 frog species per dam than in the preceding four years. Rainfall, however, has not been found to predict frog diversity in this study as there is no statistically significant (R^2=0.15) relationship when comparing all years.

The survey and weather results of 2018 support previous conclusions that temperature is a strong predictor of the number of frog species detected during surveys, whilst no relationship with rainfall can be inferred.

The list and number of frog species identified from each dam are provided in **Appendix 3**.

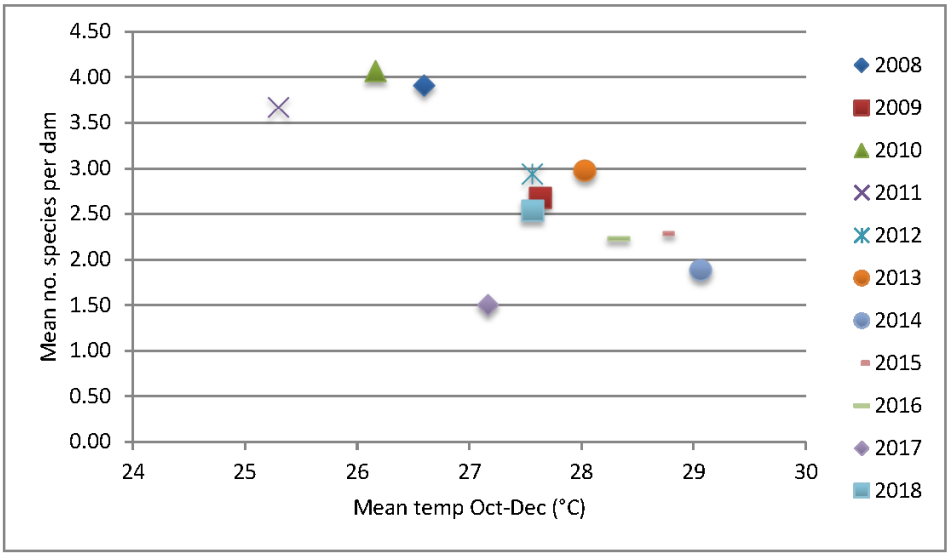


Figure 5: Relationship between mean temperature (Oct-Dec; °C) and the mean number of frog species per dam (source: Maitland Airport, previously Maitland visitors centre but now offline).

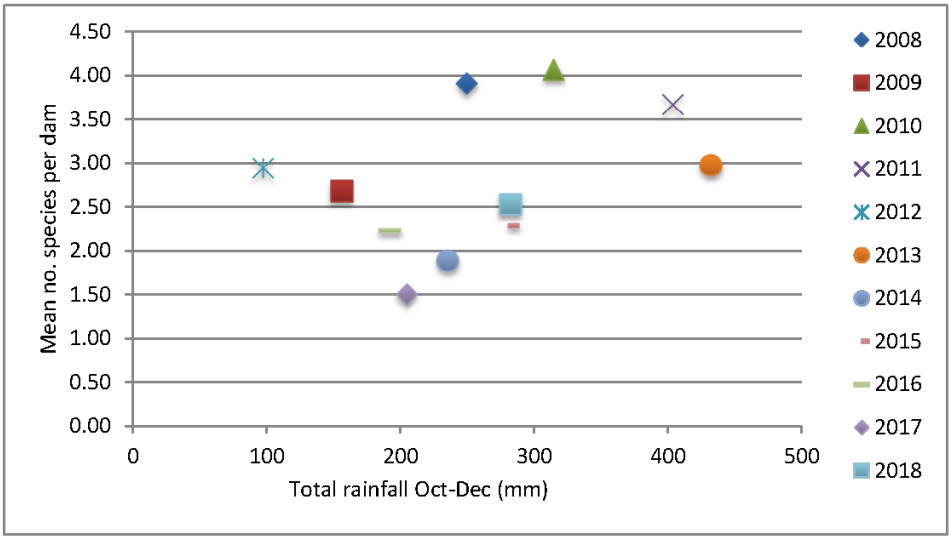


Figure 6: Relationship between total rainfall (Oct-Dec; mm) and the mean number of frog species per dam (source: Maitland Airport, previously Maitland visitors centre but now offline).

5.2 BIRDS

The Blue-billed Duck was not detected during 2018 surveys. As discussed in the methodology, only one of the four dams was surveyed due to access issues.

A total of 63 bird species, including 23 waterbirds and 40 woodland/forest birds have been recorded between 2008 and 2018 across all of the dams surveyed. The 2018 surveys detected three species (2 waterbirds and 1 woodland/forest bird) at Dam 14.

Waterbird species diversity at Dam 14 (2 species) was lower than the yearly average of four species. Overall, waterbird diversity has remained relatively constant at Dam 14 with a small decrease in 2018, although, 2013 recorded approximately twice the number of species as in other years at Dam 14. Woodland/forest species diversity has fluctuated much more widely than waterbird diversity at the dams surveyed. In particular, species diversity in 2015 at Dam 14 was twice the highest number of species previously recorded, with the 2018 result being one of the lowest results (**Figure 7**).

Waterbird abundance at Dam 14 recorded a lower number of individuals (8) to other years, which is below the yearly average of 20 individuals (**Figure 8**). Woodland/forest bird abundance was well below the yearly average (2 individuals compared to an average of 20 individuals) at Dam 14. Counts of woodland/forest birds are highly variable between years (**Figure 8**).

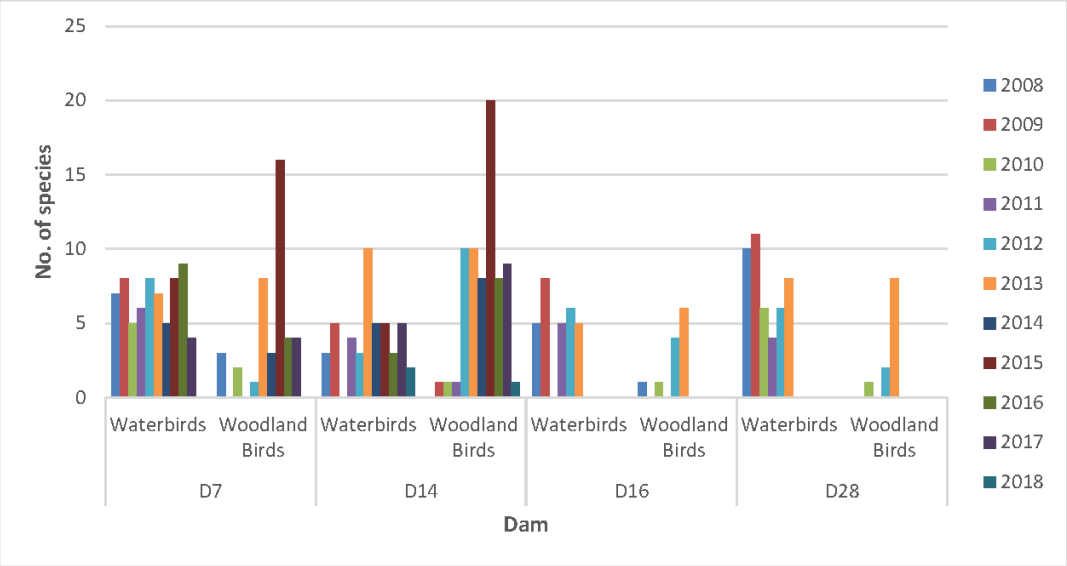


Figure 7: **Number of waterbird and woodland bird species recorded at each dam 2008-2018.**

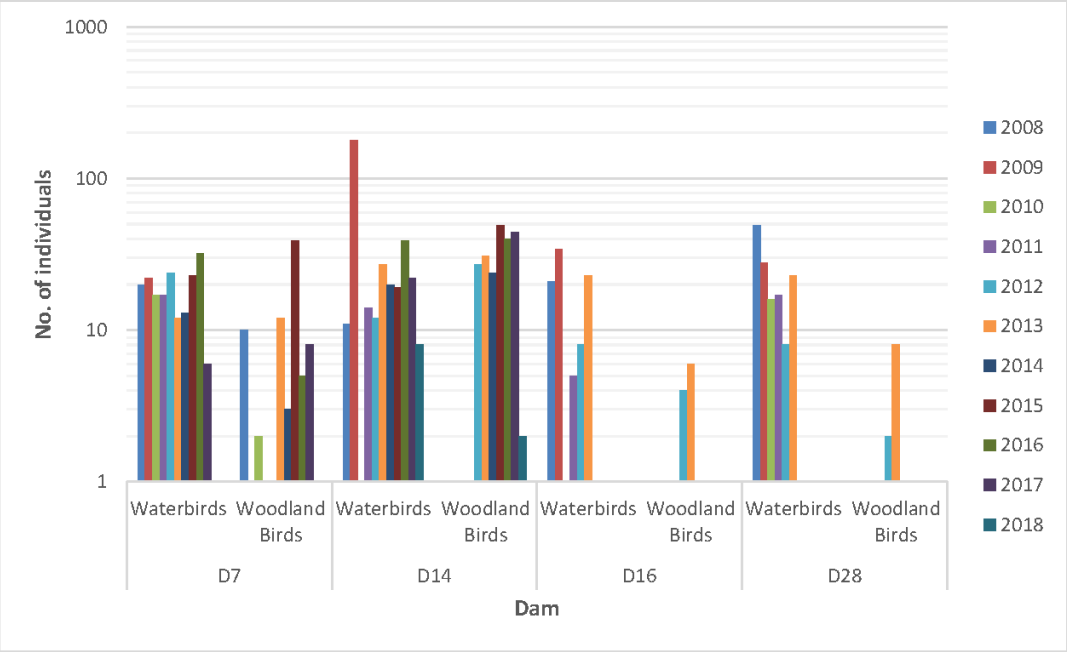


Figure 8: **Total number of individual water and woodland birds recorded at each dam 2008-2018.**

5.3 FLORA

Maundia triglochinoides was not detected at any of the 30 dams surveyed. All property owners were contacted to gain permission to access their property prior to Kleinfelder staff conducting surveys. Contact was made at the time of entering, or soon afterwards with several land owners. If the owners were not present at the time of the survey and access had been granted in the past, entry to property was assumed with field staff/vehicles to leave gates as found and to minimise disturbance to any stock present.

