Appendix 2

2013 Abel Underground Coal Mine Dam Monitoring and Management Survey

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2013 Abel Underground Coal Mine Dam Monitoring and Management Survey

Yancoal Australia

Abel Underground Coal Mine, Beresfield, NSW

March 2014

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Abel Underground Coal Mine, Beresfield, NSW

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EXECUTIVE SUMMARY

Donaldson Coal 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), comprising several different monitoring programs. This Dam Monitoring and Management Plan (DMMP) is one of the monitoring programs.

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.

Species diversity and composition data for frogs and species diversity, abundance and composition data for water-dependent bird species at each of the targeted dams were recorded for the 2013 survey. This data is then used to provide a means of measurement and evaluation of potential subsidence impacts at each of the dams over time. The data collected over the last six years will enable evaluation of potential subsidence impacts in the future.

At the time of the 2013 surveys, mining had begun below several of the dams. The likelihood of ecological impacts from subsidence being detected at this early stage is low. As such, the data compiled in this report is considered to be a continuation of sampling under baseline conditions. Depending on the extent of mine development future surveys will need to examine data for changes in baseline ecological conditions that could be attributed mine impacts.

Frog species diversity in 2013 was the highest recorded over the six years of monitoring, and was similar to 2008, 2010 and 2011 which also had relatively high rainfall during the breeding season. Lack of rainfall during these months leading up to the breeding season in 2009 and 2012 may have contributed to the reduction in calling activity and presence around breeding sites (dams). In years where rainfall has been high (2010, 2011 and 2013), an increase in frog diversity was experienced across a number of dams to levels comparable or greater

than the 2008 survey results. Trends such as this can help identify when changes in fauna species diversity are the result of natural fluctuations or from human induced impacts.

Total bird diversity over the survey period increased in 2013 with 12 new species being detected. Forty eight species have now been observed within the four dams surveyed. The 2013 survey had the highest bird diversity recorded over the six year survey period and the highest recorded diversity at all four dams surveyed. This increase follows an increase in diversity observed in 2012 which marked a change in a general decline at all dams from 2008 to 2011. Dam 14 recorded the highest species diversity and abundance in 2013 as well as in 2012. High bird diversity and abundance may be in response to drier conditions in inland Australia which have concentrated birds to the coast where conditions are more favourable.

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

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. This 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.

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1. INTRODUCTION

Donaldson Coal Pty Ltd (Donaldson) commenced operations at an underground mine (Abel) in 2008, approximately 23 kilometres north-west of Newcastle. The mine will extract up to 4.5 million tonnes per year over 21 years using high productivity continuous miner based bord and pillar systems, and pillar extraction techniques. The seams to be mined are located under the Black Hill rural and adjoining forested areas. Mine access and associated surface infrastructure will be located within the existing Donaldson Coal mine open cut void at Beresfield, with transfer of coal to the existing Bloomfield Coal Handling and Preparation Plant (CHPP) immediately 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 aquatic plant *Maundia triglochinoides*. Preferred habitat of each is detailed in **Appendix 1**.

Species diversity and composition data for frogs and species diversity, abundance and composition data for water-dependent bird species at each of the dams containing preferred habitat were recorded for the 2013 survey. These data are then used to 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 and surface facilities is shown in **Figure 1**; the current extent of the underground mine is also shown. The underground mine area is bounded on the eastern side by the F3 Freeway; the western and southern sides by a tract of forest that extends south to the Central Coast and beyond to Hornsby, and 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.

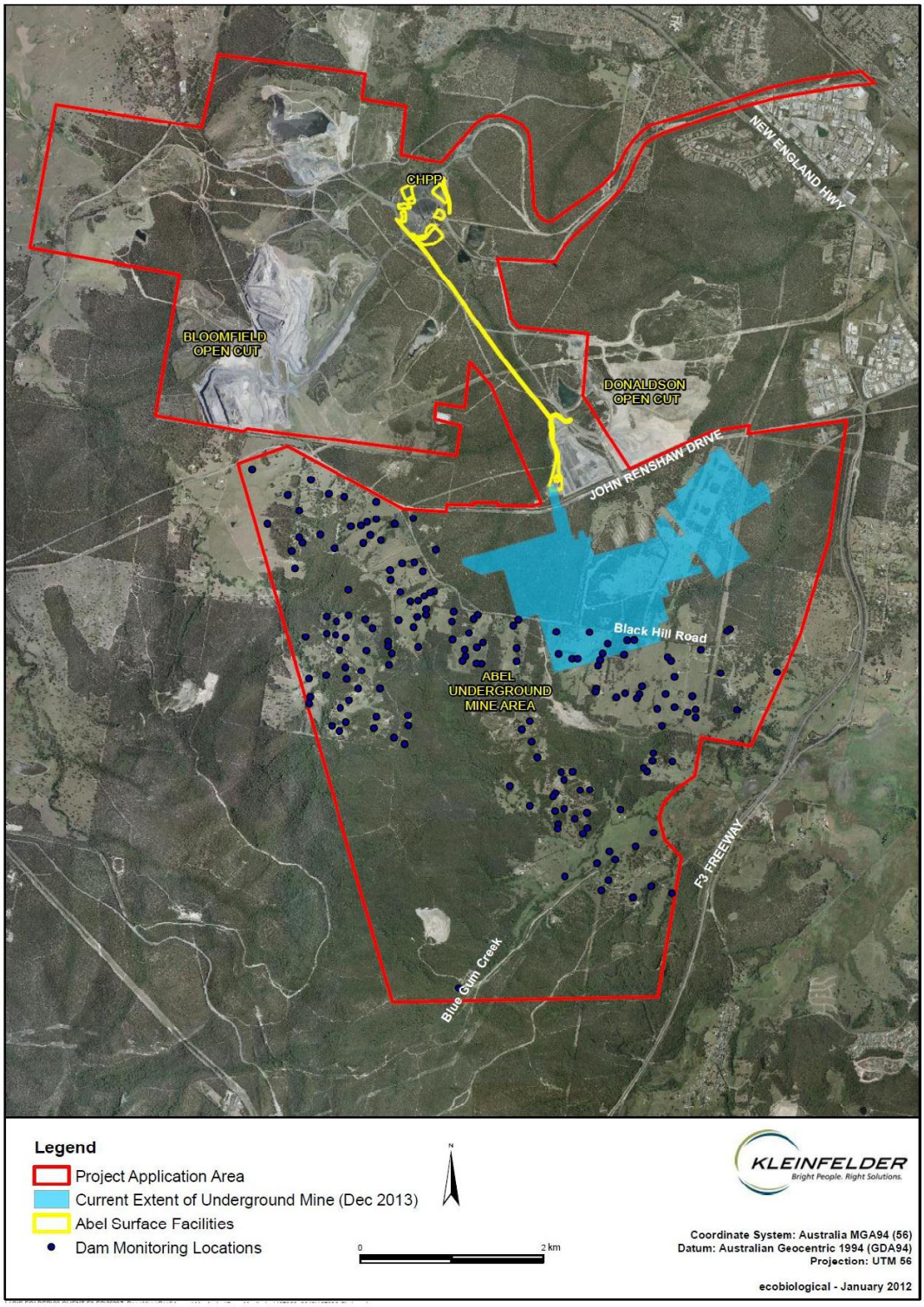

Figure 1 **The location of the Abel Underground mine area and surface facilities.**

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 targeted dams across the mine area as well as other significant surface features.

