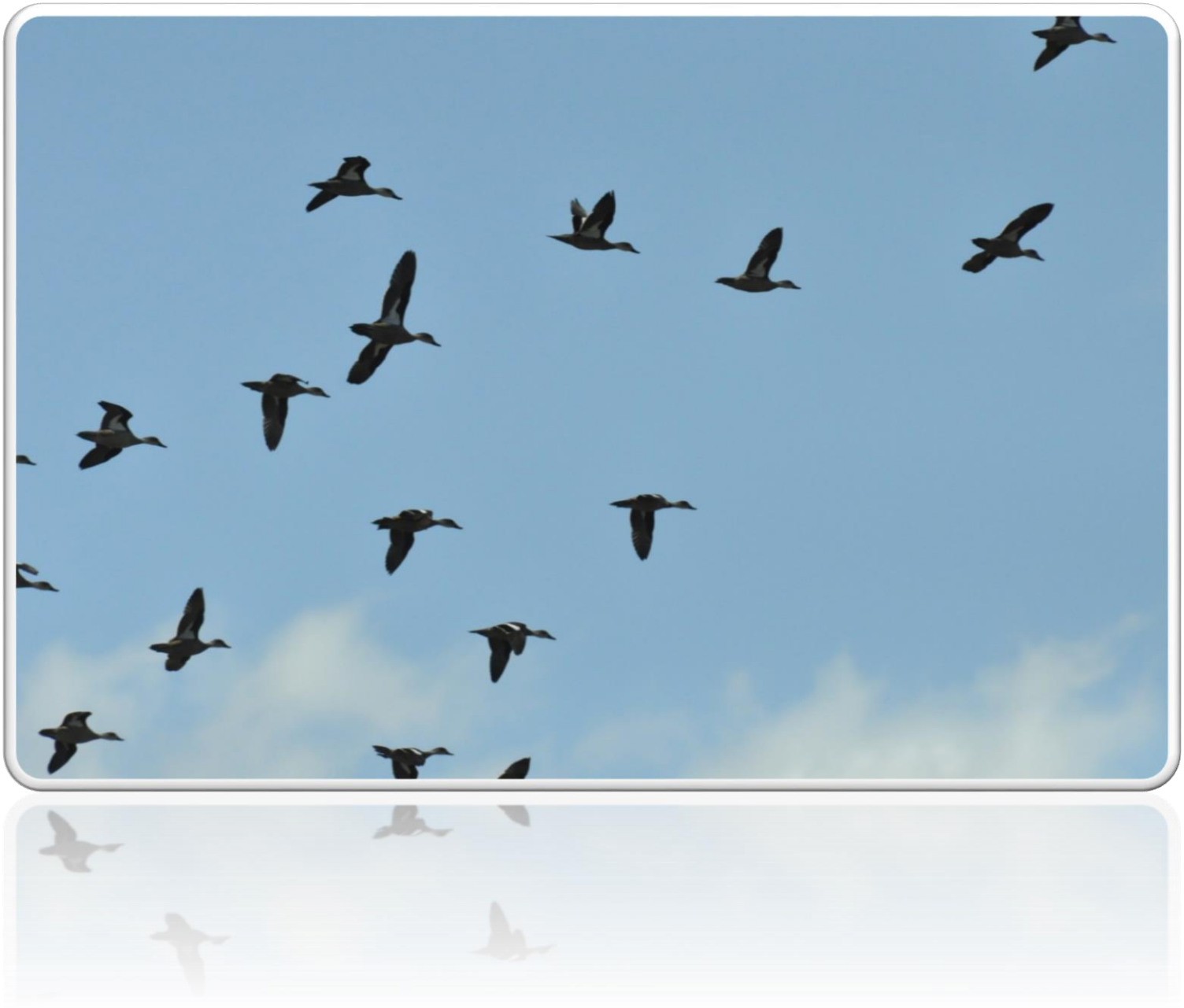

Forestry Corporation NSW

Koondrook-Perricoota Monitoring Project

Waterbird Monitoring 2016

August 2017

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1. Introduction

1.1 Flood Enhancement Project

It is generally accepted that the condition and ecological health of the Koondrook-Perricoota Forest (and other red-gum forests along the River Murray) have declined over a long period in response to gradual drying caused by increasing human demand for freshwater along the Murray River system. Regulation of the Murray River since European settlement has led to a reduction in the frequency, duration and extent of flows that reach the forest. A common aim for many stakeholders now is to try to restore the ecological function of the river and its forests.

Flood enhancement works were undertaken by the Forestry Corporation of New South Wales (FCNSW) in 2011-13 to allow for the artificial hydrological management of Koondrook-Perricoota Forest. The purpose of this was to improve the condition of the vegetation and other ecosystem components. This work formed part of an ongoing condition-monitoring program aimed at providing long-term indication of the condition of the forest, and forms part of The Living Murray (TLM) Program.

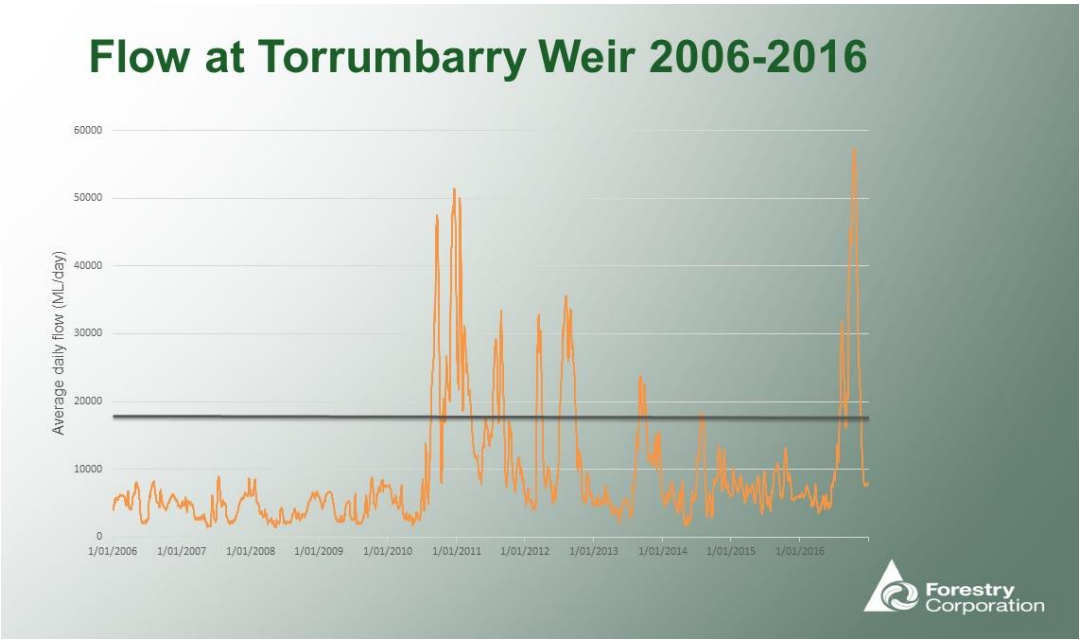
The inaugural delivery of managed floodwaters to Koondrook-Perricoota Forest occurred in July 2014. A second managed flood through the forest was planned for late 2015 but was not undertaken. However, e-water was used to fill and flood the Pollack, which is contiguous with the Koondrook-Perricoota Forest area, but lies north-west of the Barham-Deniliquin Road, at the far downstream end of the forest, and is not expected to be flooded with the Flood Management Project.

In 2016, no managed floodwater was delivered to the Koondrook-Perricoota Forest area. However, due to above-average rainfall across much of south-eastern Australia, Murray River flows during 2016 were sufficiently high and sustained to result in a large overbank event through Koondrook-Perricoota Forest. Hydrographic indicators suggest that the 2016 flood was the largest through the forest since 1993.

1.2 2016 overbank flood

The graph of Murray River flow at the Torrumbarry Weir between 2006 and 2016 is shown in Graph 1. This shows clearly the substantially higher flow in 2016 than in previous years.

During the 2016 flood, water entered the forest at various locations throughout August, then again in September until mid-November, peaking at more than 55,000 ML/day. For comparison, the water delivered to the Pollack in 2015 peaked at just under 30 ML/day. The satellite image of the forested area (dark green) in October 2016 at the peak of the flood is shown in Figure 1.



Graph 1 Murray River flow at Torrumbarry Weir from 2006-2016 (courtesy of FCNSW)

Figure 1 Satellite image of the flood extent through the Gunbower-Koondrook-Perricoota system in October 2016 (courtesy of FCNSW)

1.3 Waterbird monitoring – history and purpose

FCNSW's monitoring program for the Koondrook-Perricoota Forest includes as a core component the monitoring of waterbird responses to flood events. GHD conducted initial monitoring of waterbirds in response to the inaugural flood event in the latter half of 2014 (GHD 2015). Following on from 2014, the 2015 flood at the Pollack was monitored using similar methods. That is, aerial survey following longitudinal transects, then aerial survey of individual waterholes to allow closer inspection of waterbird hotspots, then a brief on-ground follow-up survey (this step was not done in 2014) to obtain more detail of nesting and waterbird use of the site/s. Prior to the 2014 monitoring, the Gunbower-Koondrook-Perricoota Icon site was included in the annual aerial surveys of Murray River sites by Kingsford *et al.* (2013). A summary of monitoring history is presented in Table 1.

Table 1 Summary of monitoring effort for waterbirds in Koondrook-Perricoota in recent years

Date/event	Monitoring	Purpose
2007-2012	Broadscale aerial survey that included Gunbower-Koondrook-Perricoota (Kingsford et al. 2013)	Annual monitoring of Icon sites as part of the Living Murray program.
2014 – Koondrook-Perricoota Forest	Aerial survey (GHD) (3 transects)	Targeted waterbird surveys as part of the condition monitoring in response to delivery of e-water.
2015 – The Pollack	Aerial survey (GHD) (5 transects, northern sections only) On-ground survey (GHD) On-ground Survey (D Hutton)	Targeted waterbird surveys as part of the condition monitoring in response to delivery of e-water.
2016 –– Koondrook-Perricoota Forest	Aerial survey (GHD) (5 transects) On-ground Survey (D Hutton) (The Pollack only)	Targeted waterbird surveys as part of the condition monitoring in response to delivery of e-water.

For waterbirds, the relevant outcome stated as part of the Icon Site Objective for the Gunbower-Koondrook-Perricoota forest (MDBA 2012) (and note that this includes the Victorian Gunbower section) is:

"successful breeding of thousands of colonial waterbirds at least three years in ten".

This objective was not reached for either 2014 or 2015. In response to the small flood in 2014, there were numerous sightings of ducks in pairs or small groups, but no demonstrated presence of colonial nesting birds (ibis, cormorants, herons, egrets). In 2015, colonial nesting birds (as well as the ducks) bred in small numbers at the Pollack, in response to the arrival and duration of the water. The Pollack is anecdotally one of the 'major waterbird sites', and has historically been reported to attract large numbers of breeding waterbirds when conditions are suitable. Thus, the results of the 2015 monitoring provided important context on waterbird responses to localised flooding in the area.

2. Methods

2.1 Approach

The survey methods used in 2014 and 2015 successfully achieved the aim of the monitoring in those years. Accordingly, similar methods were used for the 2016 monitoring, with minor changes in accordance with learnings and recommendations stemming from the previous monitoring years.

The 2016 monitoring involved a broadscale (aerial) survey to determine which locations were attracting the most waterbirds at a landscape level. In 2015, on-ground follow-up surveys were then done to document more information on how many birds were present, what they were doing (e.g., breeding, foraging). On-ground assessments were not undertaken by GHD in 2016, but were done intensively at the Pollack by Dan Hutton for FCNSW.

A site visit to the forest during the peak flood was undertaken in November 2016 as part of the monitoring for frogs. Waterbird observations were made opportunistically at this time.

2.2 Aerial surveys

Aerial surveys for waterbirds have been conducted along the Murray River forests for many years (e.g., Bino *et al.* 2014, Kingsford *et al.* 2013), and have been considered the established method for such assessments. On 29 and 30 November 2016, GHD conducted an aerial survey for waterbirds along the entire length of the Koondrook-Perricoota forest.