No other flora species listed as threatened under State or Commonwealth legislation or under the ROTAP (Rare or Threatened Australian Plant) scheme were recorded during field surveys.

While conducting the survey Kleinfelder staff took note of other weeds in the vicinity of the dams. Species identified included Blackberry (*Rubus fruticosus* spp. agg.), Crofton Weed (*Ageratina adenophora*), Giant Parramatta Grass (*Sporobolus fertilis*), Lantana (*Lantana camara*), Water Hyacinth (*Eichhornia crassipes*) and Wild Tobacco Bush (*Solanum mauritianum*).

GPS tracks and monitoring photos of each of the dams surveyed have not been included in this report for brevity but are available on request.

6. DISCUSSION

6.1 AMPHIBIANS

6.1.1 Green and Golden Bell Frog

While a third of all the dams identified and surveyed in 2008 were considered to contain suitable Green and Golden Bell Frog habitat, the species has not been detected in any of the 11 surveys. However, habitat characteristics (increased turbidity, change in water depth and dam profile, changes in vegetation types and densities) of target dams have changed, or have been modified by landholders; altering the suitability of the habitat for the Green and Golden Bell Frog.

The Green and Golden Bell Frog prefers large, permanent water bodies containing high levels of emergent vegetation such as Typha, Baumea and the introduced *Juncus acutus*. Many of the target dams surveyed did not contain any or few of the features required by the Green and Golden Bell Frog. Issues at some of the target dams included Water Hyacinth covering entire surfaces, no bank vegetation due to cattle grazing/clearing, no open water or herbicide weed control by landholders.

Regardless of the status of occupancy of dams by the target species, the presence of a large number of dams with habitat suitable for these species (particularly those that interconnect and form habitat complexes) is an important factor for their future recovery. This is particularly true for the Green and Golden Bell Frog, a relatively mobile species that is known to be able to travel considerable distances and traverse hostile habitats to reach suitable ones (Daly 1995).

Currently there are two recognised key populations of Green and Golden Bell Frog at opposite ends of Hexham Swamp (known as the Sandgate and Kooragang Island populations). The species was also once known to be widespread right through the Hexham Swamp and adjoining areas. Old records of this species are known from within a 10-kilometre radius of the Black Hill area; however, these populations are now thought to be extinct (M. Mahony pers. comm.). Nevertheless, should this species recover in the near future it is highly conceivable that it may migrate back through this area towards Pambalong Nature Reserve and onto the adjoining belt of farm dams.

6.1.2 Green-thighed Frog

Ephemeral pools, partly or wholly within rainforest or wet sclerophyll forest are ideal habitat for the Green-thighed Frog. They also forage in and amongst fallen leaf litter and logs. Locally, the Green-thighed Frog is only known from two records approximately 13 km from the Black Hill area and is not known for its high mobility.

In 2008, only three dams were considered to contain suitable Green-thighed Frog habitat (Dams 1, 87 and 151). While the surveys carried out were scientifically robust, Green-thighed frogs are cryptic in nature: they may only call on one or two nights of the year (Lemckert *et al.* 2006) and are very difficult to detect on other nights.

One dam (87) was able to be surveyed in 2018. Habitat observations from 2015 at the two dams where access permission was granted found that impacts from cattle grazing in and around the two dams have degraded the habitat and water quality. The two ponds which once contained suitable habitat for the Green-thighed Frog now represent habitat of little value for this species and, without habitat restoration, its presence in future surveys is not expected.

6.1.3 Non-threatened Frogs

The detection of numerous species of non-threatened frogs is a positive sign of ecosystem health. Amphibian calling activity recorded throughout the survey period was high, resulting in a high level of confidence that the majority of species present were likely to be detected.

The diversity of non-threatened frogs declined from 2010 to 2014 with fewer species being detected on average at each dam surveyed. Data from the 2018 survey indicate that species diversity per dam has increased surpassing the last four years (2014 to 2017). The total number of frog species detected has also improved with the lowest number of overall species being observed in 2013 and 2014 (6 species). The number of frog species observed in 2018 was nine, which is the best result seen since 2011 (12) and is also above the overall average for all years (8.7).

The fluctuation in frog species diversity over the last 11 years could reflect changing weather patterns across the region. Abnormally warm conditions prevailed through much of November 2009 with above average temperatures (National Climate Centre 2009), which may explain the drop in species diversity per dam in the 2009 survey (**Figure 5**). Frog diversity across all ponds, however, was not lower in 2009 (**Figure 3**). The higher temperatures and lower rainfall in 2009,

therefore, may have reduced dispersal of frogs across the landscape; leading to lower numbers of species at each dam but not lower diversity overall.

Figure 5 shows a strong negative correlation between frog species diversity at each dam and the average maximum temperature in late spring and early summer months; with higher temperatures in 2014, 2015, 2016 and 2017 associated with lower frog diversity per dam than other years. Rainfall was seen to be higher than the average in previous years. These results suggest that average maximum temperature, and total rainfall, is a contributing factor to the results observed in the past five years of surveys when compared with earlier surveys. When conditions are unfavourable, frogs conserve energy by going into torpor and foregoing/reducing breeding attempts. When conditions improve (warm temperatures and regular rainfall events) the probability of reproductive success improves, and the number of frogs observed will increase, evident by heightened activity and calling. Frog abundance has often been observed to correlate with rainfall so it is surprising that these data do not support a trend of higher rainfall and higher frog diversity. It may be that rainfall was not the limiting factor in frog diversity across the Abel Dams. Other factors that may be limiting frog diversity are survey bias, the impact of predators or pathogens and the continued removal of emergent vegetation by landowners/stock. Mosquito fish (*Gambusia holbrooki*) may also pose a great threat to frog eggs and tadpoles. Mosquito fish are known to breed quickly and adversely impact or even wipe out native tadpole populations (Anstis 2002). Mosquito fish were detected opportunistically in the majority of dams surveyed in 2014 to 2018.

The number of frogs detected may not always reflect the total species present due to a sampling bias. Survey methods for amphibians are largely focused on detecting males as they vocalise to attract a mate. When conditions to breed are not appropriate males will refrain from calling, therefore reducing their detectability. However, they may still be present in the environment but not be as obvious compared to other years. The number of dams that were inaccessible in 2018 was the highest (28) since the start of the study. Many of these dams regularly recorded over five species each year and contained species that were not usually detected in other dams. These restrictions are likely contributors to the lower total number of species being detected and the lower diversity on average per dam in recent years.

Some species of frog potentially occurring in the study area have not been detected in the 11 years of surveys, particularly the Green Tree Frog (*Litoria caerulea*), Bleating Tree Frog (*Litoria dentata*), Ornate Burrowing Frog (*Platyplectrum ornatum*), Pobblebonk (*Limnodynastes dumerilii*), Haswell's Frog (*Paracrinia haswelli*), Bibron's Toadlet (*Pseudophryne bibronii*) and Tyler's Toadlet (*Uperoleia tyleri*). One species, the Red-backed Toadlet, (*Pseudophryne*

coriacea), was detected in 2008 at one dam site that was not selected for further monitoring. The absence of these species, and the varying diversity and species composition at the dams over 11 years, may be due to a variety of factors such as the health of the dam ecosystems (cattle disturbance is widespread), or the Chytrid fungus (a pathogenic fungus that is considered largely responsible for the recent global amphibian decline) (Berger *et al.*, 1998), unsuitability of local habitat, extreme weather conditions, weed infestation or chance.

6.2 BIRDS

During the 2008 baseline surveys, four dams were considered to contain potential Blue-billed Duck habitat. This species is considered to be an uncommon visitor to the Hunter region, and has been irregularly recorded from key sites including Walka Water Works, Oakhampton Heights (approximately 8 km north of the study area) and Deep Pond, Kooragang Island (approximately 13 km east of the study area). The Blue-billed Duck is a mobile species that may re-appear at suitable deep dams at any time given suitable conditions. This species is also known from the Bloomfield Dam (NSW Wildlife Atlas 2010) to the north of the Abel mine area. Only one dam was available for surveys in 2018 due to landholder restrictions. The Blue-billed Duck was not recorded during the 2018 surveys and has not been recorded during any survey event since monitoring began in 2008.

In 2018, waterbird diversity was the second lowest recorded at Dam 14. At Dam 14 the number of waterbird species has been relatively constant over the survey years, a peak of 10 species was seen in 2013. In 2016 waterbird abundance was the second highest since surveys began at Dam 14. These results along with results from 2018 suggest there has been no negative impact on waterbird diversity or abundance at Dam 14.

Woodland/forest bird species diversity in 2018 was below the yearly average at Dam 14. The high number of woodland/forest bird species recorded in 2015 is an anomaly in the data collected to date. It was proposed in the 2015 annual report that these high numbers may have been due to increased bird activity following the cessation of a major rain event. It has been highlighted in past reports (ecobiological 2008, 2009, 2010, 2011 and Kleinfelder 2012, 2013) that bird diversity varies with rainfall in the area prior to surveys. The Hunter Region experienced a major rainfall event in the few days leading up to the 2015 survey, receiving 236 mm over three days.