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	64	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

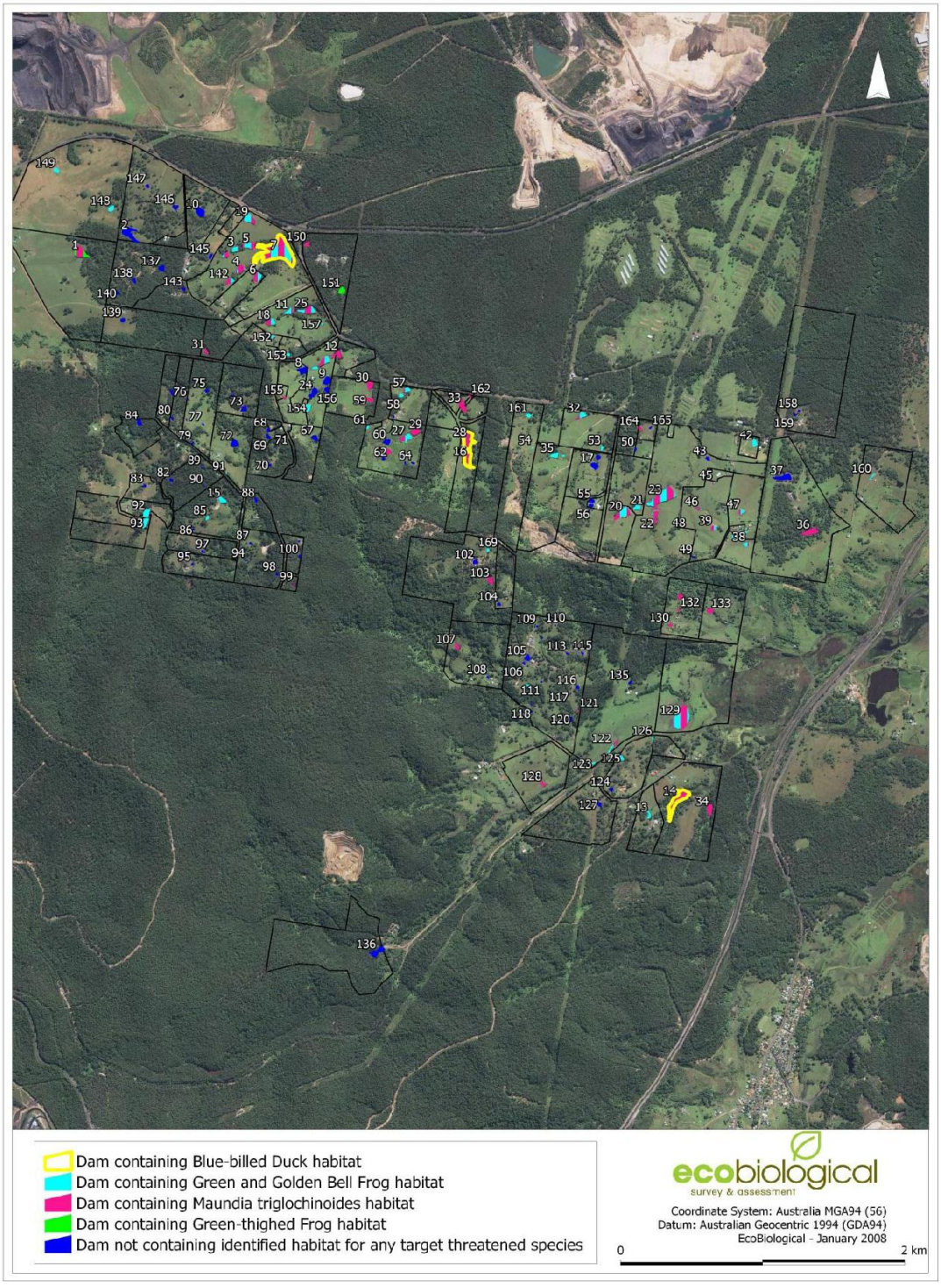

Figure 2 **Aerial photograph of the Abel Mine area showing the layout of dams surveyed and the location of dams containing habitat suitable for each targeted threatened species.**

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 this species in 2008 and 2009; however only 61 dams were surveyed in 2010 and 2011 as a result of private landholders preventing access to their land. A total of 62 dams were surveyed in 2012.

Sixty-two (62) dams were surveyed in 2013 which were conducted on the 25th - 28th November 2013 and 19th - 20th December 2013. The dams surveyed were located across the area where underground mining will occur in the future. The dams surveyed were considered to be suitably representative of the total dams present and provided the best practicable opportunity of detecting the Green and Golden Bell Frog.

Surveys are required to be completed during warm and windless weather conditions following rainfall (DEWHA 2009). During the survey period maximum daily temperatures reached 22.7-38.0°C; the conditions were calm at the time of surveys. Significant rainfall events occurred in late November (see **Section 4.1.2** for details).

Both targeted habitat surveys and call playback surveys were conducted throughout the survey period. At each dam an initial 2 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 that were calling. 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 generally consisted of around 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 by eye-shine or by physical sightings. All other amphibian species observed were also recorded.

4.1.2 Green-thighed Frog (*Litoria brevipalmata*)

Three (3) dams were deemed potentially suitable for the Green-thighed Frog. Dam 1, Dam 87 and Dam 151 were surveyed for this species on the 28th November 2013, 27th November 2013 and 25th November 2013 respectively.

Surveys are required to be completed after heavy rainfall during the breeding season (November -February) (DECC 2009). A significant rainfall event (120 mm) occurred on 18th November 2013, with further falls on the 19th November (17 mm), 23rd November (28 mm), 24th November (86 mm) and 26th November (10mm) (Maitland weather station; Bureau of Meteorology, 2014).

Quiet listening and a habitat search were carried out for the Green-thighed Frog at each dam. The species only calls on a small number of nights (usually <5) in any given season and only after significant rainfall (usually 70mm). 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 by eye-shine or by physical sightings.

4.2 BIRDS

4.2.1 Blue-billed Duck (*Oxyura australis*)

Four dams were surveyed for the Blue-billed Duck on the 18th December 2013; Dams 7, 14, 16 and 28. The remaining dams were not surveyed because an initial assessment determined that they did not contain suitable habitat for the targeted species. 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.

Targeted surveys for the Blue-billed Duck involved a 20-minute walking transect along the edge of each of the selected dams. This time period enabled the inspection of the entire surface area of each dam for the target species. The surveys were carried out during clear and warm conditions. All other waterbird 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.

Each dam surveyed was assessed as to its suitability to provide habitat for the Blue-billed Duck and other threatened waterbird species based on habitat attributes such as the amount of fringing aquatic vegetation present, the amount of deep, open water present and the proximity to other suitable dams or areas of habitat.

4.3 FLORA

4.3.1 Maundia triglochinoides

Eighty-seven (87) dams were assessed as containing suitable habitat for the aquatic plant *M. triglochinoides*. Searches were conducted on the 27th and 28th November 2013 and on the 13th December 2013 and 17th December 2013 using a random meander methodology ensuring that all water edge environments were searched. The surveys were performed in November and 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 64 dams surveyed. No Green-thighed Frogs were detected at the three dams surveyed that contained habitat for this species. No frogs listed under State or Commonwealth legislation were recorded during field surveys.

Eleven non-threatened species of frog were detected at the dams during 2013 surveys (**Appendix 3**). All are considered to be common dam or pond breeding species. Eight (8) frog species were detected at the dams during 2012 surveys. Twelve (12) frog species were detected at the dams during 2011 surveys. Eleven (11) frog species were detected at the dams during 2008 and 2009 surveys, and 10 frog species were detected during the 2010 survey. All species detected in 2013 have been recorded in previous surveys.

Between 2008 (initial survey) and 2009 there was a decline in frog diversity at most dams (47). However, 38 dams experienced an increase in frog diversity between the 2009 and 2010 surveys. Between 2010 and 2011, 20 dams recorded an increase in frog species diversity, and 13 dams had the same diversity as the year previous. From 2011 - 2012 only 15 dams recorded an increase in frog species diversity whilst 31 dams decreased in diversity. From 2012 - 2013, 39 dams recorded an increase in frog species diversity, while 12 decreased, and 12 remained the same.

The distribution of frog species diversity for each survey year is represented in **Figure 3** (frequency of frog richness across all dams each year). It is evident from these data that the diversity fluctuates regularly. For instance, the mean species diversity per dam is 4.13 in 2010 whilst it had previously dropped to 2.72 in 2009.

