Utilisation of habitat by Brolga (*Grus rubicunda*) within the vicinity of the Macarthur Wind Farm during the breeding season of 2016

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1.0 INTRODUCTION

The Macarthur Wind Farm is currently the largest wind farm in the southern hemisphere, consisting of 140 turbines with a total capacity of 420 megawatts and is located on approximately 5,500 ha of privately owned agricultural land approximately 15km east of Macarthur in south-west Victoria. (Figure 1). Construction of the wind farm was completed in late 2012 and commissioned on 31 January 2013.

The Brolga (*Grus rubicunda*) is listed as threatened under the *Flora and Fauna Guarantee Act 1988* and classified as Vulnerable on the *Advisory List of Threatened Vertebrate Fauna in Victoria - 2013*. Much of the wind farm and surrounding landscape consists of wetland areas that provide habitat for Brolga, particularly during the wetter months. To assess the risk of Brolgas colliding with wind turbines, the Planning Permit for the wind farm stipulated that a Bat and Avifauna Management Plan (BAM Plan) be developed which incorporated specific monitoring of Brolgas in the vicinity of the wind farm for at least two years following completion of the wind farm. This monitoring program was to specifically examine the presence, behaviour and movements of Brolga, particularly breeding pairs, as well as the impact of wet and dry climatic conditions on the Brolga populations' use of the wind farm and surrounding properties.

Brolga monitoring was undertaken within the vicinity of the Macarthur Wind Farm during the breeding seasons of 2013 and 2014 (Wood 2013, 2014). This consisted of weekly roaming surveys to determine the presence of Brolga in the area and examine their movements, use of habitat, behaviour and nesting success. Whilst the breeding season of 2014 was considered to be 'dry' climatic conditions, there was insufficient rainfall during the breeding season of 2013 to be defined as 'wet' climatic conditions. Consequently, further monitoring of Brolgas was required when sufficient rainfall has occurred to fill most wetlands in order to examine the impact of wet and dry climatic conditions on Brolgas use of habitat within and surrounding the wind farm.

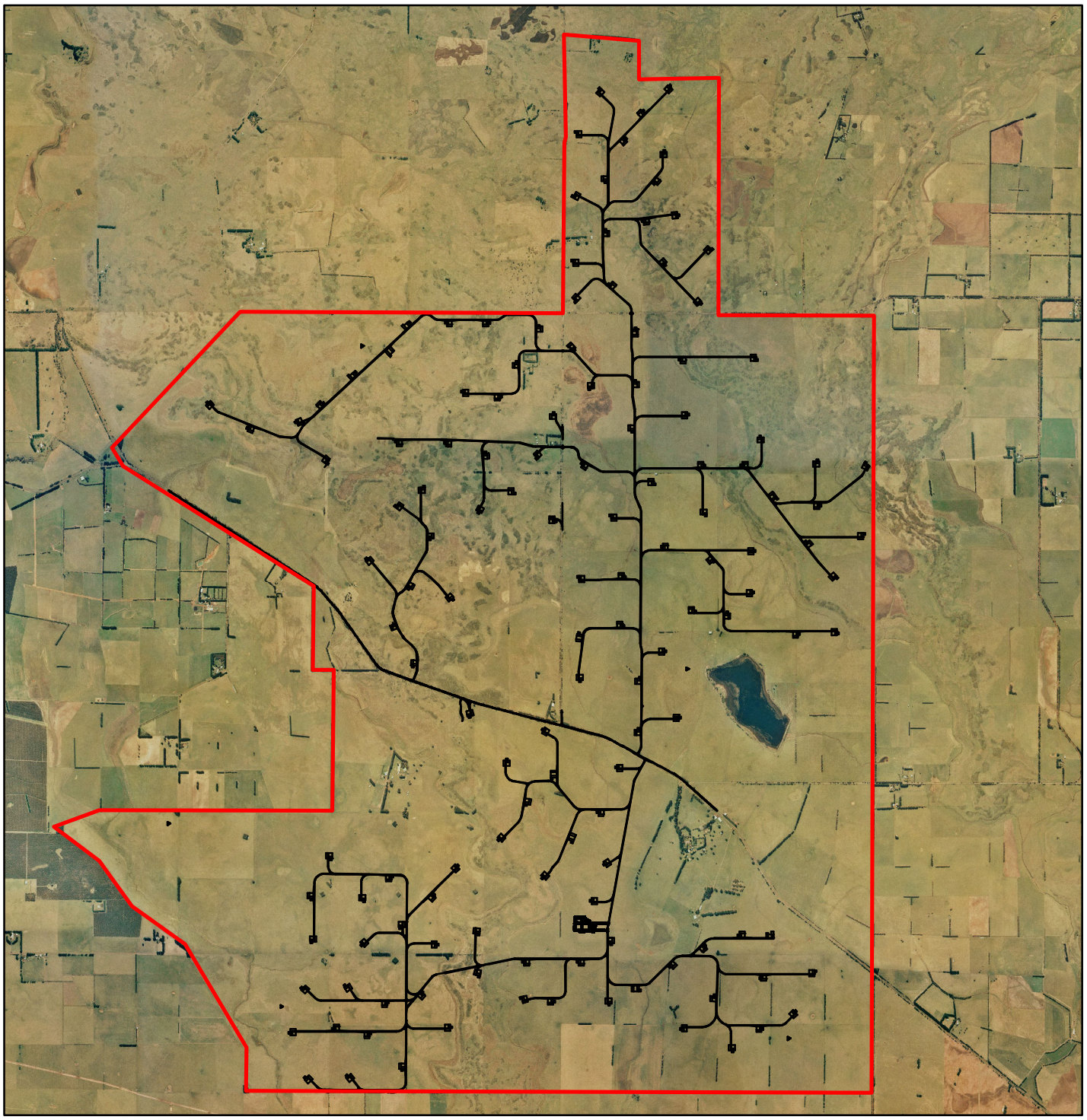
During September 2016, record rainfall and wide-spread flooding occurred throughout much of south-west Victoria. Although the Brolga breeding season had commenced approximately three months prior, typically in late June to early July, the 'wet' climatic conditions prompted Moyne Shire Council on 30 September 2016 to formerly request AGL Energy to commence additional Brolga monitoring at the Macarthur Wind Farm to survey their occurrence and habitat use for the remainder of the 2016 breeding season.