Many of the bird species that have been recorded to date are also nomadic/itinerant in that they often travel large distances and sporadically occupy multiple areas as they move. Birds of this nature are largely unpredictable in determining their specific movements and thus appear irregularly. The number of birds detected may not always reflect the total species present due to a sampling bias and the climatic conditions on the day. Collection of data on non-threatened bird species observed during the standardised surveys will be used to make comment on the ongoing health of the dam ecosystems into the future.

6.3 FLORA

While a third of all the dams identified and surveyed in 2008 were considered to contain habitat suitable for *Maundia triglochinoides*, this species was not detected in any of the previous surveys or in the present survey period.

There are several records of *Maundia triglochinoides* near the study area, one from Kooragang Wetlands (pers. obs., D. Pedersen), four from adjacent Pambalong Nature Reserve at Stockrington, one from Lenaghan and another two records from Beresfield. However, a close inspection of suitable dams over the 11-year period has not recorded this species. As this species mainly disperses via stream flow, it is unlikely that it will appear at any of the dam sites which are not generally connected to natural streams. It may also be dispersed by duck faeces; this, however, is an unlikely occurrence.

The presence of *E. crassipes* (Water Hyacinth) in seven of the dams is of concern as it has the potential to spread to water ways downstream of the dams during times of high rainfall. This is a Weed of National Significance. Legislation states that the plant must be fully and continuously suppressed and destroyed.

Other observed listed weed species included: *Rubus fruticosus* spp. agg. (Blackberry); *Ageratina adenophora* (Crofton Weed); *Lantana camara* (Lantana), *Sporobolus fertilis* (Giant Parramatta Grass), *Solanum mauritianum* (Wild Tobacco), and *Phytolacca octandra* (Inkweed).

7. CONCLUSION

Over time, the number of participants (land holders) with surveyed dams has declined due to a range of factors including lack of interest and changing ownership. In 2018, only 36 dams were surveyed for amphibians out of a possible 65 dams surveyed in 2008, only one out of the four dams were surveyed for Blue-billed Duck, and only 30 dams out of the original 87 were surveyed for *Maundia triglochinoides*. This declining participation means that the results of the study are becoming less informative over time. Discernible trends from the 2018 survey are summarised below.

Frogs

Frog species diversity in 2018 was seen to increase compared to recent years but is only slightly lower than average calculated across all years. There has been a general decline in frog species recorded from 2010 to 2014, though slightly higher numbers have been recorded in 2015, 2016, and 2018. The average maximum temperature for the three months preceding the surveys was slightly above average for this period while total rainfall recorded was above average with good falls around the survey period. There is a strong negative correlation between frog diversity per dam and average temperature of the three months preceding the survey based on temperature records from Maitland. There is no correlation between total rainfall and frog diversity per dam, suggesting that rainfall has not been the limiting factor affecting frog diversity in the area over the 11 years of monitoring. However, there is likely to be small temperature and rainfall differences between Maitland and the Black Hill area. Temperature, or the loss of emergent vegetation through clearing/stock, are the likely limiting factors impacting frog diversity across the Abel Dams. Access restrictions have also weakened the strength of conclusions of what was once a robust long-term monitoring experimental design. No targeted threatened frog species were recorded.

Birds

Due to access restrictions, only one dam (Dam 14) was surveyed in 2018. No Blue-billed Ducks, the target threatened species, were recorded in 2018. Total bird diversity and abundance in 2018 was lower for Dam 14. The number of waterbird species and individuals recorded at each dam have been relatively constant over the monitoring years. However, the number and abundance of woodland/forest birds recorded since monitoring began in 2008 has fluctuated widely (with well above average results in 2015). This may have been due to increased bird activity at the sites following a major rainfall event or due to survey bias. Despite

this variability, woodland/forest species diversity and abundance were lower than the yearly averages in 2018.

Maundia triglochinoides

The data collected over the last 11 years will enable evaluation of potential subsidence impacts in the future. At the time of the 2018 surveys many of the dams had relatively high water levels after recent storms. A single dam (Dam 134 in the Pambalong catchment area) was judged to no longer be suitable for habitat for *M. triglochinoides*. While water storage levels were better than had been observed in the 2017 survey, many dams were still not at capacity.

No individuals of the threatened plant, *Maundia triglochinoides*, were identified.

Where Weeds of National Significance were observed, land owners should be made aware of their presence.

8. RECOMMENDATIONS

It is recommended that monitoring of threatened amphibians, birds and aquatic vegetation continue to detect any impacts of the Abel underground mine should they arise in the future. Given that the health and habitat quality at several of the dams is considerably different, evident by the loss of emergent vegetation in recent years, it would be advisable to re-assess the habitat characteristics at each dam and their suitably for threatened species. This will assist in explaining changes in the presence/absence of target species and other non-threatened taxa. Farming practices are the likely cause of recent trends, though without standardised assessments of habitat quality it is difficult to conclude if this is the case rather than effects from mining.

Owners of properties where Weeds of National Significance were observed should be made aware of their presence to facilitate early control and/or access any grant funding that may be available.

An updated contact list for all land owners should be created. Despite best efforts to maintain up to date occupancy and ownership records, several of the contact details provided are no longer valid. This results in time delays or restricted access to many dams during the survey period as some land owners cannot be contacted by phone or in person despite repeated attempts. It is recommended that landowners be contacted by mail, detailing project aims and objectives to increase access to dams.

9. REFERENCES

Anstis, Marion, 2002, Tadpoles of South-eastern Australia, Reed New Holland, Australia.

Barker, J & Grigg, G 1977, A Field Guide to Australian Frogs, Rigby, Adelaide.

Barrett, GW, Silcocks, A, Barry, S, Cunningham, R & Poulter, R 2003, The New Atlas of Australian Birds, Royal Australasian Ornithologists Union, Melbourne.

Bell, FG, Stacey, TR & Genske, DD 2000, Mining subsidence and its effect on the environment: some differing examples, *Environmental Geology* 40(1-2), pp 135-152.

Berger, L, Speare, R, Daszak, P, Green, DE, Cunningham, AA, Goggin, CL, Slocombe, R, Ragan, MA, Hyatt, AD, McDonald, KR, Hines, HB, Lips, KR, Marantelli, G and Parkes, H 1998, Chytridiomycosis causes amphibian mortality associated with population declines in the rainforests of Australia and Central America, *Proc Natl Acad Sci* 95, pp 9031-9036.

Bureau of Meteorology 2018, New South Wales Daily Weather Observations, http://www.bom.gov.au/climate/dwo/

Cogger, HG 2000, Reptiles and Amphibians of Australia (6th ed), Reed Books, Australia.

Daly, G 1995, Observations on the Green and Golden Bell Frog *Litoria aurea* (Anura: Hylidae), *Herpetofauna* 25, pp 2–9.

Department of Environment and Conservation 2005a, Green and Golden Bell Frog *Litoria aurea* Recovery Plan, DEC NSW, Hurstville, NSW.

Department of Environment and Conservation 2005b, Blue-billed Duck *Oxyura australis* – vulnerable species listing: NSW Scientific Committee – final determination, DEC NSW, Sydney.

Department of Environment and Climate Change 2005c, *Maundia triglochinoides* Profile. DEC NSW, Sydney.

Department of Environment and Climate Change 2008, *Maundia triglochinoides* (a herb) – vulnerable species listing, NSW Scientific Committee final determination, DEC NSW, Sydney.

Ecobiological 2007, Abel Underground Coalmine Flora and Fauna Management Plan, A report prepared by Ecobiological for Donaldson Coal Pty Ltd.

Ecobiological 2008, Abel Underground Coalmine Dam Monitoring and Management Plan, 2008 Baseline Report.

Ecobiological 2009, Abel Underground Coalmine Dam Monitoring and Management Plan, 2009 Monitoring Report.

Ecobiological 2010, Abel Underground Coalmine Dam Monitoring and Management Plan, 2010 Monitoring Report.

Ecobiological 2011, Abel Underground Coalmine Dam Monitoring and Management Plan, 2011 Monitoring Report.

Ecobiological 2012, Abel Underground Coalmine Dam Monitoring and Management Plan, 2012 Monitoring Report.

Frith, HJ 1982, Waterfowl in Australia, Revised Edition, Angus and Robinson, Sydney.

Garnett, ST & Crowley, GM 2000 The Action Plan for Australian Birds 2000, Environment Australia, Canberra.

Hamer, AJ, Lane, SJ & Mahony, MJ 2002, Management of freshwater wetlands for the endangered green and golden bell frog (*Litoria aurea*), roles of habitat determinants and space, *Biological Conservation* 106(3), pp 413-424.

Harden, GJ (ed) 1993, Flora of New South Wales Volume 4, NSW University Press, Sydney.

Hines, H, Mahony, M & McDonald, K 1999, An assessment of frog declines in wet subtropical Australia, pp 44-63 *in* Declines and Disappearances of Australian Frogs ed. By A Campbell, Environment Australia, Canberra.

Kleinfelder 2013, Abel Underground Coal Mine Dam Monitoring and Management Survey, 2013 report.

Kleinfelder 2014, Abel Underground Coal Mine Dam Monitoring and Management Survey, 2014 report.

Kleinfelder 2015, Abel Underground Coal Mine Dam Monitoring and Management Survey, 2015 report.

Kleinfelder 2016, Abel Underground Coal Mine Dam Monitoring and Management Survey, 2016 report.

Kleinfelder 2017, Abel Underground Coal Mine Dam Monitoring and Management Survey, 2017 report.

Lemckert, F, Mahony, M, Brassil, T & Slayter, C 2006, The biology of the threatened Green-thighed Frog *Litoria brevipalmata* (Anura: Hylidae) in the central and mid-north coastal areas of New South Wales, Australian Zoologist 33(3), pp 337-344.