The fluctuating numbers in frog species diversity of the last 6 years likely reflects fluctuating weather patterns across the region. Abnormally warm conditions prevailed through much of November 2009 and average temperatures were above normal (National Climate Centre 2009) which may explain the drop in species diversity during the 2009 survey (**Figure 4**). Also, Donaldson Coal rainfall statistics for the region show an increased level of rainfall

during the 2011 monitoring period which can be reflected in the increase in frog numbers during that survey (**Figure 5**). Rainfall data show that between September and December only 202.4 millimetres of rain fell in 2009; 334 millimetres in 2010 and 479 millimetres in 2011 (source: Maitland weather station Bureau of Meteorology 2014). In 2012 the lowest recorded rainfall was experienced between September and December (119.3 millimetres). In 2013 the second highest seasonal rainfall over the six years of the survey was recorded (450 millimetres).

It is likely that this combination of lower than normal rainfall and warmer temperatures as experienced in 2009 and again in 2012, is the main contributing factor in the decrease of frog species diversity from the 2011 survey. **Figures 4** and **5** show a general trend towards higher diversity for lower maximum temperatures and higher rainfall respectively. However, the 2013 results do not show a strong correlation between lower maximum temperature and frog richness per dam. The 2013 data follow the same trend of higher rainfall and higher frog diversity. From these data, rainfall appears to be a stronger determinant of frog diversity than temperature. While 2013 had the second highest rainfall over the September to December period, 2013 had the highest average diversity per dam. This may be attributable to the 2013 survey period having the largest single rainfall event since the baseline survey which occurred in November (365 millimetres). This may also explain why 2013 scored the highest diversity per dam despite having the highest average maximum seasonal temperature.

The list of frog species identified from each dam and the totals are tallied in **Appendix 3.**

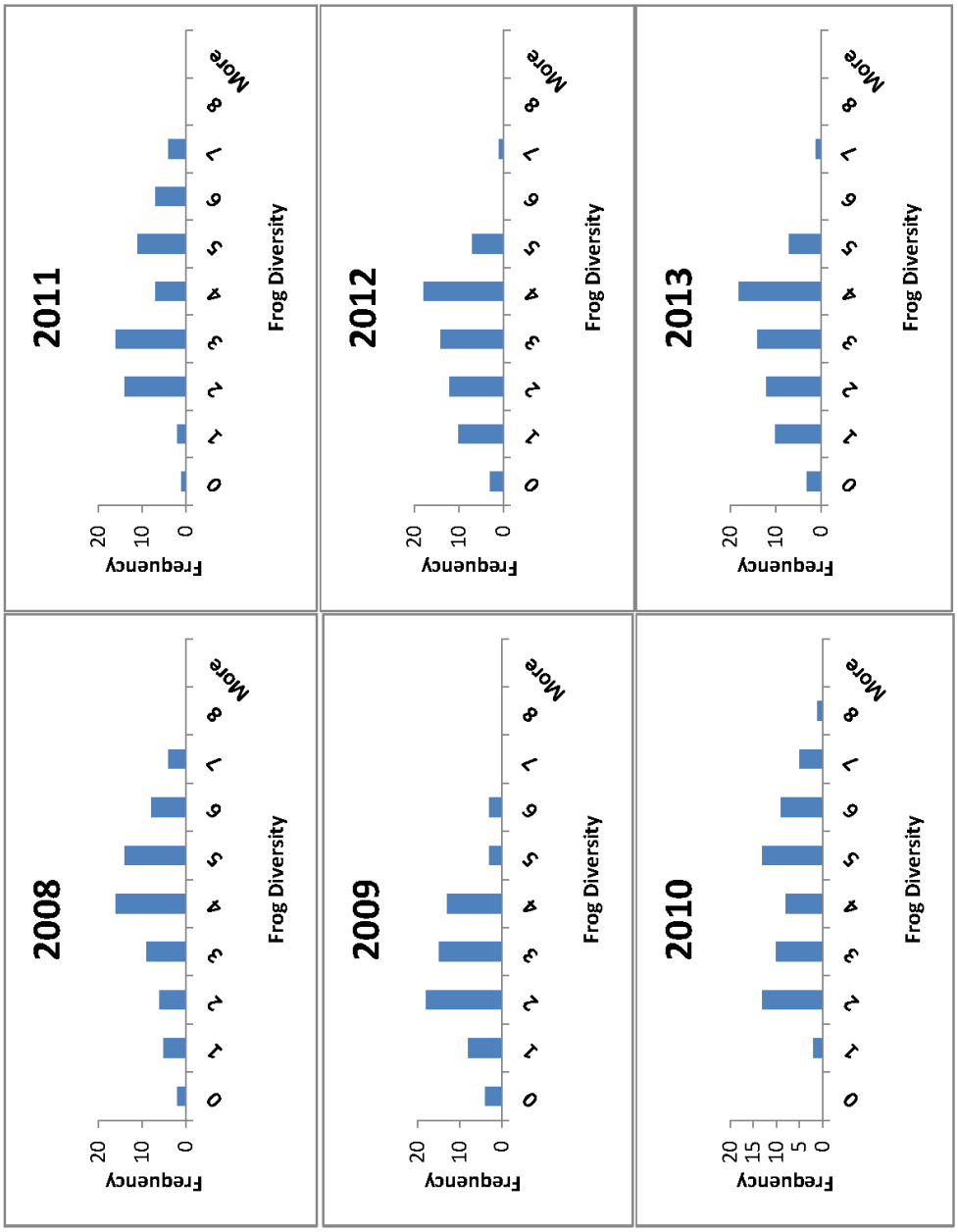

Figure 3 **Frequency distributions of the numbers of frog species recorded across all dams for each of the survey years 2008 – 2013.**

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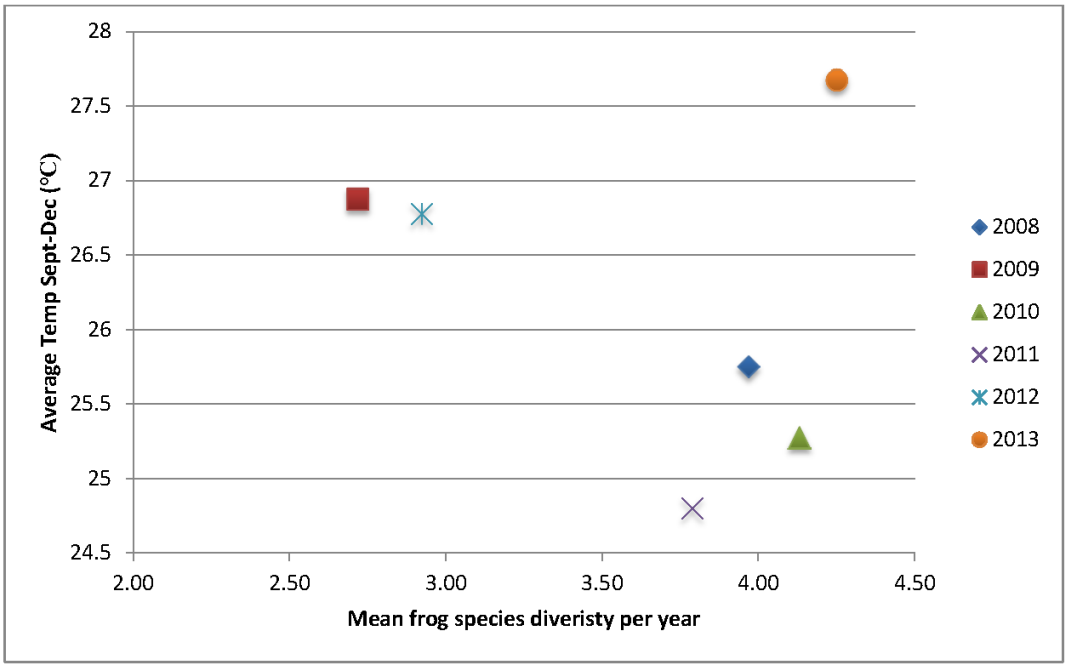

Figure 4 The effect of temperature on numbers of frog species detected.