The timing of this survey was approximately two months after the commencement of water entering the forest (overbank), and was a compromise between: 1) allowing sufficient time for the water to provide potential breeding opportunities; 2) allowing sufficient time for birds to be attracted to the flooded area and to commence breeding, if conditions were suitable; and 3) obtaining a measurement of the waterbird response before waters receded and the birds' breeding efforts were completed or abandoned.

The survey was conducted in two parts: 1) assessing waterbirds along pre-determined transect lines; and 2) closer assessment of the waterbird 'hotspots' (mainly the Pollack and some of the larger waterholes towards the northern end of the forest). These are explained in more detail below.

A helicopter was used for the aerial survey, as in 2014 and 2015. A helicopter was more suitable for directional, elevation and speed changes in response to waterbird or habitat sightings. Two ecologists flew in the helicopter, one on each side. Each ecologist had a hand-held GPS and a digital voice recorder to record where birds were seen (including bearing and distance from waypoints made along the route, if required), which species were seen (identified to species as much as possible), and how many birds were seen (counted to the nearest individual in most cases, given that flock sizes were generally small). Binoculars were not used due to aircraft vibrations and limited time during and between sightings. Results were spoken into a voice recorder (digital) during the survey. This was preferable to keeping a written record of the observations because it meant that the observers could keep their eyes on birds and potential habitat at all times. Communication between the two ecologists and the pilot during the survey reduced the incidence of double-counting (e.g., of birds that flew from one side to the other, and were thus seen by both observers).

Sound files were downloaded to a computer in the office, and listened to in real time. A spreadsheet was used to tally the numbers of birds and species by location. Results were mapped to gain a visual representation of waterbird use of the forest relative to the flood extent at the time.

2.2.1 Transects

Surveys were conducted along five parallel transects that represented reasonable coverage of the length and width of the area to be assessed (Figure 2). Transects were approximately 1 km apart, thus the five transect lines covered a forest width of approximately 4 km. The numbers of transects used in 2015 and 2016 was amended from 2014, where surveys were conducted along three parallel transects, 2 km apart. Transects 1, 3 and 5 in 2015 and 2016 matched the three transects used in 2014. Each transect was approximately 54 km long (total = ~273 km for all transects combined). Transect line coordinates (start and end points) were determined on a map prior to the flight, in an effort to gain an objective overview of waterbird abundance using the entire flooded area of forest and its surrounds, regardless of habitat characteristics and appeal to waterbirds (i.e., transect lines were not chosen because lots of waterbirds were expected to be seen there). The aim was for transect effort to be standardised, quantifiable and repeatable, which is important for year-to-year comparisons.

Along the transects, the helicopter was flown at a consistent speed (35 knots typically, but slowing to 20 – 30 knots in the vicinity of waterbird activity to allow counting, and up to 51 knots where tailwinds forced up the aircraft speed for safety) and altitude (~150 m ASL; = 50 m above ground level, and 15 m above typical canopy height). Flying time along transects took approximately eight hours over two days (five hours on November 29; three hours on November 30).

In addition to the five transects above Koondrook-Perricoota Forest, and as was done in 2015, a 10 km transect was flown over the Gunbower Forest, on the Victorian side of the Murray River, opposite Koondrook-Perricoota Forest. This was done in an effort to provide some regional context; the Gunbower Forest has received environmental watering almost annually for the last ten years or so, so may differ from the Koondrook-Perricoota system in the way it attracts waterbirds. As with the five standard transects, transect line coordinates for Gunbower (start and end points) were determined on a map prior to the flight.

All identifiable waterbirds seen from the helicopter were recorded. Most observations were of birds in the immediate vicinity of the aircraft (up to 100 m from the flight path). It is acknowledged that there is likely to be an inherent bias in some observations, particularly distant observations. Conspicuous species (e.g., pelicans or any of the white egrets and spoonbills) are more likely to be seen than cryptic species (e.g., Grey Teal), and species that are more easily disturbed (i.e., readily take flight) are more likely to be seen than species that remain motionless.

2.2.2 Detailed observations at the Pollack and other northern waterholes

After completing the transects, the focus of the aerial survey shifted to the Pollack and some of the other northern waterholes in the forest, in an effort to get better counts of species and individuals at the waterholes.

A central GPS waypoint (pre-determined prior to flying) was used to fly directly to waterholes, then as far as possible, a perimeter transect was flown (i.e., fly around the perimeter of the waterbody) in accordance with Robinson (2012).

As was done for transects, all identifiable waterbirds seen from the helicopter were recorded, including species, counts of adults, juveniles and chicks, evidence of breeding, evidence of foraging, and counts of nests seen, if any.

This form of assessment is relatively freeform, so is less standardised and quantifiable than the transect assessments, and less repeatable and comparable to future effort. However, it results in higher counts of birds, and allows a more detailed evaluation of waterbird activity. Thus, the combination of both methods is considered important.

2.3 On-ground assessments

On-ground assessment of waterholes was not done following the aerial survey in 2016 by GHD, but was conducted on a weekly basis between November 2016 and February 2017 at the Pollack by Dan Hutton (for FCNSW). Results from those on-ground assessments provide important complementary information, but do not form part of this report.

In October/November 2016, at the peak of the flood, an extensive on-ground visit was made by GHD over four days, as part of the monitoring work for frogs. Using a motor boat, canoe, walking and an amphibious vehicle (Argo), 20 Songmeter sites were visited, which effectively covered much of the forested area while it was flooded (particularly the northern area and the southern area, and along the main Murray River channel). During that site visit, observations of waterbirds were noted opportunistically, but rigorous methods were not applied to waterbird observations.

2.4 Which waterbirds were monitored?

All species of waterbird observed during the survey were recorded.

Results are reported for individual species, and for waterbird functional groups, in accordance with the long-term Murray-Darling Basin waterbird monitoring results reported by Kingsford *et al.* (2013). There are five functional groups for waterbirds: ducks and grebes (Du), herbivores (He), large wading birds (La), piscivores (Pi), and shorebirds (Sh).

Waterbird species vary in their detectability, ease of identification, abundance, behaviour and habitat use. Some species are generally rare, nocturnal, silent and secretive (e.g., Australasian Bittern), while others are common, conspicuous and diurnal (e.g., White-faced Heron).

3. Results and discussion

3.1 Species richness, functional groups and relative abundance

3.1.1 Aerial survey

In total, 1193 individual waterbirds were recorded during the aerial transects (excluding Gunbower) component of the assessment, and 598 waterbirds were recorded during the closer investigations of waterholes. In total, 50 waterbirds were recorded during the 10-km Gunbower transect (Table 2).

In total, 15 waterbird species were recorded from the air. Fourteen species were recorded while conducting the transects over Koondrook-Perricoota (Table 2), eight were recorded during the closer waterbody assessments (Table 2), and ten were recorded while conducting the Gunbower transect (Table 2). All of the species observed during the aerial survey fall into four of the five functional group categories: ducks and grebes (Du), large wading birds (La), piscivores (Pi) and herbivores (He). No species of shorebirds (Sh) were detected from the helicopter.

Ducks and grebes (Du) were the most numerous waterbird functional group during the aerial assessment (1036 observations; 56.3% of all aerial observations; Table 4), and Grey Teal was easily the most common of the four Du species seen, and of all species (816 individuals; approximately one-half of all birds seen) (Table 2). No grebes were observed from the air, but this is probably because they are very small and difficult to see from an aircraft.

Large wading birds (La) were seen consistently along transects and they were the most numerous group during the more intensive waterhole searches. Large wading birds (796 counted) accounted for 43.3% of aerial observations (Table 4). Straw-necked Ibis were the most commonly reported large wading birds during the transects (233 individuals recorded), but Nankeen Night-Herons were the most commonly reported large wading birds during the waterhole searches (358 individuals recorded). Interestingly, only one Nankeen Night-Heron was seen during the aerial transects, which does not match the numbers that were present in the forest (mainly at the Pollack) at the time. Seven species of La were observed from the air. Some white wading birds could not be identified to species from the helicopter, so were recorded as ‘egrets/spoonbills’, but were added to the species total as one species, not two.

Piscivores (Pi) and herbivores (He) were the least common of the functional groups detected from the air, with only four individuals across two species of Pi (0.2 % of the total observations) and five individuals across two species of He (0.3 % of the total observations) (Table 4).

The proportions of waterbird observations in the different functional groups in 2016 strongly resemble those from the aerial assessment in 2015 and 2014, and have some similarity to those reported by Kingsford *et al.* (2013) for long-term monitoring of wetlands across the Murray-Darling Basin. Patterns of similarity between Kingsford *et al.* (2013) and the 2014 results were discussed in GHD (2015). The major differences were:

i) That Kingsford reported almost a quarter (22.9%) of waterbirds (by abundance) being herbivores (He), yet no herbivores were observed in 2014 or 2015. In 2016, two species of Herbivores were observed during the aerial survey, but the numbers of individuals observed (5) was very low, and far lower than the ~150 mean abundance reported by Kingsford *et al.* (2013).

ii) That Kingsford reported almost a quarter (24.7%) of waterbirds being piscivores, yet only 6.7% of 2014 observations and 4.8% of 2015 observations were of piscivores. In 2016 again, very few piscivores were observed.

iii) That Kingsford reported only 35.8% of waterbirds were ducks and grebes, yet 77.7% of 2014 observations and 66.1% of 2015 observations were of species in that functional group. In 2016, the proportional abundance of Du was 56.2%, lower than in 2014 and 2015. This proportional value was reduced not by smaller numbers of Du being observed (indeed, more were observed in 2016 than either 2014 or 2015), but by the observation of much larger numbers of Large Wading Birds (La).

Shorebirds (Sh) were not reported in 2014 or at Gunbower-Koondrook-Perricoota in any of the six years of Kingsford's survey (2007-2012), but were reported in 2015. Shorebirds were not reported during the 2016 aerial survey.

Table 2 Summary of transect and waterhole results of 2016 aerial surveys. Data do not include on-ground monitoring results. Species are grouped into functional groups

Functional group / Species	T'sect 1	T'sect 2	T'sect 3	T'sect 4	T'sect 5	All KP transects	Gunbower transect	Waterhole assessment
Duck and grebes (Du)								
Teal sp. (mostly Grey)	74	88	169	127	227	685	20	111
Pacific Black Duck	13	17	3	25	42	100	5	
Australian Wood Duck	3	38	17	28	17	103	1	3
Australian Shelduck					4	4	3	
Large wading birds (La)								
White-faced Heron	6	4	9	7	4	30	4	19
White-necked Heron	4	8	5	5	4	26		38
Nankeen Night-Heron		1				1	4	358
Egrets / Spoonbills		1			3	4	4	5
Straw-necked Ibis	24	132	42	21	10	228	5	63
Australian White Ibis	1	2	1			4	3	
Piscivores (Pi)								
Australian Darter	1					1		
Great Cormorant			1			1	1	1
Herbivores (He)								
Eurasian Coot	3					3		
Black Swan	2					2		
total bird count	131	291*	246	213	311	1192*	50	598
total bird Sp. richness	10	9	8	6	8	14	10	8

* Excludes one unidentified duck

Table 3 Results of 2016 targeted aerial assessments of waterholes

	Waterbody / Functional Group	The Rookery	Long Lagoon	The Pollack	Waterhole Trail	Other (flooded grasslands)
Abundance	DU	8	36	0	0	70
	LA	13	9	396	1	64
	PI	0	0	0	0	1
	HE	0	0	0	0	0
	SH	0	0	0	0	0
	total	**21**	**45**	**396**	**1**	**135**
Richness	DU	2	2	0	0	1
	LA	4	3	4	1	3
	PI	0	0	0	0	1
	HE	0	0	0	0	0
	SH	0	0	0	0	0
	Total (8 spp.)	**6**	**5**	**4**	**1**	**5**

Table 4 Waterbird results for this assessment (right columns; excluding on-ground), previous recent assessments (GHD 2014 and GHD 2015) and for Gunbower-Koondrook-Perricoota reported by Kingsford *et al.* (2013) Table 38 p144 for the period 2007-2012 (left columns)

	Kingsford (2007-2012)			GHD 2014			GHD 2015			GHD 2016		
Functional group	No. of species	Mean abundance	% abundance	No. of species	Abundance	% abundance	No. of species	Abundance	% abundance	No. of species	Abundance	% abundance
Ducks and grebes (Du)	3	236.08	35.8	4	762	77.7	4	470	66.1	4	1036	56.3
Large wading birds (La)	6	113.69	17.2	7	152	15.6	8	203	28.6	7	796	43.3
Piscivores (Pi)	6	158.84	24.1	5	66	6.7	5	34	4.8	2	4	0.2
Herbivores (He)	3	150.63	22.9	0	0	0	0	0	0	2	5	0.3
Shorebirds (Sh)	0	0	0	0	0	0	2	4	0.6	0	0	0
Total	**18**	**659.25**	**100.0**	**16**	**980**	**100.0**	**19**	**711**	**100**	**15**	**1841**	**100**

3.1.1 On-ground observations (during frog site visit)

In total, 315 waterbirds of 17 species were recorded across 23 sites during the site visit in October/November for frogs and tadpoles (Table 5). All five functional group categories were represented during the observations.