Mahony, MJ 1999, Review of the declines and disappearances within the bell frog species group (*Litoria aurea* species group) in Australia. pp 81-93 *in* A Campbell (ed) declines and disappearances of Australian frogs, Biodiversity Group Environment Australia, Canberra.

Marchant, S & PJ Higgins (eds) 1990, Handbook of Australian, New Zealand & Antarctic Birds, Vol 1, Part A, Oxford University Press, Oxford.

National Climate Centre 2009, A prolonged spring heatwave over central and south-eastern Australia, Bureau of Meteorology, Special Climate Statement 19, http://www.bom.gov.au/climate/current/statements/scs19b.pdf

Robinson, M 1998, A Field Guide to Frogs of Australia, Reed New Holland, Sydney.

Sidle, RC, Kamil, I, Sharma, A & Yamashita, S 2000, Stream response to subsidence from underground coal mining in central Utah, *Environmental Geology* 39(3-4), pp 279-291.

Schodde, R & Tidemann, SC (eds) 1986, Reader's Digest Complete Book of Australian Birds, Reader's Digest, Sydney.

White, HM & Pyke, GH 1996, Distribution and conservation status of the green and golden bell frog, *Litoria aurea*, in New South Wales. *Australian Zoology* 30, pp 177-189.

APPENDIX 1. TARGET SPECIES PROFILES

Green and Golden Bell Frog (*Litoria aurea*)

The Green and Golden Bell Frog is a large frog with a robust body form ranging from 45 mm to 110mm in size. Diagnostic features include a gold or cream-white stripe running along the side, extending from the upper eyelids to groin, with a narrow dark stripe beneath which runs from the nostril to the eye (DEC 2005). The body colour varies; it is usually a vivid pea green with splotches of metallic brown or green and a bluish green colour on the inside of the thighs. Some individuals may have an entirely green back, but this is variable and others may be primarily covered in the metallic markings.

This species was once one of the most common frog species on the east coast of Australia. It inhabited many lentic freshwater habitats throughout its distribution which occurred predominately along the coast but also extending as far inland as Bathurst and along the highlands in the north and south of the state (White and Pyke 1996). The Green and Golden Bell Frog has undergone a widespread and unexplained range contraction since the mid 1970's and the species is now listed as endangered under the *Threatened Species Conservation Act 1995*, NSW (TSC Act) and as vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999* Cth, (EPBC Act). It is currently restricted to isolated pockets along the coast throughout its former range with only one known remaining highland population at Queanbeyan.

The habitat preference and requirements of the Green and Golden Bell Frog are not well understood and difficult to define (Mahony 1999) resulting in some disagreement and confusion. Some of the differing views on its ecology may be due to a failure to take into account the role of the pathogenic Chytrid fungus that is thought to be primarily responsible for changes in the frog's distribution and abundance in the last two decades (Berger *et al.* 1998).

The species uses different habitat components throughout the various stages of its life cycle including different breeding, foraging and refuge habitats and has been known to disperse several kilometres between these various habitats. Generally large, permanent water bodies containing high levels of emergent vegetation such as Typha, Baumea and the introduced *Juncus acutus* are favourable habitat for the Green and Golden Bell Frog, however it has been observed using a wide range of natural and man-made water bodies including; coastal swamps, marshes, dune swales, lagoons, lakes, estuary wetlands, riverine floodplain wetlands, billabongs, storm water retention basins, farm dams, bounded areas, storage tanks, water troughs, drains, ditches and other excavation areas capable of capturing water such as quarries and brick pits (DEC 2005).

Terrestrial habitat attributes that appear to favour the species include large grassy areas associated with adjacent cover from logs, rocks or tussock forming vegetation that provide shelter. There also appears to be a preference shown to habitat containing a complexity of

terrestrial and aquatic vegetation structure (Hamer *et al.* 2002). The introduced mosquito fish, *Gambusia holbrooki*, is believed to feed on small tadpoles; habitat which is free of these fish is preferred (White & Pike 1996)

The Green and Golden Bell Frog is frequently active during the day and night during warmer months and can often be observed sitting in emergent vegetation well above the water level (0.5-1m). It has also been observed well away from water altogether. The breeding period generally occurs between September and March although reproductive behaviour has been noted to occur between late winter and early autumn (DEC 2005a). Breeding events occur most often during, and just after, heavy rain events with a peak around January/February when summer storms are common. Males call while floating in the water or from pond-side vegetation mostly at night but will occasionally call during the day. Individuals or small groups of males often respond to call play back or call imitation.

Green-thighed Frog (*Litoria brevipalmata*)

The Green-thighed Frog was only discovered in 1970, originally at Wauchope, NSW and later in the Gosford area (Barker & Grigg 1977). It reaches around 40mm in length and is chocolate brown on the dorsum with yellowish lower flanks. A dark stripe runs from the snout, through the eye and tympanum and ends in the flank. The groin and backs of thighs are a distinct bright blue-green with black flecks throughout and the belly is pale cream (Robinson 1998). The Green-thighed Frog is listed as vulnerable under the TSC Act.

It is found in forests and swamps of the coast and adjacent ranges from central New South Wales to south east Queensland (Cogger, 2000; Hines *et al*. 1999). Its habitat requirements have remained highly cryptic for a long time with breeding noted to take place after heavy summer rains in rainforest and wet sclerophyll forest but also around temporary and semi-permanent ponds, flooded ditches and swamps including areas such as roadsides and power easements.

More recent research however has shed some light on the biology of this highly cryptic species, particularly in relation to its breeding habitat requirements and calling behaviour. In a study by Lemckert *et al*. (2006) it was found that over 90% of breeding sites consisted of ephemeral pools, partly or wholly within rainforest or wet sclerophyll forest (84% of the time). There are however some records from around permanent, artificial ponds within dry sclerophyll forest, and a small number from coastal forests and swamps. Natural depressions adjacent to streams (e.g. old billabongs) are the most commonly used calling sites, although breeding also occurs in artificial water bodies such as human excavated hollows and flooded road verges (around half of sites recorded). These pools are usually either leaf or shrub filled depressions, or have significant amounts of grass in and around them (Lemckert *et al*. 2006).

The duration of calling events for the species is brief, lasting for a median of only one night and a mean of 1.4 nights (Lemckert *et al*. 2006). Calling occurs between September and May, although greater than 90% of all calling activity occurs between November and February, with between 1 and >100 males calling (most commonly 2-10 individuals) (Lemckert *et al*. 2006). The species in the southern part of its range often displays only one calling event in a season, with two calling events observed on only four occasions in a study by Lemckert *et al*. (2006), and three calling events in a season observed only once. The maximum total recorded number

of nights of calling activity at any site in a season in the 2006 study was five, with only one day or less per season recorded 80% of the time, indicating that the Green-thighed Frog has the lowest number of calling days of any temperate Australian anuran species (Lemckert *et al.* 2006). Calling is likely to occur only after rainfall events that are significantly above the mean daily or three daily levels for the given time of year (when it is more likely that flooding will occur in breeding ponds), and it is believed that the flooding of the breeding pools is the significant factor in calling behaviour, rather than the intensity of the rain itself.

The majority of Green-thighed Frogs are found within 100m of a tract of natural vegetation >20ha in size and none were found in the 2006 study (Lemckert *et al*. 2006) to occur in largely cleared (>50%) grazing lands or within entirely urban areas. While broad scale habitat clearing is a clear threat for this frog, it appears that partial clearing of vegetation within an area does not prevent Green-thighed Frogs from calling at a site and that they may have some tolerance for disturbance (Lemckert *et al.* 2006). Fire, particularly high-intensity fire, is also listed as a potential threat to the Green-thighed Frog, especially when associated with multiple disturbance events in rapid succession (Lemckert *et al.* 2006).

Blue-billed Duck (*Oxyura australis*)

The adult male Blue-billed Duck has a slate blue bill with a glossy black head and neck. The back and wings are a rich chestnut and the tail coverts are a black-brown. During the summer breeding season the bill of the male turns bright blue (DEC 2005b). The adult female has a grey-brown bill with plumage darker than the male with each feather barred with narrow bands of light brown. Juveniles are similar to the adult female but paler with a grey-green bill (Marchant & Higgins 1990).

Preferred habitat is large, deep, well-vegetated swamps where they spend almost all of their time in the water, often in large flocks. Occasionally the species can be found using creeks, rivers and farm dams for foraging and breeding (Frith 1982). The Blue-billed Duck feeds on the surface of the water or by diving for aquatic insects such as chironomid larvae, caddis flies, dragonflies, damselflies, flies and water beetle larvae (Schodde & Tidemann 1986).

The Blue-billed Duck is endemic to Australia occurring mainly within temperate wetlands of the south-eastern and south-western parts of the continent (Marchant & Higgins 1990). The Blue-billed Duck has also been reported from central Australia and Tasmania with little change in reporting rate over the last 20 years (Barrett *et al.* 2003). The Blue-billed Duck is listed as vulnerable under the TSC Act. Nationally the Blue-billed Duck is classed as of 'least concern' because of the very large flocks that inhabit large artificial wetlands (Garnett & Crowley 2000) although threats such as the destruction or modification of habitat, particularly by drainage works, clearing, cropping or burning are noted (Marchant & Higgins 1990).

Maundia triglochinoides

Maundia triglochinoides is a perennial plant with rhizomes about 5mm thick and emergent tufts of leaves arising along their length. Leaves are triangular in cross section, to 80 cm long, 5 - 10mm wide. Inflorescence is up to 10cm long and 2.5 cm wide. Carpels (female parts of flower) are 6 - 8mm long, sessile, each with a spreading beak (Harden, 1993). This species is found along the NSW coast and southern Queensland. There are historic records of this species

occurring as far south as Sydney, however it is presumed extinct south of Wyong (DECC 2005). *M. triglochinoides* is listed as vulnerable under the TSC Act.