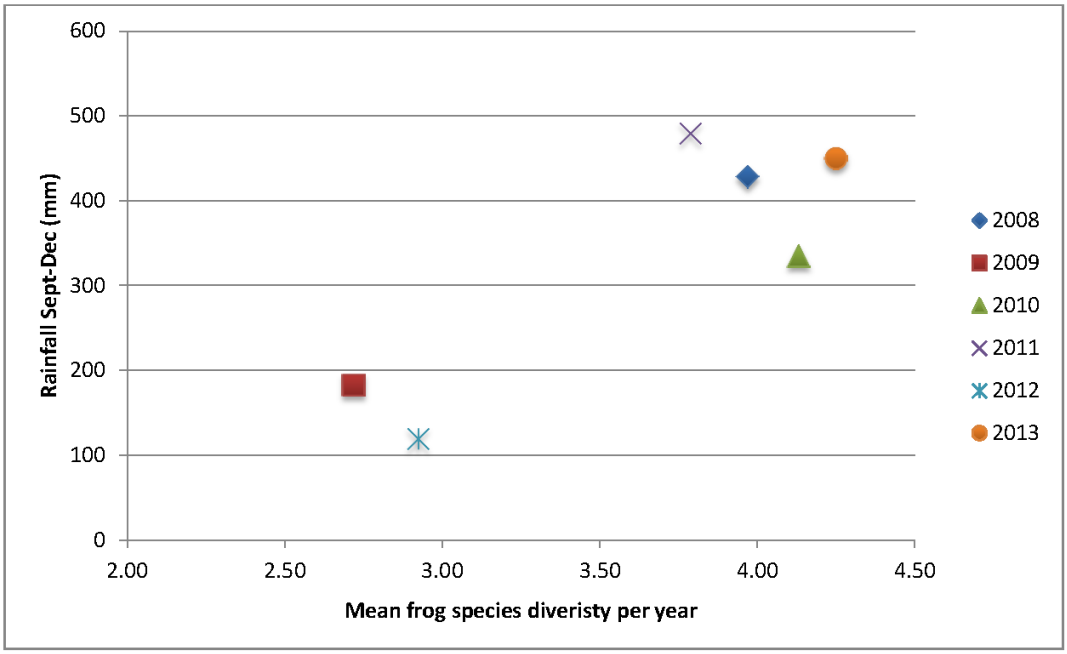

Figure 5 The effect of rainfall on number of frog species detected.

5.2 . BIRDS

The Blue-billed Duck was not detected at any of the four targeted dams surveyed. No bird species listed as threatened under State or Commonwealth legislation were recorded during field surveys.

A total of 48 bird species have been recorded between 2008 and 2013 across all of the dams surveyed (**Appendix 4**). The 2013 surveys detected 41 species across the four dams, ranging from 11 to 21 species at any one dam (**Figure 6**). An additional 12 new species were recorded that have not previously been detected at the dams. The 2013 survey recorded the highest recorded species diversity since monitoring commenced.

By comparison, the 2012 surveys detected 26 species across the four dams, ranging from 9 to 15 species at any one dam. The 2011 surveys identified 13 bird species across the surveyed dams with between 5 and 6 species detected at any one individual dam. The 2010 surveys identified 10 species with between 1 and 7 species at any one individual dam; the 2009 surveys identified 17 species with between 6 and 11 species at any one individual dam; and the 2008 surveys identified 17 species with between 3 and 10 species at any one individual dam.

In 2013, the highest bird diversity was at Dam 14 with 21 species recorded (**Figure 6**). In 2013, the number of new species recorded at each dam included four, six, one and seven new species at Dams 7, 14, 16 and 28 respectively. Between 2009 and 2011, Dams 7 and 28 show an overall declining trend in diversity, whereas Dams 14 and 16 fluctuate considerably in the number of species recorded each year. Overall diversity has increased progressively over the last several survey events.

In 2013, the total abundance increased from the previous year at dams 14, 16 and 28 (**Figure 7**). The highest abundance at any single dam in 2013 was 60 individuals recorded at Dam 14. Dam 28 had a gradual decline in abundance from 2008 to 2012 but recorded 40 individuals in 2013, compared to 10 individuals in 2012. Dam 10 has been relatively stable in total abundance of birds over the six years of the survey, whereas the remaining three dams have fluctuated more markedly, particularly Dams 14 and 16.

The twelve new species recorded in 2013 included mainly woodland birds that were observed in fringing vegetation. Despite their absence in the 2010 and 2011 surveys after large numbers were observed in 2009, Chestnut Teals were recorded once again, in higher

numbers than 2012 (one individual at Dam 14 and ten individuals at Dam 16 in 2013 compared to 2012 with one individual at Dam 16 and one at Dam 28).

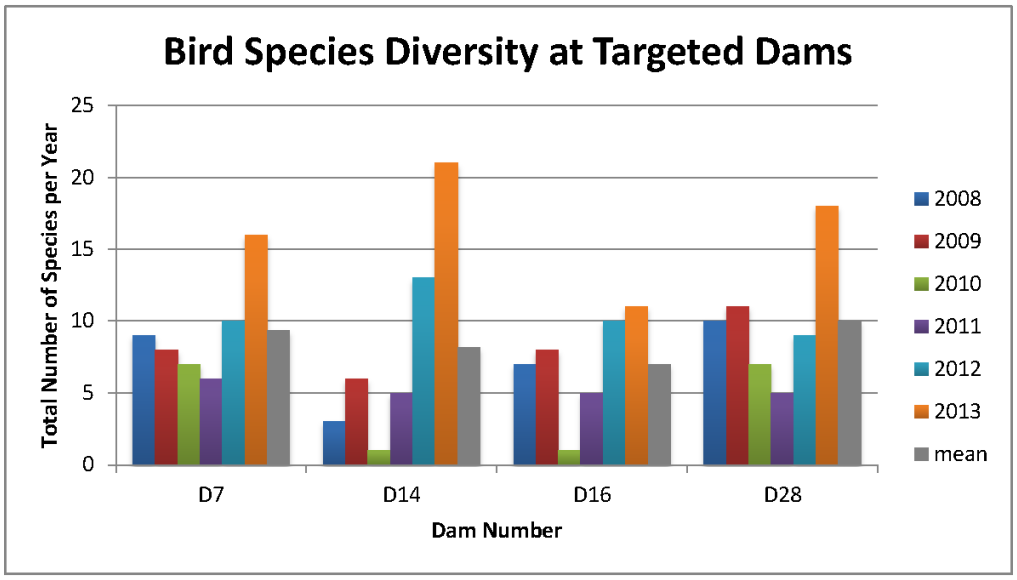

Figure 6 **Bird species diversity at surveyed dams.**

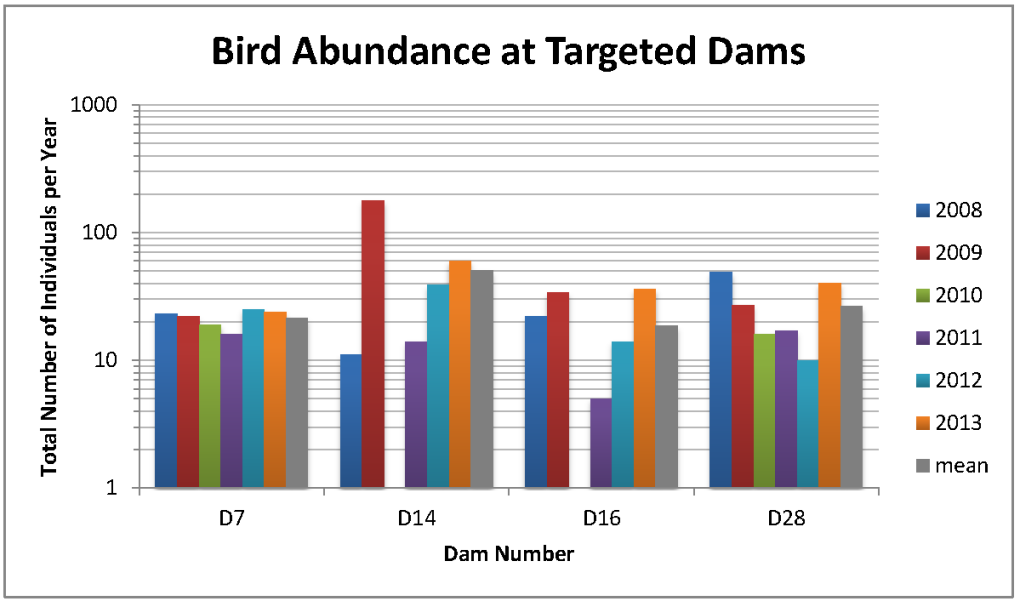

Figure 7 **Bird species abundance at surveyed dams.**

5.3 FLORA

Maundia triglochinoides was not detected at any of the 84 dams surveyed, with one dam (dam no. 87) being assessed as non-suitable habitat at the time of survey, while permission to survey three dams was not obtained from the current owners (dams no. 93, 120 and 121). 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.