Ducks and grebes (Du) and Large Wading Birds (La) were the most numerous waterbird functional groups and were observed in nearly equal numbers (162 Du and 148 La observations, which were 51.4% and 47.0% of all on-ground observations respectively). Grey Teal and Nankeen Night-Heron were the most commonly recorded species (115 and 84 individuals respectively; ~84% of all birds seen on-ground) (Table 5).

Seventeen species were observed during the on-ground surveys, which is one more than were observed during the aerial surveys. Three waterbird species recorded during the on-ground survey were not recorded during the aerial survey: Chestnut Teal (Du), Dusky Moorhen (Du) and Black-fronted Dotterel (Sh). The Chestnut Teal may have been seen from the air, but due to identification difficulties was grouped with the very similar Grey Teal. The on-ground results of 115 Grey Teal to 2 Chestnut Teal suggests that nearly all of the teal observed from the air were likely to have been Grey Teal.

Piscivores (Pi) Shorebirds (Sh) and Herbivores (He) were detected in very small numbers (3, 1, 1 individuals respectively) (Table 5).

Table 5 Waterbird observations made opportunistically during the 4-day on-ground site visit for frogs in October/November 2016

Species	Count	# locations
Du		
Grey Teal	115	8
Chestnut Teal	2	1
Pacific Black Duck	21	4
Australian Wood Duck	8	3
Australian Shelduck	13	3
Dusky Moorhen	3	2
La		
White-faced Heron	4	4
White-necked Heron	27	4
Nankeen Night Heron	84	6
Great Egret	3	2
Straw-necked Ibis	15	2
Australian White Ibis	15	2
Pi		
Australasian Darter	1	1
Great Cormorant	1	1
Little Pied Cormorant	1	1
He		
Eurasian Coot	1	1
Sh		
Black-fronted Dotterel	1	1
Grand Total	**315**	**23**

3.2 Waterbird distribution

Unlike in 2014 and 2015, large numbers of waterbirds were observed along the Koondrook-Perricoota aerial transects. The largest number of birds observed along a single transect was 311 birds (Transect 5), but >200 birds were seen along four of the five transects, and the fifth had 131, which was more birds than any transect in 2015. These larger numbers (compared with previous years) may reflect the flooded condition of the Koondrook-Perricoota Forest, and the large and widespread nature of areas that held water, and were attracting waterbirds, at the time of the survey. The larger numbers may reflect breeding success in and around Koondrook-Perricoota in previous years, and/or new birds moving in to the local area from elsewhere.

Figures 2 to 9 present, in a range of ways, the distribution and relative abundance of waterbirds observed in 2016. These maps show that birds were observed consistently along all transects and along the full length of the transects, but in higher numbers and with a denser distribution in the central and northern parts of the forest. This reflects where the water was at the time of survey; water in the upstream (southern) end of the forest had begun to recede by the time of the survey, while the central to northern areas were still in full inundation.

Ducks (Du) were commonly seen in small to large groups (2 – 67 bird category) throughout the forest. This matches the results from previous years of aerial survey. Most of the Du observations were of Grey Teal. There were two notable observations of ducks in larger groups: 100 Grey Teal in a large borrow pit at the north-eastern edge of the forest, and 200 Grey Teal and 30 Australian Shelduck sharing a large waterbody well north of the Pollack.

Large wading birds (La) were also commonly seen, but were not as ubiquitous as ducks, nor as numerous. Most records of La were of individuals and smaller groups (2 – 5 bird category). There were three notable sightings of larger numbers of La, mostly at the edge of the forest or in the surrounding agricultural land: 15 Straw-necked Ibis at a point south of Moorings Lagoon, 67 Straw-necked Ibis in a flooded paddock beyond the northern end of the forest, and 14 La (10 Straw-necked Ibis, two Australian White Ibis, two White-necked Heron) along Barbers Creek within the forest boundary.

There were only three widely separated observations of piscivores (pi) from the air.

Closer inspection of the northern waterholes (see Table 3), where the water was newest, deepest and most widespread at the time of survey, showed that the aerial transect results did not accurately reflect the patterns of bird numbers and activity. Closer inspection of waterholes showed that, as in 2015, the Pollack was the focal area for waterbirds, with nearly 400 Large Wading Birds (mostly Nankeen Night-Herons) counted. Note that only one Nankeen Night-Heron was counted during the aerial transects over Koondrook-Perricoota. It is acknowledged that the waterbody counts should be considered indicative, not absolute, because the flight path around those waterholes was circular and free-form and the birds' movements as they fled from the helicopter were very dynamic, making assessment of which birds had or hadn't been counted nearly impossible. On-ground observations at the Pollack by Dan Hutton (for FCNSW) during the course of the 2016 flood suggested that more than 400 pairs of Nankeen Night-Herons (and other species) had amassed to breed at the Pollack by about that time.

3.3 Evidence of waterbird breeding

3.3.1 As seen from the air

Other than Large Wading Birds (La) amassing at the Pollack, no direct signs of waterbird breeding (e.g., nests or chicks) were noted from the air. This was surprising, but probably explained by the speed of the aircraft, which was relatively fast when passing over small nests hidden beneath the canopy. Kingsford *et al.* (2013) also reported no breeding records at Gunbower-Koondrook-Perricoota for any of the 2007-2012 surveys.

3.3.2 On-ground observations (during frog site visit)

On-ground assessment during the October/November 2016 frog site visit showed that multiple species of waterbirds were using the flood water in various parts of the forest for the purposes of breeding (Table 6).

Eight of the nine observations were of species in the Ducks and Grebes (Du) functional group, and the other was of Nankeen Night-Heron, which is in the Large Wading Bird (La) group.

These observations were made while conducting a different activity (frog and tadpole sampling) and the numbers greatly underestimate the numbers of waterbirds that bred in the Koondrook-Perricoota forest. However, these observations do not include observations of birds at the Pollack, so they provide an indication of the waterbird breeding activity through the remainder of the forest during the peak of the flood.

Table 6 Observations of evidence of waterbird breeding made during the 4-day on-ground site visit for frogs (Oct/Nov 2016)

Bird species	# chicks	Notes
Nankeen Night-Heron (La)	2 juv	Young birds seen
Australian Shelduck (Du)	7	Pair plus 7 large, feathered ducklings in borrow pit
Pacific Black Duck (Du)	10	Pair plus 10 ducklings, fluffy, swimming
Grey Teal (Du)	10	Pair with 10 ducklings
	9	3 pairs with small broods, seen separately but nearby, one adult with anti-predator broken-wing display
	35	5 pairs with ducklings
	20	3 adults and 20 ducklings, half grown, not fluffy, not flying
	4	1 adult with brood of 4
	2	Pair with 2 ducklings, and adult with broken-wing display

3.3.1 On-ground observations by Dan Hutton

The Pollack was clearly the epicenter of waterbird activity and breeding during the 2016 flood, and the response there by waterbirds was exciting. Observations made at the Pollack by Dan Hutton (for FCNSW) for the duration of the flood event showed clearly that relatively large numbers of colonial waterbird species successfully bred to fledging at the Pollack in response to the 2016 flood. Ultimately, the numbers of pairs that reportedly bred at the Pollack were high enough to be counted in the thousands.

3.4 Discussion of results

3.4.1 How do these observations fit with historical waterbird observations at Koondrook-Perricoota?

Almost all breeding activity by colonial-nesting species in 2016 was at the Pollack. Ducks were the main group to breed in other parts of Koondrook-Perricoota Forest. This corresponds closely to historical accounts of waterbirds locally.

Disher (2000) presents historical information on breeding events between 1930 and 1999 for most of the waterbird species in the broader Koondrook-Perricoota Forest area. Breeding information provided for ducks is scarcer than it is for other species for which breeding is more notable (e.g., less common species or colonially-nesting species).

From the species' accounts that Disher provides, the favoured breeding locations across the region become apparent, and include: Kerang Lakes, Tullakool Evaporation Basins, Gunbower Island, Guttrum, Lake Tutchewop, the 'Kanowna' property, and the Pollack. Table 7 presents a comparison of historical reports of waterbirds breeding at the Pollack (Disher 2000) with observations made by Hutton and GHD as part of this 2016 monitoring.

Table 7 Comparison of historical (Disher 2000) and 2016 (Hutton/GHD) observations of waterbirds breeding at the Pollack

Species	Historical information (Disher 2000)	2016 observations (Hutton/GHD)	Significance of 2016 observation
Nankeen Night Heron	nesting colony, 75-100 nests; 1973-4	nesting colony, 400+ nests	**Far more** than expected
White-necked Heron	20 nests in 1973-4, and 15 in 1981	nesting colony, 150+ nests	**Far more** than expected
White-faced Heron	-	Present and breeding, but numbers unknown. Also bred here in 2015.	Breeding at the Pollack not reported historically
Eastern Great Egret	20 nests in 1984	50+ nests	**More** than expected
Intermediate Egret	150 nests in 1984	30+ nests	Fewer than expected, and ratio of Eastern Great to Intermediate Egrets contrasts with historical record.
Great Cormorant	up to 200 nests in 1964	15+ nests	Fewer than expected?
Pied Cormorant	-	25+ nests	Breeding at the Pollack not reported historically
Little Pied Cormorant	'Large colonies'	30+ nests	Fewer than expected?
Little Black Cormorant	considered common, but numbers not indicated	1 nest	Fewer than expected?
Glossy Ibis	38 nests in 1981	-	As expected? Species breeding at the Pollack may be rare.
Australian White Ibis	up to 1000 nests in Feb 1984	-	Fewer than expected
Royal Spoonbill	10 nests in the early 1950s	-	As expected? Species breeding at the Pollack may be rare.

Species	Historical information (Disher 2000)	2016 observations (Hutton/GHD)	Significance of 2016 observation
Yellow-billed Spoonbill	several nests in Dec 1981	-	As expected? Species breeding at the Pollack may be rare.
Baillon's Crake	several seen in Dec 1981	-	As expected? Secretive species – presence and breeding easily missed.
Eurasian Coot	one nest seen, date unknown	-	As expected. Species breeding at the Pollack may be rare.
Great Crested Grebe	one or two nests, seen in 1960, 1965, 1970	-	As expected. Species breeding at the Pollack may be uncommon.

Disher (2000) makes little specific mention of breeding by White-faced Heron or Pied Cormorant, both of which were reported to breed at the Pollack in 2016. The White-faced Heron also bred there in small numbers in response to delivery of e-water in 2015, which makes it surprising that Disher (2000) makes no mention of this species breeding at the Pollack historically.