M. triglochinoides grows in swamps, creeks or shallow freshwater 30 - 60 cm deep on heavy clay and low nutrients and it is often associated with wetland species e.g. *Triglochin procera*. Flowering occurs during warmer months (November to January). The plant is likely to be wind pollinated. Long distance dispersal is through seed and root tubers, which are probably dispersed by water. The plant spreads vegetatively, with tufts of leaves arising along the rhizomes (DECC, 2005b). The main threats to this species are loss and fragmentation of habitat, changes in hydrology and water quality, and weed invasion (DECC 2008).

APPENDIX 2. SUITABILITY OF HABITAT AT TARGET DAMS

GGBF = Green and Golden Bell Frog (*Litoria aurea*); GTF = Green-thighed Frog (*Litoria brevipalmata*); BBD = Blue-billed Duck (*Oxyura australis*). Cells highlighted red indicate dams that could not be surveyed in 2018 due to access restrictions.

Dam Number	Potential *M. triglochinoides* habitat	Environmental Weeds Observed during 2018 Survey	Date Surveyed (Flora)	GGBF suitable dams	GTF suitable dams	Date surveyed (Amphibians)	BBD suitable dams	Date surveyed (BBD)
1	Yes		Not Surveyed	x	x	Not Surveyed		
3	Yes	Blackberry, Lantana	**19/12/2018**	x		12/12/2018		
4	Yes	Blackberry	**19/12/2018**	x		12/12/2018		
5	Yes	Blackberry	**19/12/2018**	x		12/12/2018		
6	Yes		Not Surveyed	x		Not Surveyed		
7	Yes		Not Surveyed	x		12/12/2018	x	Not Surveyed
11	Yes	No weeds observed	**19/12/2018**	x		12/12/2018		
12	Yes		Not Surveyed					
13	Yes	Nil	Not Surveyed	x		Not Surveyed		
14	Yes	Lantana, Crofton	**19/12/2018**				x	19/12/2018
15	Yes		Not Surveyed	x		Not Surveyed		
16	Yes		Not Surveyed	x		Not Surveyed	x	Not Surveyed
18	Yes	Nil	**19/12/2018**	x		12/12/2018		
19	Yes	Nil	**19/12/2018**	x		12/12/2018		
20	Yes		Not Surveyed	x		17/12/2018		

Dam Number	Potential *M. triglochinoides* habitat	Environmental Weeds Observed during 2018 Survey	Date Surveyed (Flora)	GGBF suitable dams	GTF suitable dams	Date surveyed (Amphibians)	BBD suitable dams	Date surveyed (BBD)
21	Yes	Blackberry, Lantana, Wild Tobacco bush	**19/12/2018**	x		17/12/2018		
22	Yes		Not Surveyed	x		Not Surveyed		
23	No longer suitable		Not Surveyed	x		Not Surveyed		
25	Yes	Nil	**19/12/2018**	x		12/12/2018		
26	Yes		Not Surveyed	x		Not Surveyed		
27	Yes	Blackberry, Lantana, Wild Tobacco bush	**19/12/2018**	x		13/12/2018		
28	Yes		Not Surveyed	x		Not Surveyed	x	Not Surveyed
29	Yes	Nil	**19/12/2018**					
31	Yes	Nil	**19/12/2018**					
32	Yes	Blackberry	**19/12/2018**	x		17/12/2018		
33	Yes		Not Surveyed					
34	Yes	Water Hyacinth (100%), Lantana	**19/12/2018**					
35				x		17/12/2018		
36	Yes		Not Surveyed					
38	Yes	Nil	**19/12/2018**	x		17/12/2018		
39	Yes		Not Surveyed					
40	Yes	Nil	**19/12/2018**	x		17/12/2018		
41	Yes		Not Surveyed	x		Not Surveyed		
42				x		17/12/2018		
45	Yes		Not Surveyed	x		Not Surveyed		
46	Yes		Not Surveyed	x		Not Surveyed		
47	Yes		Not Surveyed	x		Not Surveyed		

Dam Number	Potential *M. triglochinoides* habitat	Environmental Weeds Observed during 2018 Survey	Date Surveyed (Flora)	GGBF suitable dams	GTF suitable dams	Date surveyed (Amphibians)	BBD suitable dams	Date surveyed (BBD)
48	Yes		Not Surveyed	x		Not Surveyed		
51				x		Not Surveyed		
53				x		17/12/2018		
54	Yes		Not Surveyed	x		Not Surveyed		
57	Yes	Nil	**19/12/2018**	x		13/12/2018		
58	Yes		Not Surveyed	x		13/12/2018		
59	Yes		Not Surveyed					
61	No Longer Suitable		Not Surveyed	x		13/12/2018		
62	Yes	Nil	**19/12/2018**	x		13/12/2018		
85	Yes		Not Surveyed	x		Not Surveyed		
87					x	13/12/2018		
91	Yes		Not Surveyed	x		13/12/2018		
92	Yes		Not Surveyed	x		Not Surveyed		
93	Yes		Not Surveyed	x		Not Surveyed		
99	Yes	Lantana	**19/12/2018**					
103	Yes	Blackberry, Crofton, Lantana	**19/12/2018**					
107	Yes	Water Hyacinth (80%), Blackberry, Lantana, Inkweed	**19/12/2018**					
112	Yes		Not Surveyed	x		Not Surveyed		
121	Yes		Not Surveyed					
122	Yes		Not Surveyed	x		Not Surveyed		
123				x		Not Surveyed		
125	Yes	Blackberry, Inkweed	**19/12/2018**	x		18/12/2018		

Dam Number	Potential *M. triglochinoides* habitat	Environmental Weeds Observed during 2018 Survey	Date Surveyed (Flora)	GGBF suitable dams	GTF suitable dams	Date surveyed (Amphibians)	BBD suitable dams	Date surveyed (BBD)
126	Yes	Water Hyacinth (10%), Blackberry	**19/12/2018**	x		18/12/2018		
128	Yes		Not Surveyed					
129	Yes	Water Hyacinth (20%)	**19/12/2018**	x		18/12/2018		
130	Yes	Water Hyacinth (10%), Blackberry, Lantana, Inkweed	**19/12/2018**	x		18/12/2018		
131	Yes	Water Hyacinth (10%), Blackberry, Lantana, Crofton	**19/12/2018**	x		18/12/2018		
132	Yes	Water Hyacinth (10%), Lantana, Crofton	**19/12/2018**					
133	Yes	Water Hyacinth (10%), Blackberry, Crofton	**19/12/2018**					
134	No Longer Suitable	Blackberry, Lantana, Crofton	**19/12/2018**					
142	Yes	Blackberry	**19/12/2018**	x		12/12/2018		
144	Yes	Lantana, Blackberry	**19/12/2018**	x		12/12/2018		
148	Yes		Not Surveyed	x		Not Surveyed		
149	Yes		Not Surveyed	x		Not Surveyed		
150			Not Surveyed					
151			Not Surveyed		x	Not Surveyed		
152	Yes		Not Surveyed	x		12/12/2018		
153	Yes		Not Surveyed	x		12/12/2018		
154			Not Surveyed	x				
155			Not Surveyed					
157			Not Surveyed	x		12/12/2018		

Dam Number	Potential *M. triglochinoides* habitat	Environmental Weeds Observed during 2018 Survey	Date Surveyed (Flora)	GGBF suitable dams	GTF suitable dams	Date surveyed (Amphibians)	BBD suitable dams	Date surveyed (BBD)
160	Yes		Not Surveyed	x		17/12/2018		
161	Yes		Not Surveyed	x		Not Surveyed		
162	Yes		Not Surveyed	x		Not Surveyed		
163			Not Surveyed	x		17/12/2018		
164	No longer suitable		Not Surveyed					
167	Yes		Not Surveyed	x		Not Surveyed		
168	Yes		Not Surveyed	x		Not Surveyed		
169			Not Surveyed	x		17/12/2018		
Total with Suitable Habitat	**69**			**64**	**3**		**4**	
Total Surveyed	**30**			**36**	**1**		**1**	
Total Suitable Habitat Not Surveyed	**39**			**28**	**2**		**3**	

APPENDIX 3: AMPHIBIAN SPECIES RECORDED IN EACH DAM SURVEYED

'x' – indicates presence; NA – No available access; Dam = Dam Number; Survey Year = 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018