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 habitat suitable for the Green and Golden Bell Frog, this species was not detected in 2008, 2009, 2010, 2011, 2012 or 2013. However, over time the habitat characteristics of some dams have changed or have been modified which has altered the suitability for the Green and Golden Bell Frog (increased turbidity, change in water depth and dam profile, changes in vegetation types and densities etc.).

Regardless of the current status of occupancy of the dams by the targeted threatened species, the presence of a large number of dams with habitat suitable for these species (particularly those that interconnect and form habitat complexes) may be an important factor for their future recovery. This may be 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 are thought to be now extinct (M. Mahoney 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

Only three dams were considered to contain habitat suitable for the Green-thighed Frog in 2008. While the surveys carried out were considered robust, it always remains a possibility that a threatened species may have been overlooked. This is particularly true for the more

cryptic species such as the Green-thighed Frog, which may only call on one or two nights of the year (Lemckert et al. 2006) and remains very difficult to detect on other nights.

The Green-thighed Frog is only known from two records some 13 km from the Black Hill area and is not known for its high mobility. However, it is considered that as the annual surveys progress, the likelihood of detecting this threatened species will increase. Similarly, habitat characteristics of some dams have changed or have been modified which has altered the suitability for the Green-thighed Frog. The three ponds which once contained suitable habitat for the Green-thighed Frog now represent little habitat for this species and its presence is highly unexpected.

6.1.3 Common Frogs

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

Data from the most recent survey (2013) suggests that diversity has increased, recovering from lower diversity in 2012 which is attributed to low rainfall in that year during the breeding season. This is considered to be natural fluctuation in frog species diversity; **Figure 5** shows a strong correlation between frog species diversity and rainfall in spring and early summer months with lower rainfall in 2009 and 2011 resulting in lower frog diversity per dam than other years. The current survey in 2013 recorded the highest frog diversity per dam over the six years of surveys and had the highest monthly rainfall event in November with 365 mm.

Frogs are a particularly resilient group of animals in that they can conserve energy by limiting their energy use when conditions are poor therefore minimising the chance of reproductive failure by going into torpor. It is anticipated that once conditions improve and the probability of reproductive success improves the number of frogs observed will increase.

Some species of frog with a possible occurrence in the study area have not been detected in the six years of surveys so far, 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. Future surveys in following years may detect some of these species or confirm their absence.

The absence of the above species and the difference in the diversity and species composition at the dams over six 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)), but may also be due to unsuitability of local habitat, changing weather conditions or just chance.

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 are still present in the environment but may not be as obvious compared to other years.

It must be noted that no matter how much expertise or effort is employed, species that may use a site may go unrecorded during ecological survey. This is due to their mobility, unpredictable movement through their habitat and cryptic nature; as well as environmental factors such as rainfall, drought and bushfire which may impact on the type and number of species which are recorded at any one time or site.

6.2 BIRDS

Only four dams were considered to contain habitat potentially suitable for the Blue-billed Duck. 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 provided conditions are suitable. This species is also known from the Bloomfield Dam (NSW Wildlife Atlas 2010) to the north of the Abel mine area.

In 2013, there was there was a considerable increase in species richness at Dams 7, 14, and 28 and a small increase at Dam 16 since the previous survey in 2012. This followed considerable increases in 2012 at all four dams when compared to 2011. In 2013, Dams 14

and 28 had the largest increases in species richness since 2012 with an increase of eight and nine species respectively. All four dams recorded new species in 2013 with the largest number of new species recorded at Dam 28 with seven new species.

The species abundance in 2013 is also above average for all four dams by varying amounts. Abundance increased markedly at Dams 14, 16 and 28 since 2012, and was similar to 2012 at Dam 7.

The substantial decline in diversity and abundance in 2010 and moderate recovery in 2011 is most likely a result of changing weather patterns across both the region and the state. Similarly, the lack of rainfall prior to the 2012 surveys may have reduced the size of other water bodies, and this trend continued in 2013. While 2013 was the driest year in NSW since 2006, the coast received above average rainfall (Bureau of Meteorology 2014). As significant breeding and foraging habitat contracts the diversity and abundance of birds may increase at the remaining ponds which still contain water. This may be reflected in the increase in both species diversity and abundance at all four dams (with the exception of a slight decrease in abundance at Dam 7 when compared to 2012). Many regions of NSW were experiencing abnormally dry conditions in 2009, 2012 and 2013 as well as abnormally warmer temperatures (2009 and 2013 were the warmest and second warmest years on record in NSW (Bureau of Meteorology 2014)). Dry inland conditions are likely to have forced many waterbirds to move to coastal areas in search of permanent water bodies in which to forage and breed. This drying trend began to reverse in November 2009 through March 2010, with many areas inland of the Great Dividing Range experiencing above average to very high rainfall during this period. The increase in rainfall across NSW in late 2009 / early 2010 is likely to have caused many of the water-dependent bird species to return inland to wetlands and lakes. In 2013 inland NSW experienced widespread dry conditions during October and December with one significant rainfall event in September (Bureau of Meteorology 2014). As such, many birds may have sought more favourable conditions by moving closer to the coast. The majority of birds that have been recorded to date are also nomadic/itinerant in that they often travel large distances and sporadically occupy multiple environments as they move. Birds of this nature are largely unpredictable in determining their specific movements and thus appear irregularly.

The 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 2008, 2009, 2010, 2011, 2012 or now in 2013.

Only three records of *Maundia triglochinoides* in close proximity to the study area exist, one from Kooragang Wetlands (pers. obs., D. Pedersen), Irrawang Wetlands (pers. obs., Dan Pedersen) and the Medowie area, some 25 km from the Abel Mine site (NSW Wildlife Atlas, 2010). However, a close inspection of suitable dams over the six 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 a relatively unlikely occurrence.

7. CONCLUSION

While suitable habitat exists at 84 dams in the Abel mine area for targeted threatened species, none have been detected in six years of surveys (Ecobiological 2008, Ecobiological 2009, Ecobiological 2010, Ecobiological 2011, Ecobiological 2012 and this report). Species diversity and composition data has been collected for frog and bird species.

Frog species diversity in 2013 was the highest recorded over the six years of survey, and was similar to 2008, 2010 and 2011 which also had relatively high rainfall during the breeding season. Lack of rainfall during these months leading up to the breeding season in 2009 and 2012 may have contributed to the reduction in calling activity and presence around breeding sites (dams). In years where rainfall has been high (2010, 2011 and 2013), an increase in frog diversity was experienced across a number of dams to levels comparable or greater than the 2008 survey results. Trends such as this can help identify when changes in fauna species diversity are the result of natural fluctuations or from human induced impacts.

Total bird diversity over the survey period increased in 2013 with 12 new species being detected. Forty-eight (48) species have now been observed within the four dams surveyed. 2013 had the highest bird diversity recorded over the six year survey period and the highest recorded diversity at all four dams surveyed. This follows an increase in diversity observed in 2012 which marked a change in a general decline at all dams from 2008 to 2011. Dam 14 recorded the highest species diversity and abundance in 2013 as well as in 2012. High bird diversity and abundance may be in response to drier conditions in inland Australia which have concentrated birds to the coast where conditions are more favourable.