Other than the Pollack, Disher (2000) makes very little mention of other waterholes in the Koondrook-Perricoota Forest area, including those that appear to be named as a result of their waterbird breeding history (i.e., The Rookery, IU Rookery). Species noted by Disher at other KP sites include:

Little Pied Cormorant (Long Lagoon and 'Koondrook State Forest')

Little Egret ('Koondrook' 1982)

White-bellied Sea Eagle (Long Lagoon, 1986)

Disher (2000) also reported that Grey Teal were common in the broader area, with flocks of up to 25,000 birds recorded (Feb 1987, Tullakool Evaporation Basins). This information matches the high numbers of this species seen during aerial surveys in 2014, 2015 and 2016.

3.4.2 How do the 2016 observations fit more generally with waterbird responses and distribution at other MDB wetlands?

Kingsford *et al.* (2013) report results for widespread aerial surveys across large areas of south-eastern Australia. As part of that project, results are reported for 2007-2012 surveys at a range of Murray Icon Wetland sites, including Gunbower-Koondrook-Perricoota (GKP).

Compared with the observations for all Murray Icon Wetland sites, Kingsford's 2007-2012 observations of functional groups at GKP show interesting differences. For all functional groups, relatively few species were detected at GKP compared with Murray Icon Wetland sites (Table 8), and the mean abundances recorded at GKP were far smaller than for Murray Icon Wetland sites (Graph 2).

Thus, for all Murray Icon Wetland sites, shorebirds and piscivores were the most common in terms of mean abundance, while piscivores had the highest species richness. Ducks and large wading birds had considerably smaller minimum counts than the other functional groups (2201 and 1258 respectively). It is notable that no shorebirds were reported at GKP, yet these were the most numerous species across the Icon sites generally.

The species recorded most commonly during the KP surveys (2014-2016) generally match those reported by Kingsford *et al*. 2013 as the most common waterbird species across the Murray River catchment. In order of relative abundance, these are Grey Teal, Straw-necked Ibis, Pacific Black Duck and Australian White Ibis. Kingsford *et al*. (2013) found that two species (Grey Teal and Australian Wood Duck) made up approximately half of the waterbird community. Nankeen Night Heron was not one of the top 12 recorded species for the 2007-2012 surveys at KPG.

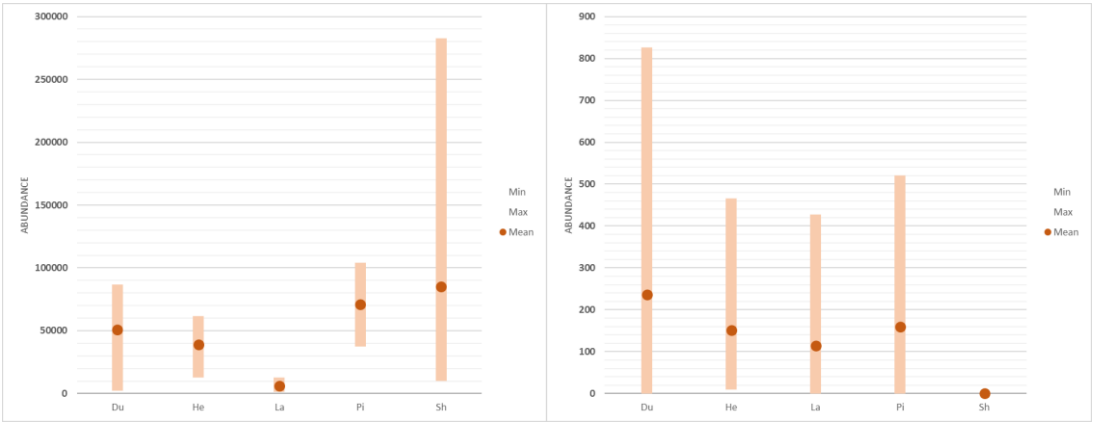
Across the 1983-2012 study, most waterbirds were found on a relatively small number of wetlands. In any given year, about 80% of all birds were recorded from the 20 highest ranking wetlands in that year, and about 60% were recorded from the 10 highest ranking wetlands. This matches the skewed numbers of waterbirds reported at the Pollack during the 2014 – 2016 aerial surveys. Clearly, waterbirds move around to amass at favoured locations rather than simply breeding at the nearest available waterhole.

Kingsford *et al*. 2013 conclude that MDB waterbird abundance over the 30 years of survey was governed by boom and bust periods driven by river flows and local rainfall in the Murray-Darling Basin, which result in large peaks and troughs in wetland area over time. Waterbird abundance reported for KPG between 2007 and 2012 was lowest in the dry year of 2009 (considerably lower that year than in other years) and highest in the wetter years of 2010 and 2011. Three of the four recorded functional guilds reduced to near-zero in 2009; herbivores were different and remained present in higher numbers in that year. All four recorded functional guilds showed a similar increase in abundance with wetter years.

Across the entire MBD, the predictor variables that best explained (i.e., contributed most to) waterbird abundance included 'one-year lagged wetland area of MDB' (i.e., wetland area the year before), and 'total annual flows in the MDB'. For the Murray River catchment, the predictor variables that best explained waterbird abundance included wetland area the year before, and 'one-year lag of total rainfall across the MDB'. Breeding by waterbirds occurred in response to floods. In the year/s following floods, total abundance of waterbirds increased, presumably as young birds join the ranks of independent birds. Thus, waterbird abundance in a given year depends on breeding opportunities and success the previous year. Kingsford *et al*. 2013 conclude that this underlines the importance of large floods in maintaining waterbird populations over time.

Table 8 Numbers of species for each functional group reported by Kingsford *et al*. (2013) for Murray Icon Wetland sites and Gunbower-Koondrook-Perricoota (2007-2012 data), and for 2014-2016 aerial surveys (GHD)

Functional group	No. species (Murray Icon Wetland sites)	No. species (GKP only)	No. species (2014-2016 aerial surveys GHD)
Du	10	3	4
He	11	3	8
La	13	6	5
Pi	15	6	2
Sh	9	0	2



Graph 2 2007-2012 observations for waterbird functional groups for Murray Icon Wetland sites (left) and Gunbower-Koondrook-Perricoota (right). (Data from Kingsford *et al.* 2013)

What does this suggest about waterbirds at KP? Were higher numbers at the Pollack in 2015 and more broadly across KP in 2016 a result of KP flooding the previous year? Not clearly or simply. The dominant species that bred at the Pollack in 2016 (mainly Nankeen Night Heron, but also cormorants and egrets) were all but absent in 2014 and 2015. This suggests that the abundance and richness of waterbirds that visit the Pollack to breed when conditions are favourable are determined by breeding opportunities and success in previous years at other locations.

In some ways, the results of the 2016 overbank flood may not reflect the potential for the infrastructure built by FCNSW to manage e-water in the KP. Birds certainly arrived at KP (particularly the Pollack) to exploit the favourable conditions in 2016, but birds were likely attracted to other areas across the landscape also. If e-water is delivered to KP in otherwise dry years (i.e., when flood water is not available elsewhere), then disproportionately large numbers of waterbirds may arrive to exploit the conditions that water provides. It will be interesting to see if birds perceive the increase in flow through the KP, without flow or rainfall increases elsewhere. That is, will birds recognise the delivery of e-water, or will it go unnoticed? Kingsford suggests that local rainfall is important as it strongly influences the filling of wetland ecosystems. Kingsford does not address the question of separating rainfall and flow from commencement of breeding. Will waterbirds find a site and commence breeding if larger landscape cues (i.e., rainfall, wetland area and flows) are absent?

3.4.3 How do the 2016 observations fit with expected breeding patterns exhibited by the different waterbird species?

Generally, the specifics of breeding in waterbirds in Australia are poorly known. Breeding appears to be highly variable, with different species responding to different cues, including local conditions and those further afield, such as season and food availability. An account of the typical breeding and foraging patterns for the main species observed at KP is provided below (from Marchant and Higgins 1990), along with commentary on KP observations from the 2014 – 2016 monitoring.

Nankeen Night Heron – a freshwater and estuarine species that prefers permanent waterbodies. Opportunistic feeder, usually feeding on fish, but also frogs, crayfish, insects, and will take nearly anything when available (e.g., hatchling sea-turtles, mice, human refuse). This opportunism allows the species to arrive and potentially succeed at any stage of the flood cycle. Nests in dense cover of trees or shrubs in freshwater or saline wetlands. Colonial nesting, in small (<10 nests) to large (up to 3000 nests) colonies. Often in mixed-species colonies.

Widespread breeding locations reported in south-east Australia. The observed breeding by this species, and in dominating numbers, at KP in a non-permanent waterhole (the Pollack) is of note. Whether similarly large colonies were reported elsewhere concurrently is not known.

White-necked Heron – Mostly freshwater species, but occasionally estuarine. Dispersive and occasionally irruptive. Forages in shallow water for small aquatic and terrestrial animals; rarely fish. Nests in flooded or fringing trees in rivers, lakes, swamps. Loose breeding colonies (2-30 pairs), occasionally larger. Mixed-species colonies. The observations of this species at KP closely match the typical pattern. Species such as the White-necked Heron, which eat a broad range of invertebrates, tadpoles and frogs are likely able to colonise newly flooded areas quickly, because their food source responds quickly to flooding. Other species that eat fish typically require the water to be present for some time to allow the fish populations to increase before they can exploit the conditions. The fact that this species tends not to feed on fish suggests that it can arrive and potentially succeed at any stage of the flood cycle, but may be favoured if it arrives early (before fish have colonised) to avoid nesting competition from piscivores.

White-faced Heron – Freshwater, estuarine and coastal species. Forages in shallow water or dry habitats. Eats a wide range of aquatic invertebrates and vertebrates. Marchant and Higgins (1990) reports that the breeding specifics for White-faced Heron are poorly known, and states that the species nests solitarily rather than colonially (one Australian record of a colony of 8 nests near Goondiwindi, Qld). Breeding/nesting sites are reported as anywhere with trees in open country or trees along watercourses, but not in extensive woodlands or closed forests – this, and the observation of mostly solitary nesting, contrast with the observations at the Pollack in 2015 and 2016.

Eastern Great Egret – Freshwater, estuarine and coastal species. Forages in shallow water, and prefers permanent or semi-permanent water. Eats aquatic animals; mostly fish, but also frogs, insects and small birds. Nests in flooded or fringing trees in rivers, lakes, swamps; nests in trees standing in water, usually high up. Nests in colonies, and colonies may contain up to several hundred nests. Mixed-species colonies. MDB is a major breeding area for this species in south-eastern Australia, but there is no mention of KP in particular in Marchant and Higgins (1990). The 2016 flood at the Pollack lasted from September to early February, which perhaps was sufficiently permanent water for this species. The tendency for this species to eat mostly fish may explain the delay before this species commenced breeding at the Pollack in 2016.

Intermediate Egret – Mostly freshwater species. Forages in shallow water among dense vegetation, hunting for aquatic animals; mostly fish, but also frogs, lizards, grasshoppers. Nests in trees standing in or near water; usually in water. Colonial, nesting in dense mixed-species colonies. Colonies sometimes large; up to thousands of nests. If swamps dry out, breeding does not start until maximum flood reached. MDB is a major breeding area for this species in south-eastern Australia. Species breeds at sites along the Murray River east to Albury. The only known breeding record in Victoria is from Gunbower Island. The tendency for this species to eat mostly fish, and to wait for maximum flood, may explain the delay before this species commenced breeding at the Pollack in 2016.

Great Cormorant – Freshwater and marine species. Piscivorous, and able to forage in deep water. Eats mostly fish and occasionally arthropods. Nests in trees, bushes or reeds in or near water, but uses a diverse range of nesting sites, from lakes, swamps, rivers, billabongs, to estuaries and shallow coastal lagoons. Occupies mixed-species colonies. The tendency for this species to eat mostly fish may explain the delay before this species commenced breeding at the Pollack in 2016.

Pied Cormorant – Mainly marine species, but uses inland terrestrial waterways and wetlands. Piscivorous, and able to forage in deep water. Feeds extensively on non-native fish (Common Carp and Redfin). Extensively coastal breeding, but inland breeding occurs in nests in trees standing in lakes or swamps. Occupies mixed-species colonies. The Pollack may be one of the few breeding locations in the KP region. The presence of large numbers of carp may help this species.