DAM	*Litoria fallax* (Dwarf Green Tree Frog)											*Litoria peronii* (Emerald-spotted Tree Frog)											*Litoria tyleri* (Southern Laughing Tree Frog)											*Litoria latopalmata* (Broad-palmed Frog)										
	08	09	10	11	12	13	14	15	16	17	18	08	09	10	11	12	13	14	15	16	17	18	08	09	10	11	12	13	14	15	16	17	18	08	09	10	11	12	13	14	15	16	17	18
1	x	x	x	x	x	x	NA	NA	NA	NA	NA	x		x	x	x	x	NA	NA	NA	NA	NA	x		x	x	x	x	NA	NA	NA	NA	NA					x		NA	NA	NA	N	NA
3	x	x		x	x	x	x	x	x	x	x		x						x																		x	x			x	x	x		
4	x	x	x		x	x	x	x	x	x	x				x	x	x										x							x	x		x	x		x	x	x	x	x
5	x	x	x	x	x	x	x	x	x	x	x		x		x	x	x		x	x	x		x							x	x	x	x			x							x
6	x	x	x	x	x	x	NA	NA	NA	NA	NA						x	NA	NA	NA	NA	NA							NA	NA	NA	NA	NA				x		x	NA	NA	NA	NA	NA
7	x	x	x	x	x	x	x	x	x	x	NA				x		x		x	x		NA	x								x		NA				x	x		x		x		NA
11	x	x	x	x	x	x	x	x	x	x		x	x			x	x	x	x	x			x				x	x													x	x		
13	x	x	x	x	x	x			x	x	NA	x	x	x	x	x	x	x	x	x	x	NA	x	x	x	x	x	x		x	x	x	NA			x	x	x		x				NA
15	x	x	x	x	x	x	x	x	x	x	NA	x	x				x		x	x		NA						x		x	x		NA	x	x			x	x			x		NA
16	x		x	x	x	x	NA	NA	NA	NA	NA			x		x	NA	NA	NA	NA	NA	NA				x	x	NA	NA	NA	NA	NA	NA	x		x			NA	NA	NA	NA	NA	NA
18	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x			x	x			x	x											x				x	x	
19	x	x	x	x	x	x	x	x	x	x	x																				x													
20	x	x	x	x	x	x	x	x	x	x	x	x		x	x		x	x	x	x			x		x		x			x	x						x	x	x	x	x	x		x
21	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x			x	x	x				x	x	x	x	x			x	x
22	x	x	x	x	x	x	x		NA	x	NA					x				NA		NA			x						NA		NA	x	x	x	x					NA		NA
23	x	x	x	x	x	x	x	x	NA	x	NA		x							NA		NA			x			x			NA		NA	x	x	x				x		NA	x	NA
25	x	x	x	x	x	x	x	x	x	x	x	x			x	x			x		x										x	x					x	x				x		x
26	x		x	x	x	x	x	x			NA	x			x	x						NA				x							NA										x	NA
27	x	x	x	x	x	x	x	x		x	x	x		x	x	x	x					x	x		x		x									x	x	x					x	x
28	x		x	x	x	x	NA	NA	NA	NA	NA			x		x	x	NA	NA	NA	NA	NA				x	x		NA	NA	NA	NA	NA	x		x	x			NA	NA	NA	NA	NA
32	x	x	x	x	x	x	x		x	x	x	x		x	x	x			x				x		x		x	x		x					x		x	x	x	x	x	x	x	x
35	x		x	x	x	x	x	x	x	x	x											x			x	x		x							x		x							x	x
38	x	x	x	x	x	x	x	x	NA	x		x		x	x	x	x			NA											NA			x		x	x	x	x	x		NA		
39	x	x	NA	NA	x	x	NA	NA	NA			x	x	NA	NA	x	x	NA	NA	NA			x		NA	NA			NA	NA	NA			x		NA	NA	x	x	NA	NA	NA		
40	x	x	x	x	x	x		x	NA	x	x	x		x	x		x		x	NA						x		x			NA			x	x	x	x	x	x			NA		x

DAM	*Litoria fallax* (Dwarf Green Tree Frog)											*Litoria peronii* (Emerald-spotted Tree Frog)											*Litoria tyleri* (Southern Laughing Tree Frog)											*Litoria latopalmata* (Broad-palmed Frog)										
	08	09	10	11	12	13	14	15	16	17	18	08	09	10	11	12	13	14	15	16	17	18	08	09	10	11	12	13	14	15	16	17	18	08	09	10	11	12	13	14	15	16	17	18
41	x	x	x	x	x	x	NA	NA	NA		NA		x	x	x	x	x	NA	NA	NA		NA				x		x	NA	NA	NA		NA	x	x	x			x	NA	NA	NA		NA
42	x		x	x		x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x					x		x	x	x	x	x	x	x	x		x	x		x	x	
45	x	x	NA	NA	x	x	NA	NA	NA	NA	NA	x		NA			x	NA	NA	NA	NA	NA	x	x	NA	NA	x	x	NA	NA	NA	NA	NA	x	x	NA	NA		x	NA	NA	NA	NA	NA
46	x	x	NA	NA	x	x	NA	NA	NA	NA	NA	x		NA	NA	x		NA	NA	NA	NA	NA	x		NA	NA		x	NA	NA	NA	NA	NA	x	x	NA	NA	x		NA	NA	NA	NA	NA
47			x	x	x	x	NA	NA	NA	NA	NA					x		NA	NA	NA	NA	NA				x	x	x	NA	NA	NA	NA	NA						x	NA	NA	NA	NA	NA
48	x	x	x	x	x	x	x	x	NA	NA	NA	x		x	x					NA	NA	NA	x		x	x		x			NA	NA	NA	x		x			x			NA	NA	NA
51	x	x	x	x	x	x	x	x	NA		NA									NA		NA			x						NA		NA	x		x		x		x		NA		NA
53	x	x	x	x		x	NA		x		x							NA								x		x	NA										x	NA				x
54	x			x	x		NA	NA	NA		NA	x		x				NA	NA	NA		NA							NA	NA	NA		NA	x		x	x	x	x	NA	NA	NA		NA
57	x		x	x	x	x	x	x	x	x	x			x	x	x	x	x	x		x							x		x						x	x	x	x	x	x	x	x	x
58			x	x	x	x	x	x	x					x	x	x				x	x					x										x	x	x	x	x		x	x	
61	x	x	x	x	x	x	x							x				x					x		x	x	x	x								x	x						x	
62	x	x	x	x	x	x	x	x	x	x			x	x	x		x							x				x								x				x	x		x	
85	x	x	x	x	x	x	x	x	x	x	NA	x			x	x	x	x	x			NA				x	x	x		x	x	x	NA					x		x	x		x	NA
87											x									x		x										x							x	x		x	x	x
91								x									x		x									x									x			x				
92	x	x	x	x	x	x	NA	NA	NA	NA	NA	x	x	x		x	x	NA	NA	NA	NA	NA	x		x	x		x	NA	NA	NA	NA	NA						x	NA	NA	NA	NA	NA
93					x	x	NA	NA	NA	NA	NA					x		NA	NA	NA	NA	NA					x	x	NA	NA	NA	NA	NA							NA	NA	NA	NA	NA
112	x	x	x	x	NA	x	NA	NA	NA	NA	NA		x	x	x	NA	NA	NA	NA	NA	NA	NA	x	x	x	x	N/A	NA	NA	NA	NA	NA	NA			x		N/A	NA	NA	NA	NA	NA	NA	NA
122	x	x	x	x	x	x	x	x	x	NA	NA										NA	NA										NA	NA									NA	NA	NA
123	x	x	x	x	x	x	x	x	x	NA	NA										NA	NA			x	x		x				NA	NA									NA	NA	NA
125	x		x	x	x	x	x	x		x	x			x		x									x	x		x					x			x			x					
126	x	x	x	x	x	x	x	x			x											x			x	x	x	x			x		x										
129	x	x	x	x	x	x	x	x	x	NA													x		x	x		x				NA										NA	
130	x	x	x	x	x	x	x	x	x		x		x								NA						x																
131	NA	NA	NA	NA	x	x	x	x	x			NA	NA	NA	NA		x						NA	NA	NA	NA	x	x		x				NA	NA	NA	NA							
142	x	x	x	x	x	x		x	x	x					x																							x		x	x		x
144	x	x		x	x	x		x	x	x	x		x		x	x	x							x															x				
148	x	x	x	x	x	x	NA	NA	NA	NA	NA					x		NA	NA	NA	NA	NA			x	x	x		NA	NA	NA	NA	NA	NA	x	x			x	x	NA	NA	NA	NA	NA
149	x	x	x	x	x	x	NA	NA	NA	NA	NA							NA	NA	NA	NA	NA						x	NA	NA	NA	NA	NA			x	x		x	NA	NA	NA	NA	NA
151	x	x	x	x	x	x	x	x	NA	x	NA		x			x	x			NA	x	NA			x			x	x	x	NA		NA									NA		NA

DAM	*Litoria fallax* (Dwarf Green Tree Frog)											*Litoria peronii* (Emerald-spotted Tree Frog)											*Litoria tyleri* (Southern Laughing Tree Frog)											*Litoria latopalmata* (Broad-palmed Frog)										
	08	09	10	11	12	13	14	15	16	17	18	08	09	10	11	12	13	14	15	16	17	18	08	09	10	11	12	13	14	15	16	17	18	08	09	10	11	12	13	14	15	16	17	18
152	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x			x	x	x	x			x	x	x		x	x			x			x	x		x		x		x
153	x			x	x	x	x	x			x	x		x	x	x	x	x	x		x				x	x	x	x	x	x	x	x				x	x			x			x
154	x	x	x	x	x	x	x	x	x	x	NA				x		x					NA				x							NA				x				x			NA
157					x	x	x										x																	x	x		x				x	x	x	x
160	x	x	x	x	x	x	x	x	x		x	x		x	x	x	x	x	x		x	x			x	x				x			x	x	x	x	x	x	x	x		x	
161	x		x	x	x	x	NA	NA	NA	NA	NA	x		x	x	x		NA	NA	NA	NA	NA	x		x	x	x	x	NA	NA	NA	NA	NA	x		x	x	x	x	NA	NA	NA	NA	NA
162			x	x	x	x	NA	NA	x	NA	NA			x		x		NA	NA		NA	NA	x		x	x	x	x	NA	NA	x	NA	NA			x	x			NA	NA	x	NA	NA
163	x		x	x		x		x					x												x												x							x
167	x			x	x	x	x	x			NA	x							x			NA				x							NA										NA
168	x		x	x	x	x		x	x		NA											NA					x						NA					x					NA
169			x	x		x																				x										x	x		x		x	x	x	x