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

The data collected over the last six years will enable evaluation of potential subsidence impacts in the future. At the time of the 2013 surveys, mining had begun below several of the dams. The likelihood of ecological impacts from subsidence being detected at this early stage is low. As such, the data compiled in this report is considered to be a continuation of sampling under baseline conditions. Depending on the extent of mine development future surveys will need to examine data for changes in baseline ecological conditions that could be attributed mine impacts.

More detailed statistical analyses will be appropriate following the 2014 annual monitoring event to evaluate impacts arising from the mine expansion currently occurring in the study area. An accompanying water quality and condition assessment at the target dams is recommended to identify factors, such as eutrophication, recent fertiliser applications or nutrient runoff and local surface runoff. Any of these factors may impact species abundance and diversity at each of the targeted dams.

8. RECOMMENDATIONS

It is recommended that in future amphibian surveys, water quality and aquatic habitat assessments of the relevant dams be made to determine if any future changes in frog diversity or species composition at the dams may be explained by local environmental factors. Indices of water quality that can be collected with minimal cost and effort include temperature, pH and salinity (EC) as well as visual observations of water and aquatic vegetation health.

It is also recommended that the habitat suitability for Green and Golden Bell Frogs and Green-thighed frogs at each dam be reassessed as habitat characteristics have changed overtime.

This will assist in the future to identify factors, such as eutrophication of dams from stock, recent fertiliser applications, or nutrient runoff from farming practices and local surface runoff which may contribute to local frog and bird decline rather than effects from mining.

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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 45-110mm 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 it 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, whereas, others backs 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 NSW Threatened Species Conservation (TSC) Act 1995, and as vulnerable under the federal Environmental Protection and Biodiversity Conservation Act 2000. Its distribution today is restricted to isolated pockets along the coast at various scattered locations 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 between biologists studying the species. Some of the differing views on Green and Golden Bell Frog ecology between biologists may be due to a failure to take into account the role of disease (a pathogenic fungus) that is probably primarily responsible for changes in its 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 distances of up to 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 for the detection of 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 at day and night in the 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 NSW TSC Act.

It is distributed 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, with calling lasting for a median of only 1 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 habitat on a broad scale 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, particularly 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 males bill 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 in 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 and 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 NSW 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 are noted as being the destruction or modification of habitat, particularly by drainage works, clearing, cropping or burning (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 old records of

this species occurring as far south as Sydney, however it is presumed extinct from these sites, and Wyong in now thought to be the southern limit of its range (DECC 2005). Maundia triglochinoides is listed as vulnerable under the NSW TSC Act.

Maundia 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 procerum. The flowering occurs during warmer months (November to January). The plant is likely to be wind pollinated. The long distance dispersal is the 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 further loss and fragmentation of habitat, changes in hydrology and water quality, and weed invasion (DECC 2008).

APPENDIX 2. SUITABILITY OF HABITAT AT TARGET DAMS

M. triglochin = *Maundia triglochinoides*; *E. crass* = *E. crassipes*; GGBF = Green and Golden Bell Frog (*Litoria aurea*); GTF = Green-thighed Frog (*Litoria brevipalmata*); BBD = Blue-billed Duck (*Oxyura australis*). Permission to access dams shaded red was denied in the 2012 survey.

Dam Number	*M. triglochin*	GGBF	GTF	BBD
1	✓	✓	✓	
3	✓	✓		
4	✓	✓		
5	✓	✓		
6	✓	✓		
7	✓	✓		✓
11	✓	✓		
12	✓			
13	✓	✓		
14	✓			✓
15	✓	✓		
16	✓	✓		✓
18	✓	✓		
19	✓	✓		
20	✓	✓		
21	✓	✓		
22	✓	✓		
23	✓	✓		
25	✓	✓		
26	✓	✓		
27	✓	✓		
28	✓	✓		✓
29	✓			
31	✓			
32	✓	✓		
33	✓			
34	✓			
35	✓	✓		
36	✓			
38	✓	✓		
39	✓	✓		
40	✓	✓		
41	✓	✓		
42	✓	✓		
45	✓	✓		
46	✓	✓		

Dam Number	*M. triglochin*	GGBF	GTF	BBD
47	✓	✓		
48	✓	✓		
51	✓	✓		
53	✓	✓		
54	✓	✓		
57	✓	✓		
58	✓	✓		
59	✓			
61	✓	✓		
62	✓	✓		
85	✓	✓		
87	Not Suitable			
91	✓	✓		
92	✓	✓		
93	✓			
99	✓			
103	✓			
107	✓			
112	✓	✓		
121	✓			
122	✓	✓		
123	✓	✓		
125	✓	✓		
126	✓	✓		
128	✓			
129	✓	✓		
130	✓	✓		
131	✓			
132	✓			
133	✓			
134	✓			
142	✓	✓		
144	✓	✓		
148	✓	✓		
149	✓	✓		
150	✓			
151	✓		✓	
152	✓	✓		
153	✓	✓		
154	✓	✓		
155	✓			
157	✓	✓		
160	✓	✓		
161	✓	✓		
162	✓	✓		
163	✓	✓		
164	✓			
167	✓	✓		

Dam Number	*M. triglochin*	GGBF	GTF	BBD
168	✓	✓		
169	✓	✓		
Total	87			
Total with Suitable Habitat	86	64	2	4
Total Surveyed	84			

APPENDIX 3. AMPHIBIAN SPECIES RECORDED IN EACH DAM SURVEYED

L. fallax = Dwarf Green Tree Frog (*Litoria fallax*); L. peronii = Emerald-spotted Tree Frog (*Litoria peronii*); L. tyleri = Southern Laughing Frog (*Litoria tyleri*); L. lato. = Broad-palmed Frog (*Litoria latopalmata*); L. nasuta = Rocket Frog *(Litoria nasuta);* L. verr. = Whistling Tree Frog (*Litoria verreauxii*); Lim. per. = Striped Marsh Frog (*Limnodynastes peronii*); Lim. tas. = Spotted Grass Frog (*Limnodynastes tasmaniensis*); U. fusca = Dusky Toadlet (*Uperoleia fusca*); U. laev. = Smooth Toadlet (*Uperoleia laevigata*); C. sig. = Common Eastern Froglet (*Crinia signifera*); A. brevis = Tusked Frog (*Adelotus brevis*);

'x' – indicates presence NA – No available access Dam = Dam Number Survey Year = 2008, 2009, 2010, 2011, 2012, 2013

Dam	L. fallax						L. peronii						L. tyleri						L. lato.						L. nasuta						L. verr.					
	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013
1	x	x	x	x	x	x	x		x	x	x	x	x		x	x	x	x					x					x			x	x		x	x	x
3	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
5	x	x	x	x	x	x		x		x	x	x	x									x											x	x		x
6	x	x	x	x	x	x						x										x		x							x	x		x		x
7	x	x	x	x	x	x				x		x	x									x	x								x	x			x	x
11	x	x	x	x	x	x	x	x			x	x	x				x	x													x					x
13	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x	x	x													
15	x	x	x	x	x	x	x	x				x						x	x	x			x	x												
16	x		x	x	x	NA			x		x	NA				x	x	NA	x		x			NA						NA		x	x			NA
18	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
20	x	x	x	x	x	x	x		x	x		x	x		x		x					x	x	x													x

Dam	L. fallax						L. peronii						L. tyleri						L. lato.						L. nasuta						L. verr.					
	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013
21	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				x				x	x	x	x											x			
23	x	x	x	x	x	x		x							x			x	x	x	x												x			
25	x	x	x	x	x	x	x			x	x											x	x								x	x	x	x		x
26	x		x	x	x	x	x			x	x					x																			x	x
27	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			x		x	x				x	x		x		x	x											x			x
32	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			
38	x	x	x	x	x	x	x		x	x	x	x							x		x	x	x	x												
39	x	x	NA	NA	x	x	x	x	NA	NA	x	x	x		NA	NA			x		NA	NA	x	x			NA	NA					NA	NA		
40	x	x	x	x	x	x	x		x	x		x				x		x	x	x	x	x	x	x										x		
41	x	x	x	x	x	x		x	x	x	x	x				x		x	x	x	x			x									x			
42	x		x	x		x	x		x	x	x	x	x					x	x	x	x	x		x								x				
45	x	x	NA	NA	x	x	x		NA			x	x	x	NA	NA	x	x	x	x	NA	NA		x			NA	NA					NA	NA		
46	x	x	NA	NA	x	x	x		NA	NA	x		x		NA	NA		x	x	x	NA	NA	x				NA	NA					NA	NA		
47			x	x	x	x					x					x	x	x						x												
48	x	x	x	x	x	x	x		x	x			x		x	x		x	x		x			x									x			
51	x	x	x	x	x	x									x				x		x		x										x			
53	x	x	x	x		x										x		x						x												x
54	x			x	x		x		x										x		x	x	x	x									x			