Little Pied Cormorant – Mainly freshwater species, and able to forage in deep water, but also able to use smaller and more vegetated wetlands than other cormorants. Piscivorous, but also feeds extensively on a diversity of crustaceans (e.g., yabbies). Fish eaten include non-native fish (particularly carp and perch). Nests in trees, bushes in or near water, and sometimes over dry land. Small to large colonies, with Marchant and Higgins (1990) reporting a 'larger' colony at 'Koondrook' (100 nests)(no date given). Mixed-species colonies.

Little Black Cormorant – Mainly freshwater species, and able to forage in deep water. Piscivorous, with favoured prey items being smelt, carp and perch. Favours flooded trees for nesting sites, well away from land in remote parts of large wetlands (Marchant and Higgins 1990). Breed in swamps with ribbonweed and abundant fish. Usually small colonies (<100 pairs), but sometimes thousands. Mixed-species colonies. Conditions at the Pollack in 2016 would seem to be suitable for this species, yet only one nest was seen.

Grey Teal – Nests mostly in tree holes/hollows; occasionally on the ground. Newly-hatched ducklings jump from tree and 'float' to ground or water. Not colonial. Widespread and common within and beyond MDB. Attracted to waterbodies by abundance of food (aquatic vegetation, seeds of aquatic plants, invertebrates). Uses wetlands with inundated or fringing timber (e.g., Koondrook-Perricoota wetlands), but prefers open or discontinuously wooded wetlands. Early stages of a wetland, after drying and refilling, provide ideal conditions for breeding, with increased levels of organic matter and abundant aquatic flora and invertebrates (Crome 1988, in Marchant and Higgins 1990). This may be the factor that results in numerous Grey Teal foraging and breeding in all flooded areas at KP, not just the larger waterholes that attract other species.

Pacific Black Duck – Nests in tree holes, but also in disused nests of other large birds (e.g., corvids, raptors), and occasionally on the ground. Not colonial, but nests can be close if conditions are favourable for breeding. As is the Grey Teal, the Pacific Black Duck is attracted to waterbodies by abundance of water and food (aquatic vegetation, seeds of aquatic plants).

Australian Wood Duck – Eats vegetation (grass, clover, green herbage), and insects when green vegetation unavailable. Nests in tree holes/hollows. Newly-hatched ducklings jump from tree and 'float' to ground or water. Not colonial. Widespread and common within and beyond MDB. Widespread and common in KP.

4. Conclusions and recommendations

4.1 Conclusions

The 2016 'overbank' flood resulted in relatively large numbers of waterbirds visiting the KP forest. As for the smaller flood in 2015, the focus of the 2016 waterbird activity was large numbers of colonial nesting waterbirds arriving at and breeding successfully at the Pollack, with smaller numbers of waterbirds attempting breeding (most not successfully) at other northern waterholes (Dan Hutton, pers. comm.).

Ultimately, the numbers of pairs that reportedly bred at the Pollack were high enough to be counted in the thousands, which goes part-way to satisfying the outcome stated as part of the Icon Site Objective for the Gunbower-Koondrook-Perricoota forest (MDBA 2012):

> "successful breeding of thousands of colonial waterbirds at least three years in ten".

The aerial transects were done each year at a similar time following the peak flood, and successfully detected the overall increase in waterbird numbers from previous years of sampling:

- 2014 transects (Flooded channels through whole forest): 319 waterbirds observed over 138 km of travel (~2.3 birds per km)
- 2015 transects (Flooded Pollack): 96 waterbirds observed over 115 km of travel (~0.8 birds per km)
- 2016 transects (Overbank flood through entire forest): 1193 waterbirds observed over 273 km of travel (~4.4 birds per km)

However, the aerial transects mainly detected larger numbers of ducks throughout the forest, and failed to detect the breeding event by colonially nesting species (mainly large wading birds at the time of the assessment). Even the closer waterhole investigations (aerial) failed to measure the full scale of the colonial breeding event that took place, mainly at the Pollack. A much more comprehensive and accurate account of that event came from Dan Hutton's on-ground observations at weekly intervals during the course of the flood. This demonstrates the effort required to 'measure' the colonially nesting waterbirds' response to a flood event, when it is relatively localized as this one was.

Comparing the small 2014 managed flood with the large 2016 'overbank' flood, similar patterns are evident for the distribution and likely breeding activity of ducks throughout the KP forest. Small groups of ducks (multiple species, but mostly Grey Teal) bred in areas of the KP forest that had water. The raw numbers of breeding ducks may have been higher in 2016 than 2014, but the on-ground densities appeared to be similar, and no focal breeding locations were observed, unlike with colonially breeding species. With the larger flood of 2016, more water was available, and more of their preferred habitat was available across larger areas of the forest. Therefore, the response to flooding by ducks (mainly Grey Teal) appears to follow a relatively simple relationship, and may be influenced foremost by the area of forest that is flooded.

This observation of Grey Teal through the forest matches documented information for the species. Marchant and Higgins (1990) report that the Grey Teal is attracted to abundance of food (aquatic vegetation, seeds of aquatic plants, invertebrates), and that the early stages of a wetland, after drying and refilling, provide ideal conditions for breeding, with increased levels of organic matter and abundant aquatic flora and invertebrates (Crome 1988, in Marchant and Higgins 1990). This suggests that the wetland vegetation responded sufficiently well to the 2016 flood to attract and support large numbers of ducks. Where those larger numbers of ducks in 2016 (compared with 2014) came from is not known. Some are likely to have been young of previous years, but it is also possible that some of the region's birds did not arrive to breed in the smaller 2014 flood. Also unknown is where the large numbers of ducks go to when the flood waters subside. At least some of them are likely to remain in the region and visit surrounding irrigated agricultural land.

The responses by colonially nesting waterbirds (La and Pi) differed. The small 2014 managed flood did not result in a breeding event for La and Pi functional groups. The 2015 flooding of the Pollack did attract small numbers of La species, and allowed breeding success in some of those, but did not attract large numbers of birds. The overbank event in 2016 attracted far larger numbers of colonially nesting birds, and a larger diversity of La and Pi species. The species that were the most common in 2016 (particularly Nankeen Night-Heron) were all but absent in 2015 (which was mainly White-faced Heron and White-necked Heron). The prolonged duration of the flood at the Pollack in 2016/2017 also attracted a range of different species over time (D. Hutton pers. comm.), each species presumably seeking particular characteristics of the flooded area, and/or the foraging conditions that might support the raising of chicks. Large numbers of Nankeen Night-Herons were first to arrive, along with smaller but significant numbers of White-faced Herons and White-necked Herons. Then, other species of egret arrived to commence breeding (in small numbers), and then various Pi species arrived to breed (cormorants). Interestingly, the focal area used for breeding by colonially nesting waterbird species in 2016 was similar to the areas used in 2015, despite the availability of other flooded waterholes that were (anecdotally) used by colonially nesting species. In both years, the Pollack was the clear focus, and few birds chose to breed in other flooded waterholes in the KP forest (some did in 2016: D. Hutton pers. comm.). These species appear to have a more complex relationship with water in the KP forest, and aspects such as duration, depth, trees, drying rate, and season may all contribute to which species arrive, whether or not they breed, and whether or not their breeding efforts succeed.

According to one trusted historical account (Disher 2000), the large numbers of Nankeen Night Herons (and to a lesser extent, White-necked Herons) at the Pollack in 2016 were disproportionately large and may represent a previously unseen event. Also, the presence and breeding of White-faced Heron, in 2015 and 2016, had apparently not been reported before. Conversely, the 2016 flood attracted other species to the Pollack in smaller than expected (i.e., smaller than historically reported) numbers. Among them were Intermediate Egret, Great Cormorant, Little Pied and Little Black Cormorant, and possibly Australian White Ibis.

The historical account (Disher 2000) suggests that large floods at the Pollack in past decades attracted large numbers of a larger range of colonially nesting waterbirds. However, it is possible that a flood in any one year results in only a few dominant species breeding (Nankeen Night Heron and White-necked Heron in 2016), such that all species manage to breed in large numbers over an extended period, but that not all breed in large numbers each year. When flooded, a wetland such as the Pollack may provide suitable breeding conditions for most species, with the eventuating dominant species determined by other factors, including history of breeding in previous years, availability of wetland habitat elsewhere, preferences by the birds themselves *en masse* at the time. It may simply be that enough birds of a species arrive at a wetland and provide critical mass to start a colony, then others join as the word spreads.

Many of the waterbirds are reported to nest in trees standing in water, which is presumably an anti-predator measure. However, Marchant and Higgins (1990) reports that predators of these species at breeding time are mostly birds (corvids and raptors) and humans (egg collecting or disturbance such that predatory birds get access to eggs/chicks); not possums, varanids, snakes, against which water may provide protection. The preference of many waterbirds to nest in trees standing in water may be determined through more complex factors than predation alone.

It is also of interest that the 2016 flood appeared to be insufficient to support large scale breeding by colonially nesting waterbirds anywhere other than the Pollack. According to anecdotal historical accounts, there are 18 waterholes other than the Pollack through the Koondrook-Perricoota Forest that are considered to be (or to once have been) minor (7), moderate (8) or major (3) waterbird breeding locations. Appreciating the rainfall that was needed and the volume of water that was required to result in the 2016 overbank event, it is difficult to see how these other waterbird breeding locations will ever attract colonially nesting waterbirds in future. The Pollack may be the only location at Koondrook-Perricoota where large numbers of colonially-nesting waterbirds are likely to breed in response to delivery of e-water. Ducks are likely to benefit from the addition of e-water through the forest.

The benefits of flooding for waterbirds are inextricably linked to the influence of flooding on prey items and habitats used for foraging, breeding and roosting. Reproductive performance in waterbirds is likely to reflect ecosystem productivity at lower trophic levels, in turn influenced by the system's long-term environmental condition (Kushlan 1993, in Rogers 2009). Recent observations of large breeding numbers of colonially nesting waterbirds at the Pollack, and widespread breeding by ducks through the remainder of the forest, provide an optimistic outlook for the benefits of delivering environmental water to the KP forest in future years.

4.2 Recommendations

Given that the Koondrook-Perricoota forest experienced very different watering regimes for 2014, 2015 and 2016, the waterbird monitoring over those years leads to a range of recommendations. These recommendations are proposed in an effort to maximise the ecological cost/benefit of managed water delivery to the forest, and in an effort to measure the health/condition of the forest through an understanding of the waterbirds' response to changing watering regime.

Recommendations are:

- Continue aerial survey along five transects as the initial and overall method for waterbird census at Koondrook-Perricoota forest. Given that this aspect of the survey is repeatable, the 'birds per km' metric provides a useful comparative tool for condition monitoring. However, aerial transects should not be relied on for providing all information.
- During a waterbird breeding event, plan for and undertake multiple on-ground assessments. Results from on-ground surveys at the Pollack during the 2016 flood (Dan Hutton, for FCNSW) show that numerous on-ground visits are required to pick up the full range of species that breed at Koondrook-Perricoota, and to determine the success of breeding efforts. The 2016 flood showed that different species arrived at different times to commence breeding, and the timing was presumably influenced by water distribution and duration.
- When the Pollack is inundated (naturally or artificially) in future years to the point that colonially nesting waterbirds are attracted, continue to deliver water sufficient to prolong flooding for at least two to three months (from outset). This would increase the likelihood of successful breeding by colonially nesting waterbirds.