DAM	*Litoria nasuta* (Rocket Frog)											*Litoria verreauxii* (Whistling Tree Frog)											*Limnodynastes peronii* (Striped Marsh Frog)											*Limnodynastes tasmaniensis* (Spotted Grass Frog)										
	08	09	10	11	12	13	14	15	16	17	18	08	09	10	11	12	13	14	15	16	17	18	08	09	10	11	12	13	14	15	16	17	18	08	09	10	11	12	13	14	15	16	17	18
1				x			NA	NA	NA	NA	NA	x	x		x	x	x	NA	NA	NA	NA	NA	x		x				NA	NA	NA	NA	NA						NA	NA	NA	NA	NA
3															x		x						x					x																
4																x	x			x							x																
5														x	x		x												x		x												
6							NA	NA	NA	NA	NA	x	x		x		x	NA	NA	NA	NA	NA		x	x	x			NA	NA	NA	NA	NA						NA	NA	NA	NA	NA
7											NA	x	x			x	x					NA	x			x		x	x		x		NA				x					NA
11												x					x							x			x		x		x			x		x							
13											NA											NA											NA				x	x					NA
15											NA											NA	x	x	x				x	x	x		NA										NA
16						NA	NA	NA	NA	NA	NA		x	x			NA	NA	NA	NA	NA	NA	x				x	NA	NA	NA	NA	NA	NA						NA	NA	NA	NA	NA
18													x		x	x	x																										
19													x				x					x								x												
20																	x						x		x																		x
21														x									x																			
22									NA		NA			x						NA		NA	x	x	x	x		x	x	x	NA		NA							NA		NA
23									NA		NA			x						NA		NA	x		x	x	x	x	x	x	NA	x	NA				x			NA		NA
25												x	x	x	x		x						x	x		x							x				x	x				
26											NA					x	x					NA					x						NA									NA
27												x	x	x		x	x						x	x	x	x		x	x													
28							NA	NA	NA	NA	NA			x			x	NA	NA	NA	NA	NA	x		x	x	x		NA	NA	NA	NA	NA						NA	NA	NA	NA	NA
32														x									x	x			x															
35														x											x	x	x	x	x	x	x									x		
38									NA											NA						x	x			x	NA			x		x					NA		
39			NA	NA			NA	NA	NA					NA	NA			NA	NA	NA	NA				NA	NA	x		NA	NA	NA	NA				NA	NA			NA	NA	NA	NA	

DAM	*Litoria nasuta* (Rocket Frog)											*Litoria verreauxii* (Whistling Tree Frog)										*Limnodynastes peronii* (Striped Marsh Frog)										*Limnodynastes tasmaniensis* (Spotted Grass Frog)									
	08	09	10	11	12	13	14	15	16	17	18	08	09	10	11	12	13	14	15	16	17	18	08	09	10	11	12	13	14	15	16	17	18	08	09	10	11	12	13	14	15	16	17	18
40									NA						x						NA			x	x	x			x			NA		x	x	x	x					NA		x
41							NA	NA	NA		NA			x				NA	NA	NA		NA		x			x		NA	NA	NA		NA						NA	NA	NA		NA
42													x						x									x		x				x		x	x							
45			NA	NA			NA	NA	NA	NA	NA			NA	NA			NA	NA	NA	NA	NA	x		NA	NA	x	x	NA	NA	NA	NA	NA	x	x	NA	NA			NA	NA	NA	NA	NA
46			NA	NA			NA	NA	NA	NA	NA			NA	NA			NA	NA	NA	NA	NA	x		NA	NA		x	NA	NA	NA	NA	NA			NA	NA			NA	NA	NA	NA	NA
47							NA	NA	NA	NA	NA							NA	NA	NA	NA	NA				x	x	x	NA	NA	NA	NA	NA							NA	NA	NA	NA	NA
48									NA	NA	NA			x						NA	NA	NA								x	NA	NA	NA	x		x						NA	NA	NA
51									NA		NA			x						NA		NA				x	x			x	NA		NA									NA		NA
53							NA										x	NA					x	x	x	x	x	x	x	x	x		x							NA			x
54							NA	NA	NA		NA			x				NA	NA	NA		NA							NA	NA	NA		NA	x		x				NA	NA	NA		NA
57																																		x		x								
58																												x						x										
61																									x		x		x															x
62																								x					x	x													
85											NA											NA			x		x	x	x	x			NA										NA
87																												x				x												x
91																	x						x		x	x		x															
92							NA	NA	NA	NA	NA		x					NA	NA	NA	NA	NA		x					NA	NA	NA	NA	NA						NA	NA	NA	NA	NA
93							NA	NA	NA	NA	NA							NA	NA	NA	NA	NA					x		NA	NA	NA	NA	NA						NA	NA	NA	NA	NA
112					NA	NA	NA	NA	NA	NA	NA			x		NA	NA	NA	NA	NA	NA	NA			x	x	NA	NA	NA	NA	NA	NA	NA			x		NA		NA	NA	NA	NA	NA
122										NA	NA										NA	NA	x		x	x						NA	NA	x		x	x				NA	NA
123										NA	NA										NA	NA										NA	NA			x					NA	NA
125														x		x							x		x	x	x	x		x			x	x								
126																							x		x	x					x		x			x							

DAM	*Litoria nasuta* (Rocket Frog)											*Litoria verreauxii* (Whistling Tree Frog)											*Limnodynastes peronii* (Striped Marsh Frog)											*Limnodynastes tasmaniensis* (Spotted Grass Frog)										
	08	09	10	11	12	13	14	15	16	17	18	08	09	10	11	12	13	14	15	16	17	18	08	09	10	11	12	13	14	15	16	17	18	08	09	10	11	12	13	14	15	16	17	18
129										NA											NA					x	x	x		x	x	NA				x							NA	
130																											x	x	x	x	x	x	x											
131	NA	NA	NA	NA								NA	NA	NA	NA												x				x		x										
142																	x			x							x				x											
144												x	x	x																													
148							NA	NA	NA	NA	NA						x	NA	NA	NA	NA	NA	x					NA	NA	NA	NA	NA	NA						NA	NA	NA	NA	NA
149							NA	NA	NA	NA	NA						x	NA	NA	NA	NA	NA				x		x	NA	NA	NA	NA	NA				x		NA	NA	NA	NA	NA
151		x							NA		NA	x					x			NA		NA	x		x	x	x	x	x		NA		NA							NA		NA
152	x																x																										
153																	x								x			x	x						x								
154	x	x									NA	x										NA			x	x	x		x				NA									NA	
157																	x									x										x							
160																													x		x			x	x	x							
161							NA	NA	NA	NA	NA			x			x	NA	NA	NA	NA	NA	x		x	x			NA	NA	NA	NA	NA							NA	NA	NA	NA	NA
162							NA	NA		NA	NA	x		x			x	NA	NA		NA	NA	x			x	x	x	NA	NA	x	NA	NA							NA	NA		NA	NA
163																													x		x					x								x
167											NA											NA		x	x	x	x	x	x	x			NA											NA
168											NA			x			x					NA	x			x	x	x	x				NA	x										NA
169																													x							x	x							x

DAM	*Uperoleia fusca* (Dusky Toadlet)											*Uperoleia laevigata* (Smooth Toadlet)											*Crinia signifera* (Common Eastern Froglet)											*Adelotus brevis* (Tusked Frog)										
	08	09	10	11	12	13	14	15	16	17	18	08	09	10	11	12	13	14	15	16	17	18	08	09	10	11	12	13	14	15	16	17	18	08	09	10	11	12	13	14	15	16	17	18
1	x		x				NA	NA	NA	NA	NA	x		x	x			NA	NA	NA	NA	NA				x			NA	NA	NA	NA	NA							NA	NA	NA	NA	NA
3			x									x	x	x		x								x	x																		
4			x	x							x	x	x	x		x						x	x								x											
5				x								x											x	x	x																	
6			x				NA	NA	NA	NA	NA	x						NA	NA	NA	NA	NA	x	x	x	x	x		NA	NA	NA	NA	NA							NA	NA	NA	NA	NA
7				x							NA											NA	x	x	x								NA										NA
11												x	x	x	x								x		x																		
13			x	x							NA	x										NA	x										NA										NA
15											NA	x										NA	x	x		x							NA										NA
16							NA	NA	NA	NA	NA							NA	NA	NA	NA	NA	x	x	x				NA	NA	NA	NA	NA							NA	NA	NA	NA	NA
18												x			x								x	x	x																		
19																								x	x																		
20												x		x									x	x																			
21												x											x	x																			
22									NA		NA	x								NA	x	NA	x								NA		NA								NA		NA
23									NA		NA									NA		NA	x	x	x		x				NA		NA								NA		NA
25			x	x								x		x									x	x	x																		
26											NA	x	x									NA	x	x	x								NA										NA
27												x													x																		
28							NA	NA	NA	NA	NA				x			NA	NA	NA	NA	NA	x	x					NA	NA	NA	NA	NA							NA	NA	NA	NA	NA
32																				x																							
35												x				x								x																			
38									NA			x		x						NA			x								NA										NA		
39			NA	NA			NA	NA	NA	NA				NA	NA			NA	NA	NA	NA			x	NA	NA			NA	NA	NA	NA				NA	NA			NA	NA	NA	NA	