Dam	L. fallax						L. peronii						L. tyleri						L. lato.						L. nasuta						L. verr.					
	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013
57	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												
61	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															
85	x	x	x	x	x	x	x			x	x	x				x	x	x					x													
87																								x												
91												x						x					x													x
92	x	x	x	x	x	x	x	x	x		x	x	x		x	x		x						x								x				
93					x	x					x						x	x																		
112	x	x	x	x	NA	NA		x	x	x	NA	NA	x	x	x	x	NA	NA			x		NA	NA					NA	NA			x		NA	NA
122	x	x	x	x	x	x																														
123	x	x	x	x	x	x									x	x		x																		
125	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																		
129	x	x	x	x	x	x							x		x	x		x																		
130	x	x	x	x	x	x		x									x							x												
131	NA	NA	NA	NA	x	x	NA	NA	NA	NA		x	NA	NA	NA	NA	x	x	NA	NA	NA	NA			NA	NA	NA	NA			NA	NA	NA	NA		
142	x	x	x	x	x	x				x		x						x																		
144	x	x		x	x	x		x		x	x			x										x							x	x	x			x
148	x	x	x	x	x	x					x	x			x	x	x		x	x			x													
149	x	x	x	x	x	x												x			x	x		x												x

Dam	L. fallax						L. peronii					
	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013
151	x	x	x	x	x	x		x			x	
152	x	x		x	x	x	x	x	x	x	x	x
153	x			x	x	x	x		x	x	x	x
154	x	x	x	x	x	x				x		x
157					x	x						x
160	x	x	x	x	x	x	x		x	x	x	x
161	x		x	x	x	x	x		x	x	x	x
162			x	x	x	x			x		x	
163	x		x	x		x		x				
167	x			x	x	x	x					
168	x		x	x	x	x						
169			x	x		x						

Dam	L. tyleri						L. lato.					
	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013
151			x			x						x
152	x			x	x	x	x			x	x	
153			x	x	x	x	x			x	x	
154				x						x		
157							x	x		x		
160			x	x			x	x	x	x	x	
161	x		x	x	x	x	x		x	x	x	x
162	x		x	x	x	x			x	x		x
163			x							x		
167				x								
168					x						x	
169				x					x	x		

Dam	L. nasuta						L. verr.					
	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013
151		x					x					x
152												x
153												x
154	x	x					x					x
157												
160												x
161									x			
162							x		x			x
163												x
167												
168									x			
169												x

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Dam	Lim. per.						Lim. tas.						U.fusa						U. laev.						C. signif.						A.brevis					
	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013
1	x		x									x	x		x				x		x	x		x				x									
3	x					x									x				x	x	x		x			x	x			x						
4					x										x	x			x	x	x		x	x	x	x				x						
5																x			x					x	x	x	x									
6		x	x	x											x				x						x	x	x	x	x							
7	x			x		x				x						x									x	x	x			x						
11		x			x		x		x			x							x	x	x	x		x	x		x									
13									x	x					x	x			x						x											
15	x	x	x									x							x						x	x		x								
16	x				x	NA						NA						NA						NA	x	x	x			NA						NA
18																			x			x			x	x	x									
19																										x	x			x						
20	x		x																x		x				x	x										
21	x																		x						x	x										
22	x	x	x	x		x													x						x											
23	x		x	x	x	x			x																x	x	x		x	x						
25	x	x		x					x	x					x	x			x		x				x	x	x			x						
26					x														x	x					x	x	x									
27	x	x	x	x		x													x								x			x						
28	x		x	x	x																	x		x	x	x										
32	x	x			x							x												x												
35			x	x	x	x													x				x	x		x				x						
38				x	x		x		x										x		x				x											

Dam	Lim. per.						Lim. tas.						U.fusa						U. laev.						C. signif.						A.brevis					
	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013
39			NA	NA	x				NA	NA					NA	NA					NA	NA				x	NA	NA					NA	NA		
40	x	x	x			x	x	x	x	x									x	x	x	x		x	x	x										
41		x			x							x							x	x		x	x	x	x	x	x									
42						x	x		x	x																x										
45	x		NA	NA	x	x	x	x	NA	NA					NA	NA			x		NA	NA	x	x			NA	NA					NA	NA		
46	x		NA	NA		x			NA	NA					NA	NA					NA	NA					NA	NA					NA	NA		
47				x	x	x						x															x									
48							x		x										x	x																
51				x	x																				x	x										
53	x	x	x	x	x	x						x						X	x							x				x					
54							x		x			x							x	x	x	x		x		x				x					
57							x		x															x		x									
58						x	x					x										x			x	x									
61			x		x					x									x	x	x	x		x	x	x	x								
62		x																	x					x	x	x									
85			x		x	x																													
87						x						x																		x					
91	x		x	x		x						x																		x					
92		x																	x			x		x		x	x			x					
93					x																														
112			x	x	NA	NA			x		NA	NA			x		NA	NA	x	x			NA	NA					NA	NA					NA	NA
122	x		x	x			x		x	x		x							x		x			x		x	x	x		x					
123									x																										

Dam	Lim. per.						Lim. tas.						U.fusa						U. laev.						C. signif.						A.brevis					
	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013
125	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									
129				x	x	x			x			x			x	x			x		x	x		x		x	x	x								
130					x	x																x		x	x	x	x									
131	NA	NA	NA	NA	x		NA	NA	NA	NA			NA	NA	NA	NA			NA	NA	NA	NA			NA	NA	NA	NA			NA	NA	NA	NA		
142					x														x		x															
144																			x	x			x			x	x			x						
148	x											x										x		x		x										
149				x						x												x		x		x				x						
151	x		x	x	x	x						x										x	x	x	x		x									
152						x								x	x	x			x	x	x			x												
153			x					x						x	x					x	x	x	x	x	x	x										
154			x	x	x	x													x	x					x	x	x	x		x						
157				x					x															x		x										
160							x	x	x			x							x		x	x	x	x												
161	x		x	x															x	x		x	x	x		x										
162	x			x	x										x	x			x	x		x		x	x	x		x								
163						x			x			x													x	x										
167		x	x	x	x														x	x					x	x	x			x						
168	x			x	x	x	x								x				x	x	x			x	x	x	x									
169						x			x	x		x									x	x		x				x		x						