- As soon as possible, test the water delivery infrastructure to see whether it is possible to achieve a prolonged flood in the Pollack via the inlet regulator, the forest itself and Barber Creek. Can the artificial watering regime be used to replicate a large-scale, bird-attracting flood matching the 2016 overbank event?
- Deliver water to the forest whenever the opportunity arises, and preferably annually. Delivering small volumes of water is unlikely to attract colonially nesting waterbirds through the forest (even the 2016 flood did not do that), but delivering water each year will help ducks, which breed in Koondrook-Perricoota even with small floods. The more water delivered, the more ducks are likely to breed. Delivery of water each year will also keep soil moisture high and prepare the forest for large-flood years.
- Test the waterbirds' response to continued successive floods (i.e., back-to-back floods). Historically, since river regulation, forest floods have been irregular and generally not annual. Following the responses to the 2015 and 2016 floods in the Pollack, a question arises in regard to waterbird responses across multiple successive floods. Will colonially nesting waterbirds respond year after year, and will it be the same species each time, or is there a limit to their breeding efforts? Does every flood carry the same potential for waterbird response, or are some years likely to be wasted effort in terms of waterbird reproductive success?
- Try to avoid delivery of water to the forest (or just to the Pollack, if insufficient water is available) at the same time of year each time. Different waterbird species (including ducks and colonially nesting species) may have seasonal breeding preferences, and delivery of water to the forest at the same time of year each time may inadvertently favour one species over another. Investigate this through continued long-term waterbird monitoring across years of differently-timed floods. This recommendation may meet with overwhelming resistance from those keen to see flood timing in line with the natural precedent, and those seeking to avoid hypoxic water which often results from summer flooding.
- Ducks and grebes (Du) appears to be the main Functional Group that uses the Koondrook-Perricoota forest (aside from the Pollack in large flood years) for breeding. Undertake monitoring investigations (during small or large floods) to understand habitat preferences by the different duck species (channels, vegetated grassland, borrow pits, deeper waterholes). This will allow FCNSW to initiate more targeted water management to help particular duck populations (or groups of duck species) in future, if required.
- Undertake investigations (desktop and/or field) across the broader landscape (i.e., beyond Koondrook-Perricoota) to understand how important flooding of Koondrook-Perricoota Forest is to regional duck populations. If water is not delivered to Koondrook-Perricoota Forest, are the regional duck populations likely to decline or will the birds just breed elsewhere?
- The lack of frequent flooding through the forest in recent decades is likely to have changed the ecology of the forest's terrestrial and wetland vegetation. The gradual degradation of the condition of overstorey and wetland vegetation is likely to take a long period to return to its optimal state, as in turn, are other ecological components that drive waterbird responses (e.g., food sources such as fish). Analysing the vegetation and fish results alongside the bird results to determine which species best represent the ecological changes brought about by delivery of environmental water.
- Measure bird, fish and vegetation responses concurrently for the next flood, to try to obtain definitive data on cues used by waterbirds for the onset of their nesting and breeding. Is it when water levels reach a certain point? Is it when certain fish populations reach a certain density? Is it when certain plant species begin to flower or seed?

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6. Limitations

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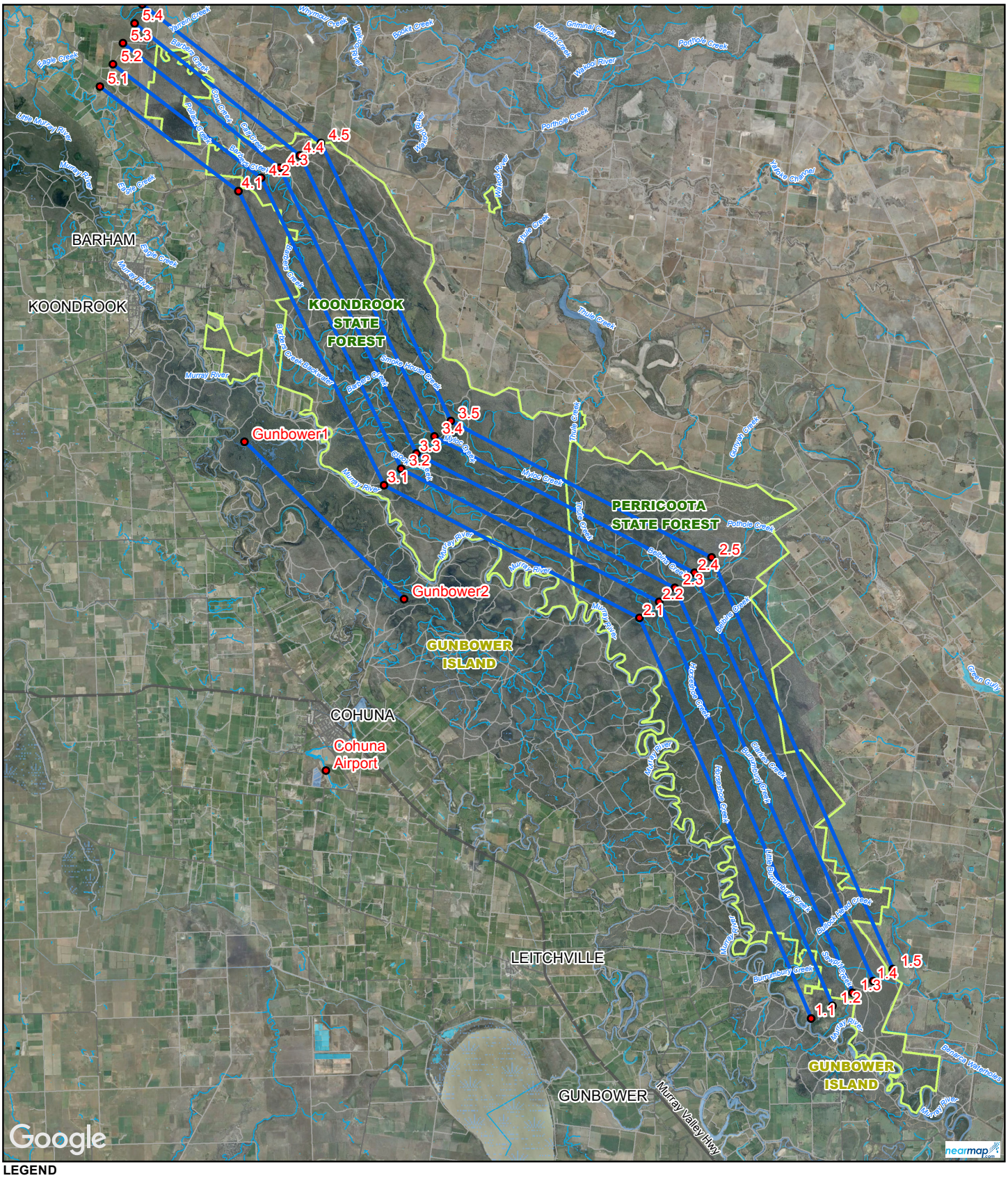
The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

7. Maps



LEGEND

- Aerial Transects
- Transect Lines
- Koondrook-Perricoota Forest
- Watercourse
- Lake
- Swamp
- Watercourse

Paper Size A4

0 1,450 2,900 5,800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

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Forestry Corporation of NSW
Monitoring for Koondrook-Perricoota Forest

Job Number 31-31878
Revision A
Date 15 Aug 2017

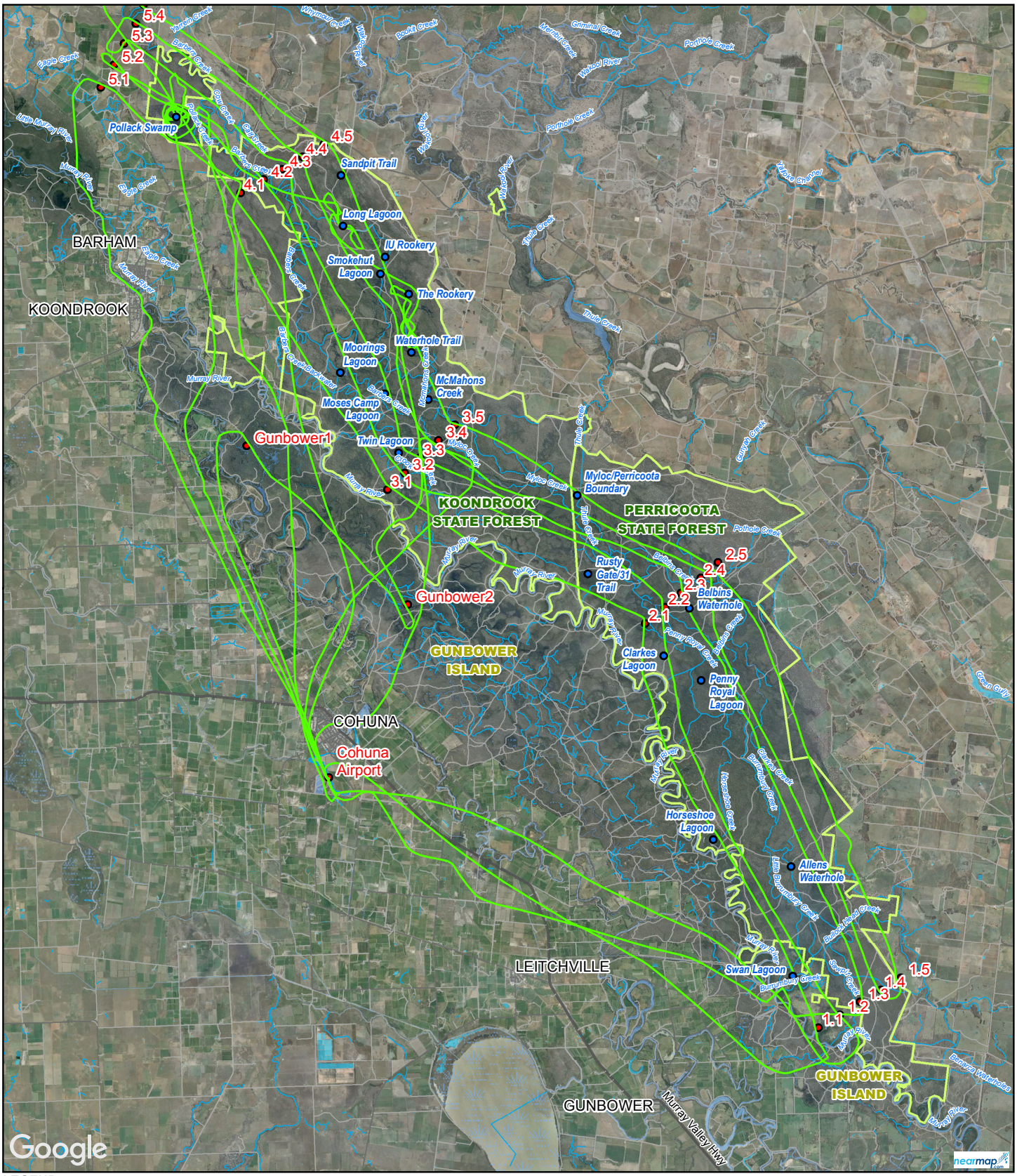
Aerial transects

Figure 2

180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

G:\31\31878\GIS\Maps\Working\31-31878_001_Mapbook_Map_2015_A4P.mxd [KBM: 12]

Data source: DELWP, VicMap, 2016; Imagery; Google Earth Pro, extracted 26/02/2015. Created by: mjahanshahi



LEGEND

- Waterbird-Waterhole Sites
- Actual Flight Path
- Aerial Transects
- Koondrook-Perricoota Forest
- Watercourse
- Lake
- Swamp
- Watercourse

Paper Size A4

0 1,450 2,900 5,800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Forestry Corporation of NSW
Monitoring for Koondrook-Perricoota Forest