DAM	*Uperoleia fusca* (Dusky Toadlet)											*Uperoleia laevigata* (Smooth Toadlet)											*Crinia signifera* (Common Eastern Froglet)											*Adelotus brevis* (Tusked Frog)										
	08	09	10	11	12	13	14	15	16	17	18	08	09	10	11	12	13	14	15	16	17	18	08	09	10	11	12	13	14	15	16	17	18	08	09	10	11	12	13	14	15	16	17	18
40									NA			x	x	x	x				x	NA			x	x							NA											NA		
41							NA	NA	NA		NA	x	x		x	x		NA	NA	NA		NA	x	x	x				NA	NA	NA		NA							NA	NA	NA		NA
42																								x																					
45			NA	NA			NA	NA	NA	NA	NA	x		NA	NA	x		NA	NA	NA	NA	NA			NA	NA			NA	NA	NA	NA	NA			NA	NA			NA	NA	NA	NA	NA
46			NA	NA			NA	NA	NA	NA	NA			NA	NA			NA	NA	NA	NA	NA			NA	NA			NA	NA	NA	NA	NA			NA	NA			NA	NA	NA	NA	NA
47							NA	NA	NA	NA	NA							NA	NA	NA	NA	NA			x				NA	NA	NA	NA	NA							NA	NA	NA	NA	NA
48									NA	NA	NA	x	x							NA	NA	NA									NA	NA	NA								NA	NA	NA
51									NA		NA									NA		NA	x	x							NA		NA								NA		NA
53							NA					x						NA				x		x					NA						NA								
54							NA	NA	NA		NA	x	x	x	x			NA	NA	NA		NA		x					NA	NA	NA		NA							NA	NA	NA		NA
57																								x																				
58															x						x		x	x																				
61												x	x	x	x								x	x	x																				
62												x											x	x																					
85											NA									x		NA											NA											NA
87											x											x																						
91																																												
92							NA	NA	NA	NA	NA	x			x			NA	NA	NA	NA	NA		x	x				NA	NA	NA	NA	NA							NA	NA	NA	NA	NA
93							NA	NA	NA	NA	NA							NA	NA	NA	NA	NA							NA	NA	NA	NA	NA							NA	NA	NA	NA	NA
112			x		NA		NA	NA	NA	NA	NA	x	x			NA		NA	NA	NA	NA	NA					NA		NA	NA	NA	NA	NA					NA		NA	NA	NA	NA	NA
122										NA	NA	x		x							NA	NA		x	x	x				x		NA	NA								NA	NA
123										NA	NA										NA	NA											NA	NA								NA	NA
125			x								x	x			x				x				x			x											x						
126			x								x	x		x	x									x	x																			

DAM	*Uperoleia fusca* (Dusky Toadlet)											*Uperoleia laevigata* (Smooth Toadlet)											*Crinia signifera* (Common Eastern Froglet)											*Adelotus brevis* (Tusked Frog)										
	08	09	10	11	12	13	14	15	16	17	18	08	09	10	11	12	13	14	15	16	17	18	08	09	10	11	12	13	14	15	16	17	18	08	09	10	11	12	13	14	15	16	17	18
129			x	x						NA		x		x	x						NA			x	x	x					NA										NA	
130											x				x				x				x	x	x																	
131																																											
142												x		x																												
144												x	x			x								x	x																	
148							NA	NA	NA	NA	NA				x			NA	NA	NA	NA	NA		x					NA	NA	NA	NA	NA							NA	NA	NA	NA	NA
149							NA	NA	NA	NA	NA				x			NA	NA	NA	NA	NA		x					NA	NA	NA	NA	NA							NA	NA	NA	NA	NA
151									NA		NA				x	x				NA		NA	x		x						NA		NA								NA		NA
152		x	x	x								x	x	x																													
153		x	x							x	x		x	x	x	x		x		x		x	x	x																			
154											NA	x	x									NA	x	x	x	x							NA										NA
157																								x																			
160												x		x	x	x		x	x	x		x																					
161							NA	NA	NA	NA	NA	x	x		x	x		NA	NA	NA	NA	NA		x					NA	NA	NA	NA	NA							NA	NA	NA	NA	NA
162			x	x			NA	NA		NA	NA	x	x		x			NA	NA		NA	NA	x	x		x			NA	NA		NA	NA							NA	NA		NA	NA
163																							x	x																			
167											NA	x	x									NA	x	x	x								NA										NA
168			x								NA	x	x	x								NA	x	x	x								NA										NA
169														x	x			x								x																	

Dam	Number of amphibian species recorded each year										
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
D1	7	2	6	7	5	4	NA	NA	NA	NA	NA
D3	3	4	3	3	3	3	1	3	2	2	3
D4	4	4	3	3	7	3	2	2	4	2	4
D5	4	3	3	5	2	3	2	3	4	3	3
D6	4	4	4	5	2	4	NA	NA	NA	NA	NA
D7	5	3	2	6	3	4	3	2	5	1	3
D11	7	4	4	2	4	4	3	3	4	1	3
D13	5	3	6	6	4	3	3	2	3	NA	NA
D15	6	5	2	2	2	4	2	4	5	1	NA
D16	4	2	5	2	4	NA	NA	NA	NA	NA	NA
D18	5	4	3	5	5	2	1	2	2	2	2
D19	1	3	2	1	1	1	1	2	2	1	2
D20	6	2	5	3	3	3	3	4	4	1	3
D21	6	4	5	4	4	3	3	3	3	4	2
D22	5	3	5	3	2	2	2	1	NA	2	NA
D23	4	4	7	2	3	3	3	2	NA	3	NA
D25	6	4	6	7	3	2	1	2	3	3	3
D26	4	2	2	3	4	2	1	1	0	1	NA
D27	6	3	7	4	5	4	2	1	0	2	0
D28	4	1	5	5	4	3	NA	NA	NA	NA	NA
D32	5	2	5	3	5	3	2	3	3	2	2
D35	3	1	5	3	3	3	2	2	2	3	3
D38	6	1	5	4	4	3	2	2	NA	1	1
D39	4	3	NA	NA	4	3	NA	NA	NA	NA	NA
D40	7	6	6	7	2	4	0	3	NA	1	4
D41	4	6	5	4	4	4	NA	NA	NA	NA	NA
D42	5	3	4	4	1	5	3	5	4	NA	3
D45	7	4	NA	NA	4	5	NA	NA	NA	NA	NA
D46	5	2	NA	NA	3	3	NA	NA	NA	NA	NA
D47	0	0	2	3	4	4	NA	NA	NA	NA	NA
D48	6	2	6	3	1	3	1	2	NA	NA	NA
D51	3	2	4	2	3	1	2	2	NA	0	NA
D53	3	3	2	3	1	5	1	1	2	0	5
D54	5	2	5	3	2	1	NA	NA	NA	NA	NA
D57	2	1	4	3	3	4	3	4	2	3	2
D58	2	1	3	5	3	3	2	3	3	3	3
D61	4	3	7	5	3	2	3	0	0	1	1
D62	3	5	3	2	1	3	3	3	1	2	3
D85	2	1	2	3	5	4	3	5	3	3	NA

Dam	Number of amphibian species recorded each year										
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
D87	NA	NA	NA	0	0	2	1	0	3	2	6
D91	1	0	1	1	1	3	0	2	0	0	1
D92	4	5	4	2	2	4	NA	NA	NA	NA	NA
D93	0	0	0	0	4	2	NA	NA	NA	NA	NA
D112	3	4	8	5	NA	1	NA	NA	NA	NA	NA
D122	4	2	5	4	1	1	1	2	1	NA	NA
D123	1	1	3	2	1	2	1	1	1	NA	NA
D125	5	0	7	6	4	4	1	3	0	1	4
D126	4	2	7	4	2	2	1	1	2	0	4
D129	3	2	6	6	2	3	1	2	2	0	0
D130	2	3	2	2	3	3	2	3	2	1	3
D131	NA	NA	NA	NA	3	3	1	2	2	0	1
D142	2	1	2	2	2	3	0	2	4	1	1
D144	3	6	2	2	3	2	0	1	2	1	1
D148	3	3	2	3	4	2	NA	NA	NA	NA	NA
D149	1	2	2	5	1	4	NA	NA	NA	NA	NA
D151	4	3	4	3	4	5	3	2	NA	2	NA
D152	5	4	3	5	4	3	2	3	4	2	3
D153	4	4	5	5	5	4	5	4	2	3	4
D154	5	4	3	6	2	2	2	2	1	1	NA
D157	1	2	1	2	1	2	2	1	1	1	1
D160	5	3	6	5	4	3	5	5	3	2	4
D161	6	2	6	6	5	4	NA	NA	NA	NA	NA
D162	5	2	6	7	4	4	NA	NA	4	NA	NA
D163	2	2	3	2	0	1	1	1	1	0	2
D167	4	3	2	3	2	2	2	3	0	NA	NA
D168	5	2	5	2	4	3	1	1	1	0	NA
D169	0	0	4	6	0	2	2	1	1	0	3
Number of NA	**2**	**2**	**5**	**4**	**1**	**1**	**17**	**17**	**23**	**23**	**31**
Number surveyed	**65**	**65**	**62**	**63**	**66**	**66**	**50**	**50**	**44**	**44**	**36**
Mean per year	**3.91**	**2.68**	**4.06**	**3.67**	**2.94**	**2.97**	**1.88**	**2.28**	**2.23**	**1.48**	**2.58**

APPENDIX 4. STAFF CONTRIBUTIONS

The following staff were involved in the compilation of this report.

Name	Qualification	Title/Experience	Contribution
Gayle Joyce	BSc (Forestry) (Hons)	GIS Specialist	Map preparation
Mark Dean	BEnvSc & Mgt	Ecologist	Field surveys and report preparation
Kristy Peters	B.ParkMngt /BSc (Hons)	Senior Ecologist	Quality review
Luke O'Brien	BEnvSc & Mgt	Ecologist	Field surveys
Nigel Fisher	BSc (Hons) PhD	Senior Soil Microecologist	Field surveys and report preparation

This page has intentionally been left blank

APPENDIX 5. LICENSING

Kleinfelder employees involved in the current study are licensed or approved under the NSW *Biodiversity Conservation Act 2016* (License Number: SL100730, Expiry: 31 March 2019) and the Animal Research Act 1985 to harm/trap/release protected native fauna and to pick for identification purposes native flora and to undertake fauna surveys.

This page has intentionally been left blank