Dam Number	Number of amphibian species recorded each year						
	2008	2009	2010	2011	2012	2013	Mean per dam
D1	7	2	6	7	5	6	**5.50**
D3	3	4	3	3	3	4	**3.33**
D4	4	4	3	3	7	5	**4.33**
D5	4	3	3	5	2	4	**3.50**
D6	4	4	4	5	2	4	**3.83**
D7	5	3	2	6	3	5	**4.00**
D11	7	4	4	2	4	6	**4.50**
D13	5	3	6	6	4	3	**4.50**
D15	6	5	2	2	2	5	**3.67**
D16	4	2	5	2	4	NA	**2.83**
D18	5	4	3	5	5	2	**4.00**
D19	1	3	2	1	1	3	**1.83**
D20	6	2	5	3	3	4	**3.83**
D21	6	4	5	4	4	3	**4.33**
D22	5	3	5	3	2	2	**3.33**
D23	4	4	7	2	3	4	**4.00**
D25	6	4	6	7	3	3	**4.83**
D26	4	2	2	3	4	2	**2.83**
D27	6	3	7	4	5	5	**5.00**
D28	4	1	5	5	4	4	**3.83**
D32	5	2	5	3	5	5	**4.17**
D35	3	1	5	3	3	5	**3.33**
D38	6	1	5	4	4	3	**3.83**
D39	4	3	NA	NA	4	3	**2.33**
D40	7	6	6	7	2	6	**5.67**
D41	4	6	5	4	4	6	**4.83**
D42	5	3	4	4	1	5	**3.67**
D45	7	4	NA	NA	4	6	**3.50**
D46	5	2	NA	NA	3	3	**2.17**
D47	0	0	2	3	4	5	**2.33**
D48	6	2	6	3	1	3	**3.50**
D51	3	2	4	2	3	1	**2.50**
D53	3	3	2	3	1	8	**3.33**
D54	5	2	5	3	2	4	**3.50**
D57	2	1	4	3	3	6	**3.17**
D58	2	1	3	5	3	4	**3.00**
D61	4	3	7	5	3	3	**4.17**
D62	3	5	3	2	1	4	**3.00**
D85	2	1	2	3	5	4	**2.83**
D87	NA	NA	NA	0	0	4	**0.67**
D91	1	0	1	1	1	6	**1.67**
D92	4	5	4	2	2	6	**3.83**
D112	3	4	8	5	NA	2	**3.67**
D122	4	2	5	4	1	NA	**2.67**
D123	1	1	3	2	1	4	**2.00**
D125	5	0	7	6	4	2	**4.00**
D126	4	2	7	4	2	6	**4.17**

Dam Number	Number of amphibian species recorded each year						
	2008	2009	2010	2011	2012	2013	Mean per dam
D129	3	2	6	6	2	4	**3.83**
D130	2	3	2	2	3	5	**2.83**
D131	NA	NA	NA	NA	3	4	**1.17**
D142	2	1	2	2	2	3	**2.00**
D144	3	6	2	2	3	3	**3.17**
D148	3	3	2	3	4	3	**3.00**
D149	1	2	2	5	1	6	**2.83**
D151	4	3	4	3	4	7	**4.17**
D152	5	4	3	5	4	7	**4.67**
D153	4	4	5	5	5	5	**4.67**
D154	5	4	3	6	2	6	**4.33**
D157	1	2	1	2	1	3	**1.67**
D160	5	3	6	5	4	4	**4.50**
D161	6	2	6	6	5	5	**5.00**
D162	5	2	6	7	4	5	**4.83**
D163	2	2	3	2	0	5	**2.33**
D167	4	3	2	3	2	2	**2.67**
D168	5	2	5	2	4	3	**3.50**
D169	0	0	4	6	0	4	**2.33**
Mean per year	**3.85**	**2.64**	**3.82**	**3.50**	**2.88**	**4.12**	**3.47**

APPENDIX 4. BIRD SPECIES ABUNDANCE AT TARGET DAMS

Scientific Name	Common Name	Dam No. 7						Dam No. 14						Dam No. 16						Dam No. 28					
		2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013
Anhinga novaehollandiae	Australasian Darter					1	1							1									1	1	1
Tachybaptus novaehollandiae	Australasian Grebe				1		1		2		1	2			4		1	1		2	3			2	
Cracticus tibicen	Australian Magpie																								1
Pelecanus conspicillatus	Australian Pelican																				1				
Corvus coronoides	Australian Raven						3																		1
Acrocephalus australis	Australian Reed Warbler				h	1	1														h			1	
Chenonetta jubata	Australian Wood Duck	6				4		6	4		10		10	10	4					26	3	5			
Geopelia humeralis	Bar-shouldered Dove											1						1							
Manorina melanophrys	Bell Miner											10	20						5						
Coracina novaehollandiae	Black-faced Cuckoo-shrike												1												1
Cygnus atratus	Black Swan	1															1					5	1		
Falco berigora	Brown Falcon																								1
Ardea ibis	Cattle Egret																1		1						4
Anas castanea	Chestnut Teal							4	40				2		10			1	10	2				1	
Gallinula tenebrosa	Dusky Moorhen		2	2		1					2	4	1	2	2		1	1		3	2	1	2	1	2
Platycercus eximius	Eastern Rosella						2																		
Parrot Hybrid	Eastern Rosella/Mallee Ringneck												2												
Acanthorhynchus tenuirostris	Eastern Spinebill						1																		
Eopsaltria australis	Eastern Yellow Robin											1	1												

Scientific Name	Common Name	Dam No. 7						Dam No. 14						Dam No. 16						Dam No. 28					
		2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013
Fulica atra	Eurasian Coot	4	1	2	8	11	3						1		2					2	1			1	4
Pachycephala pectoralis	Golden Whistler												1												
Phalacrocorax carbo	Great Cormorant			1									1												
Rhipidura albiscapa	Grey Fantail						2						1						2						1
Anas gracilis	Grey Teal								60						6					5					
Aythya australis	Hardhead														1			1	4	3					1
Dacelo novaeguineae	Laughing Kookaburra												1						1						1
Myiagra rubecula	Leaden Flycatcher												1												
Meliphaga lewinii	Lewin's Honeyeater																	1							
Phalacrocorax sulcirostris	Little Black Cormorant	4	2	2	3	3	2						1						2	2	3	2	3		
Phalacrocorax melanoleucos	Little Pied Cormorant		1		2	1	1														1				
Vanellus miles	Masked Lapwing		1			1	1						1	2											2
Nycticorax caledonicus	Nankeen Night Heron						2											1			1			1	
Oriolus sagittatus	Olive-backed Oriole						1					1													
Anas superciliosa	Pacific Black Duck	1	4					1	72		1	6		5	5			3		2	10		10		
Phalacrocorax varius	Pied Cormorant												1	1											1
Porphyrio porphyrio	Purple Swamphen	2	10	10	2	1							8				1		6	2	2	2			7
Rhipidura rufifrons	Rufous Fantail											2													
Todiramphus sanctus	Sacred Kingfisher	1		1					1	1	h	1				1						h			
Malurus cyaneus	Superb Fairy-wren						1											2	1					1	
Circus approximans	Swamp Harrier	2												1											
Hirundo neoxena	Welcome Swallow						1					8						2							
Haliastur sphenurus	Whistling Kite			1									2												
Haliaeetus leucogaster	White-bellied Sea-Eagle											1							3						3
Egretta novaehollandiae	White-faced Heron	2	1										1									1			

Scientific Name	Common Name	Dam No. 7						Dam No. 14						Dam No. 16						Dam No. 28					
		2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2012	2013
Rhipidura leucophrys	Willie Wagtail					1						1												1	
Lichenostomus chrysops	Yellow-faced Honeyeater											1													8
Zosterops lateralis	Silvereye												1												
Total individuals recorded on each dam		23	22	19	16	25	24	11	179	1	14	39	60	22	34	1	5	14	36	49	27	16	17	10	40
No. of species recorded on each dam		9	8	7	6	10	16	3	6	1	5	13	21	7	8	1	5	10	11	10	11	7	5	9	18

h=heard

APPENDIX 5: CONTRIBUTIONS AND QUALIFICATIONS OF KLEINFELDER STAFF

Name	Qualification	Title	Contribution
David Russell	B.Sc. (Biology/Geography)	Ecologist	Data analysis and report writing
Daniel O'Brien	B. Env. Sc. & Mgt. (Biol.). (Hons)	Ecologist	Amphibian survey
Thomas Garnham	B.Env.Sc.&M. (Hon)	Ecologist	Amphibian survey
Samara Schulz	B. Sc. (Biology)	Ecoliogist	M. triglochinoides survey
Aaron Mulcahy	B. Sc. (Biology)	Ecologist	M. triglochinoides survey
Shawn Capararo	B. Nat. Res. (Hons)	Ecologist	Blue-billed Duck/bird surveys
Gayle Joyce	B. Sc (Forestry) (Hons)	GIS Officer	Map preparation

APPENDIX 6. LICENSING

Kleinfelder employees involved in the current study are licensed or approved under the *National Parks and Wildlife Act 1974* (License Number: SL100730, Expiry: 31st March 2014) 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.