Job Number 31-31878
Revision A
Date 15 Aug 2017

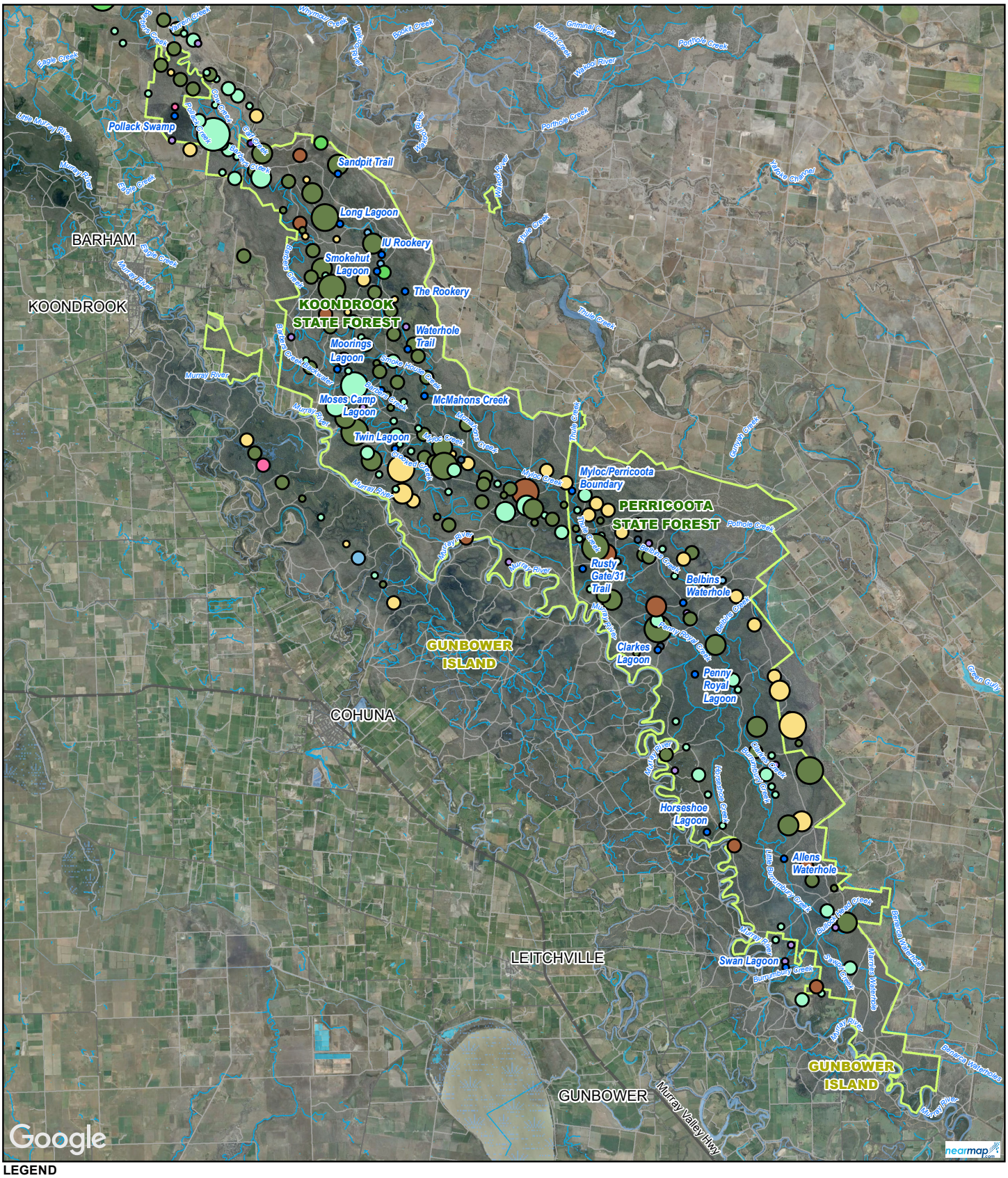
Actual Flightpath

Figure 3

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

G:\31\31878\GIS\Maps\Working\31-31878_001_Mapbook_Map_2015_A4P.mxd [KBM: 13]

Data source: DELWP, VicMap, 2016; Imagery; Google Earth Pro, extracted 26/02/2015. Created by: mjahanshahi



LEGEND

Waterbird-Waterhole Sites **Species**

Abundance

- 1
- 2 - 5
- 6 - 10
- 11 - 30
- 31 - 67

- Australian Shelduck
- Australian White Ibis
- Australian Wood Duck
- Egrets (white)
- Nankeen Night Heron
- Pacific Black Duck
- Straw-necked Ibis
- Teal sp.
- White-faced Heron
- White-necked Heron
- Koondrook-Perricoota Forest
- Watercourse
- Lake
- Swamp
- Watercourse

Paper Size A4

0 1,450 2,900 5,800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Forestry Corporation of NSW
Monitoring for Koondrook-Perricoota Forest

Transect observations
Abundance

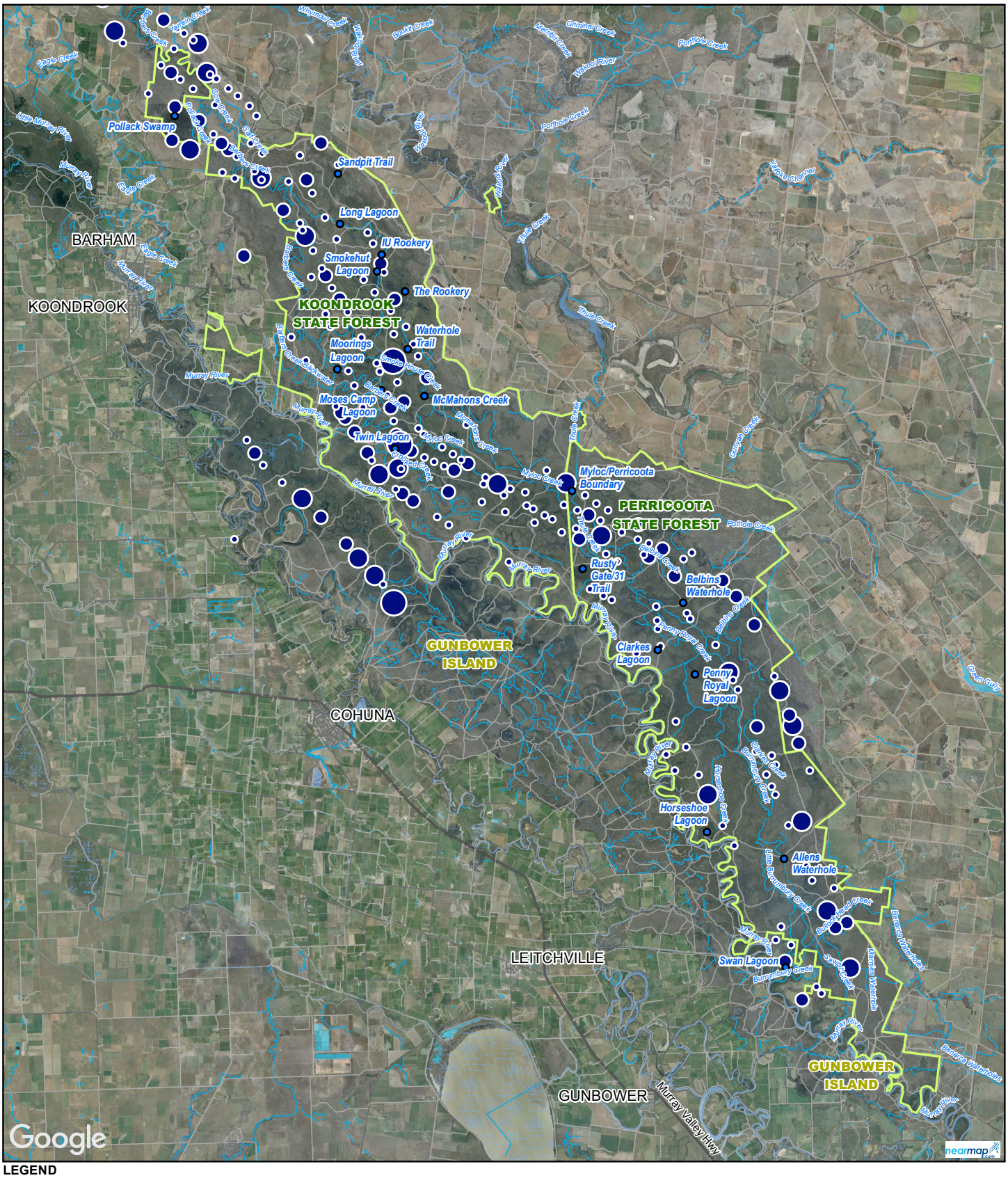
Job Number 31-31878
Revision A
Date 16 Aug 2017

Figure 4

180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

G:\31\31878\GIS\Maps\Working\31-31878_001_Mapbook_Map_2015_A4P.mxd [KBM: 14]

Data source: DELWP, VicMap, 2016; Imagery; Google Earth Pro, extracted 26/02/2015. Created by: fklandy



LEGEND

- Waterbird-Waterhole Sites
- **Species Richness**
  - 1
  - 2
  - 3
  - 4
- Koondrook-Perricoota Forest
- Watercourse
- Lake
- Swamp
- Watercourse

Paper Size A4

0 1,450 2,900 5,800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Forestry Corporation of NSW
Monitoring for Koondrook-Perricoota Forest

Transect observations
Richness

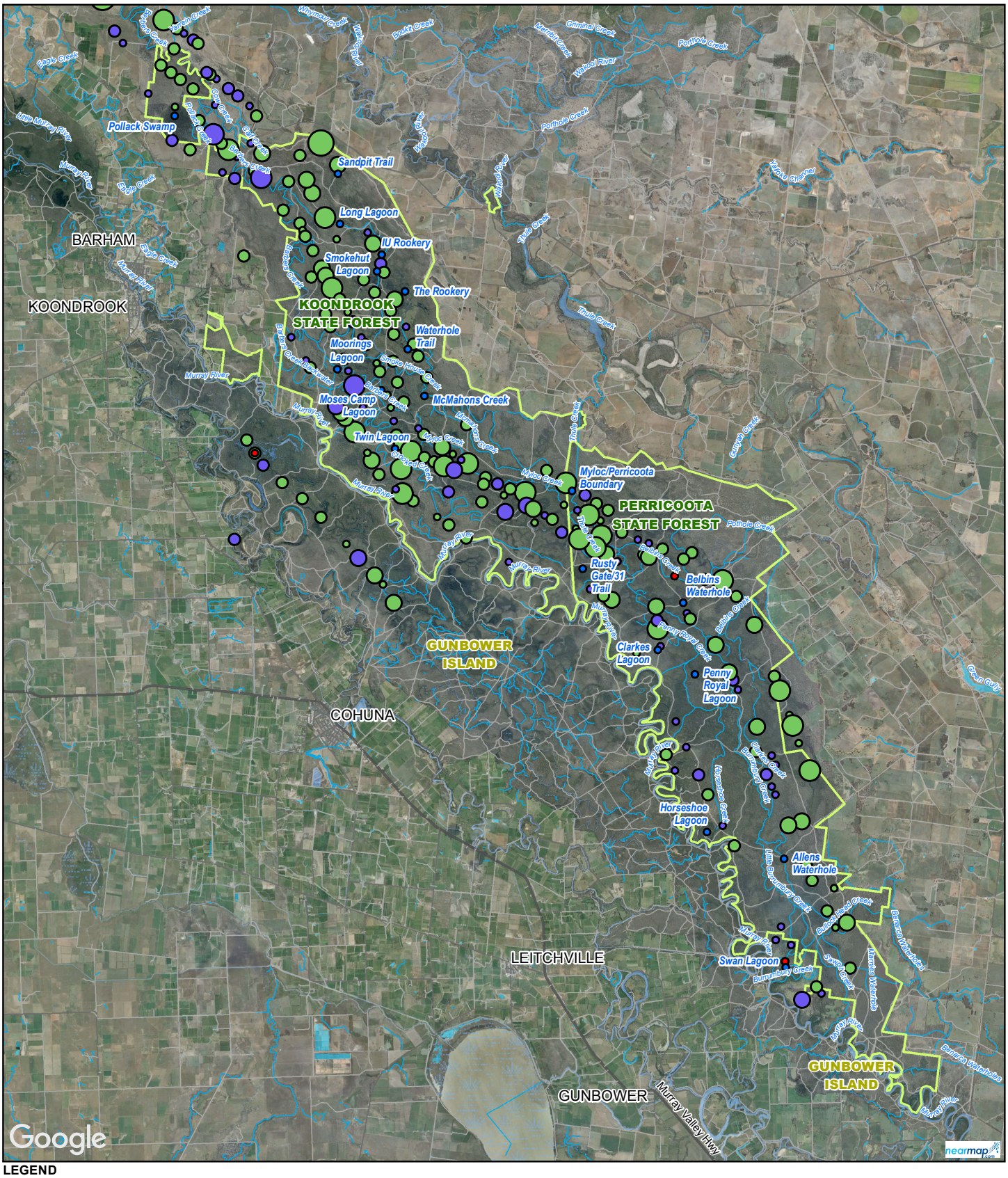
Job Number 31-31878
Revision A
Date 15 Aug 2017

Figure 5

180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

G:\31\31878\GIS\Maps\Working\31-31878_001_Mapbook_Map_2015_A4P.mxd [KBM: 15]

Data source: DELWP, VicMap, 2016; Imagery; Google Earth Pro, extracted 26/02/2015. Created by: fklandy



LEGEND

Waterbird-Waterhole Sites **FG and Abundance LA Category**

PI Category

- 1
- 2 - 5
- 6 - 10
- 11 -31
- 32 - 235

DU Category

- 1
- 2 - 5
- 6 - 10
- 11 - 67
- 67 - 230

LA Category

- 1
- 2 - 5
- 6 - 10
- 11 - 67

Koondrook-Perricoota Forest
Watercourse
Lake
Swamp
Watercourse

Paper Size A4
0 1,450 2,900 5,800
Metres
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

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Forestry Corporation of NSW
Monitoring for Koondrook-Perricoota Forest

Transect observations by FG - Abundance

Job Number 31-31878
Revision A
Date 15 Aug 2017

Figure 6

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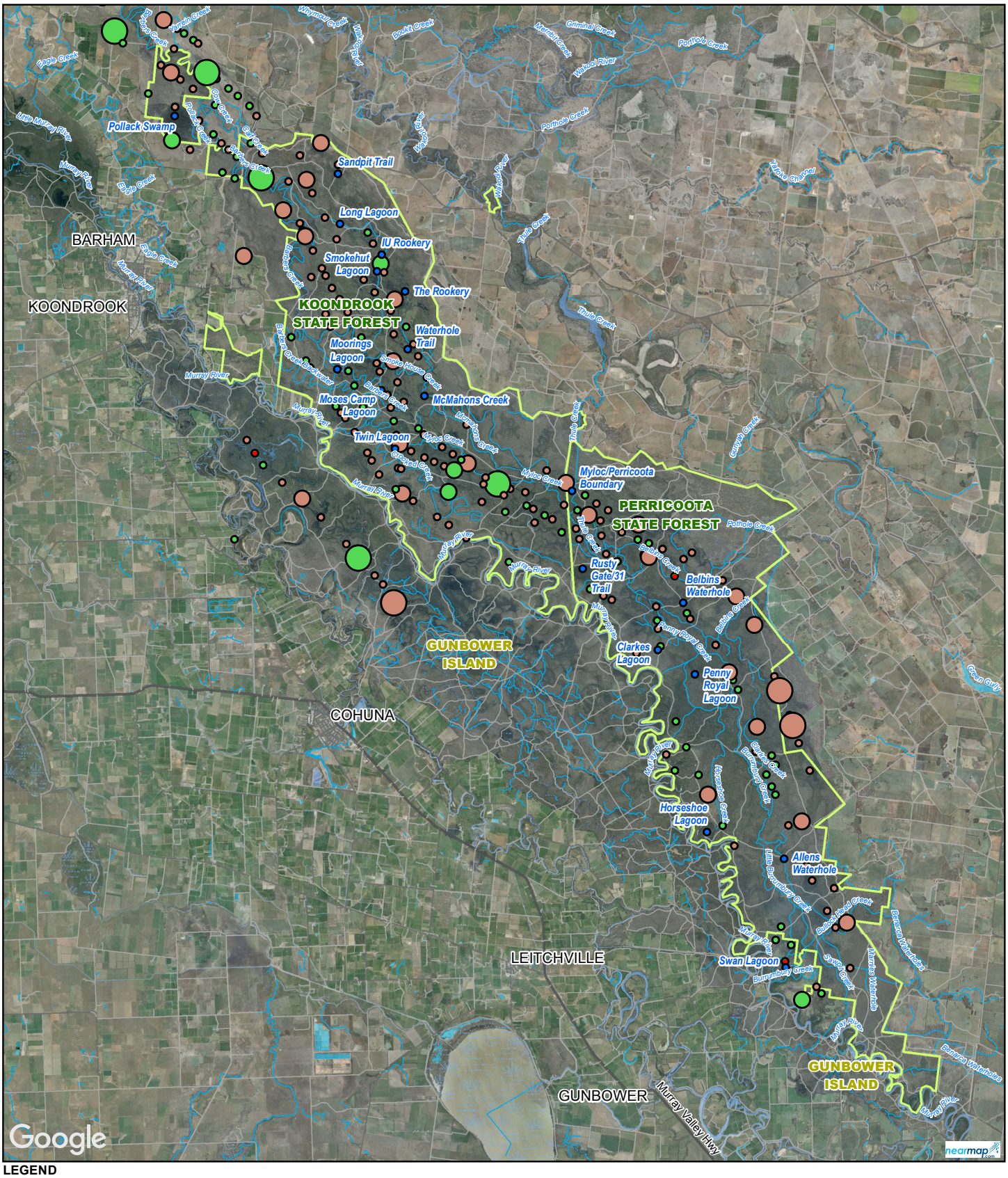
G:\31\31878\GIS\Maps\Working\31-31878_001_Mapbook_Map_2015_A4P.mxd [KBM: 16]

Data source: DELWP, VicMap, 2016; Imagery; Google Earth Pro, extracted 26/02/2015. Created by: fklandy



LEGEND

- Waterbird-Waterhole Sites
- **PI Category**: 1, 2, 3
- **FG and Richness DU Category**: 1, 2, 3
- **LA Category**: 1, 2, 3
- Koondrook-Perricoota Forest
- Watercourse
- Lake
- Swamp
- Watercourse

Paper Size A4

0 1,450 2,900 5,800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

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Monitoring for Koondrook-Perricoota Forest

Transect observations by FG - Richness

Job Number 31-31878
Revision A
Date 15 Aug 2017

Figure 7

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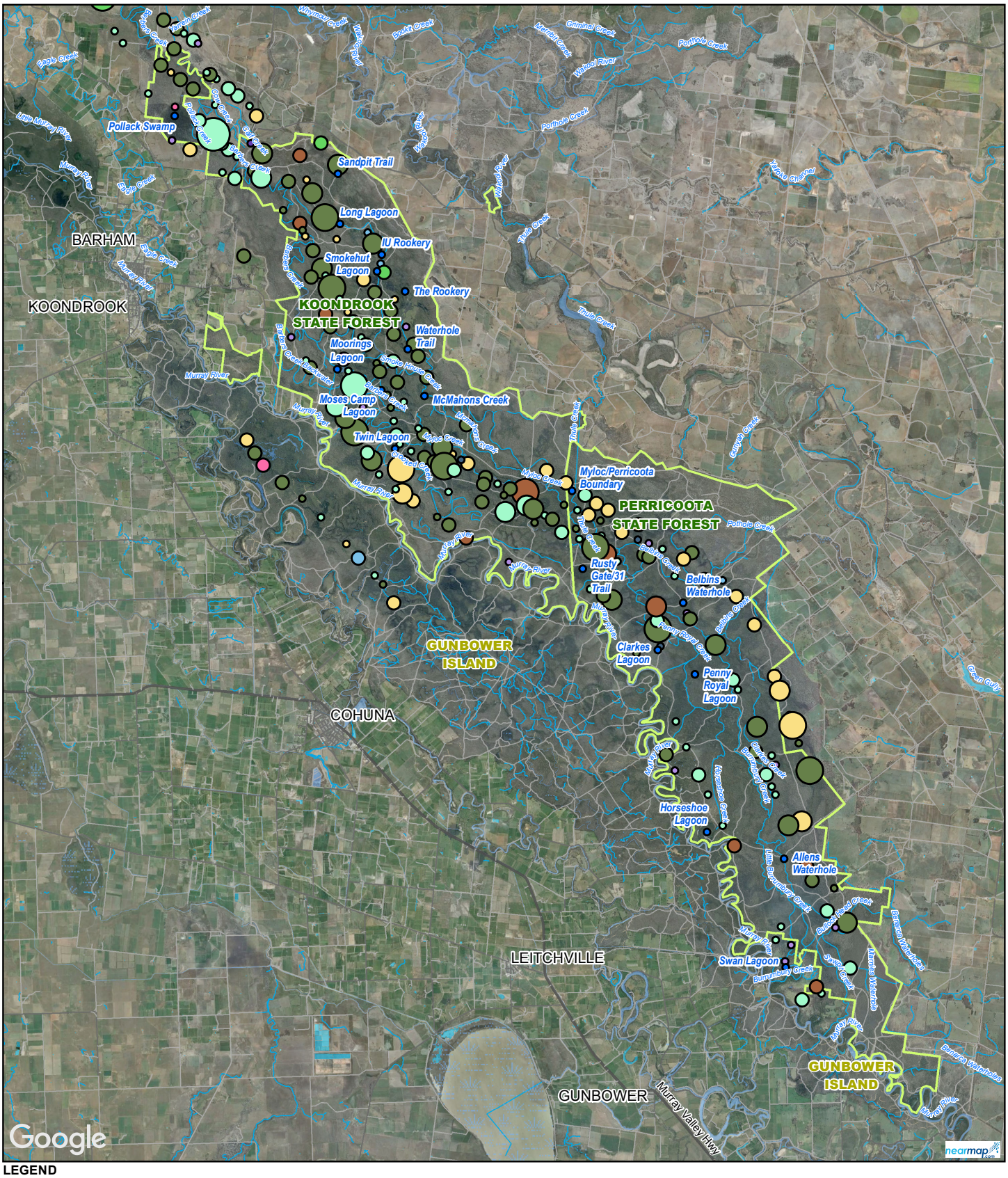
Data source: DELWP, VicMap, 2016; Imagery; Google Earth Pro, extracted 26/02/2015. Created by: mjahanshahi



LEGEND

Waterbird-Waterhole Sites **Species**

Abundance

- 1
- 2 - 5
- 6 - 10
- 11 - 30
- 31 - 67

- Australian Shelduck
- Australian White Ibis
- Australian Wood Duck
- Egrets (white)
- Nankeen Night Heron
- Pacific Black Duck
- Straw-necked Ibis
- Teal sp.
- White-faced Heron
- White-necked Heron
- Koondrook-Perricoota Forest
- Watercourse
- Lake
- Swamp
- Watercourse

Paper Size A4

0 1,450 2,900 5,800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Forestry Corporation of NSW
Monitoring for Koondrook-Perricoota Forest

Transect observations by Species - Abundance

Job Number 31-31878
Revision A
Date 15 Aug 2017

Figure 8

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Data source: DELWP, VicMap, 2016; Imagery; Google Earth Pro, extracted 26/02/2015. Created by: fklandy

LEGEND

Waterbird-Waterhole Sites **Species**

Abundance

- 1
- 2 - 5
- 6 - 10
- 11 - 30
- 31 - 200

- Egrets (white)
- Nankeen Night Heron
- Straw-necked Ibis
- Teal sp.
- White-necked Heron
- Flight Path - Waterbodies
- Koondrook-Perricoota Forest
- Watercourse
- Lake
- Swamp
- Watercourse

Paper Size A4

0 625 1,250 2,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Forestry Corporation of NSW
Monitoring for Koondrook-Perricoota Forest

Waterbody observations
Abundance

Job Number 31-31878
Revision A
Date 15 Aug 2017

Figure 9

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Data source: DELWP, VicMap, 2016; Imagery; Google Earth Pro, extracted 26/02/2015. Created by: fklandy

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Document Status

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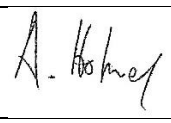
		Name	Signature	Name	Signature	Date
Draft						27/03/2017
0	R. Retallick	A Holmes		T. Wills		21/08/2017

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