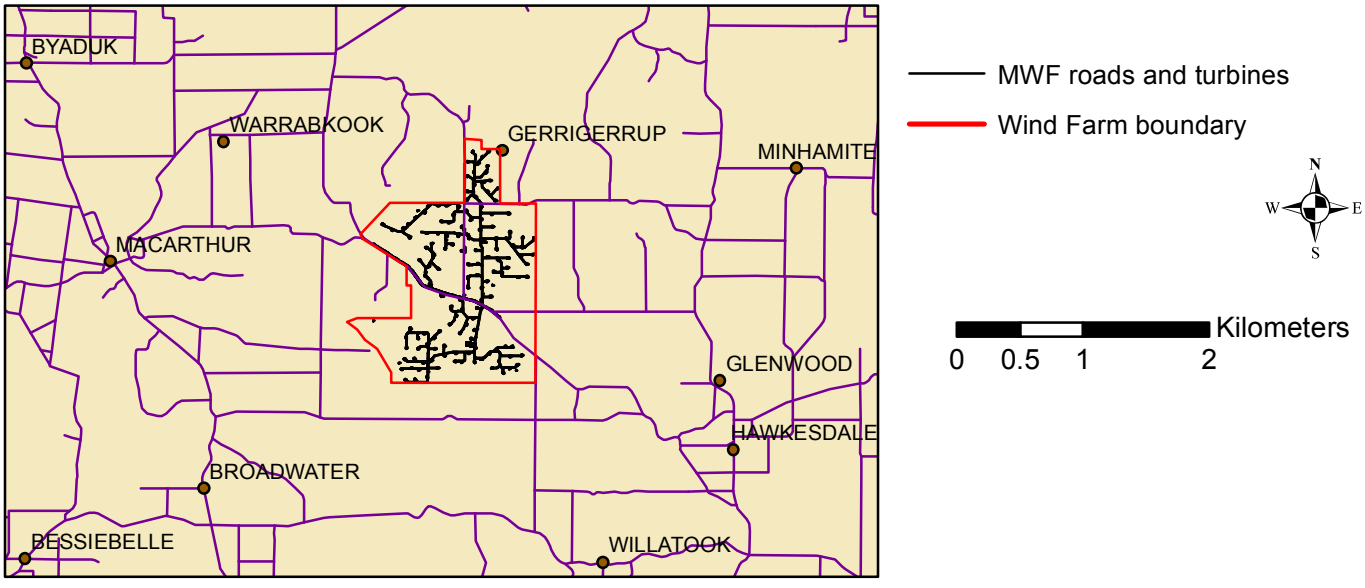
In addition to the requirements of the Panning Permit, the Bat and Avifauna Management Plan for the Macarthur Wind Farm stipulates that all wetlands are assessed to examine their habitat quality and potential for use as breeding sites by Brolga. This assessment was undertaken during August 2013 in which 25 wetlands were identified as potential breeding habitat. However, not all wetlands could be inspected, particularly those that were on surrounding private property where access was not possible. The greater extent of wetland filling experienced recently may have increased habitat availability for Brolga by not only increasing the spatial extent and duration of surface water in wetlands, but by filling wetlands which in dryer years may contain little to no surface water. As such,

an additional assessment of potential Brolga habitat was undertaken to determine if any other wetlands provide suitable breeding habitat, given the greater extent of wetland filling that has occurred this year.

This report details the results of the wetland assessments and Brolga monitoring undertaken during the latter half of the 2016 breeding season. The number of Brolga present, use of habitat and breeding success is compared to that observed in ‘dry’ climatic conditions experienced during the breeding season of 2014.

Figure 1. Location of the Macarthur Wind Farm





2.0 METHODS

An aerial survey was undertaken on 13 October 2016 in an attempt to determine the number and location of any Brolga and/or nests at the Macarthur Wind Farm and surrounding properties within 3 km of the wind farm, particularly since access to private property and visibility of wetlands from the ground was often restrictive. A total of 32 transects orientated in an east – west direction, each 12.5 km long and spaced 500 m apart, were surveyed to cover the entire breeding season search area (Figure 2). The aerial survey followed the methodology outlined in "Appendix A: Recommended Survey Methodology for Conducting Aerial Surveys for Breeding Brolga" in the *Interim Guidelines for the Assessment, Avoidance, Mitigation and Offsetting of Potential Wind Farm Impacts on the Victorian Brolga Population* (DSE 2012) with the exception of flying at an altitude of 500 ft above the highest point of the turbine blade as opposed to 500 ft above ground level. A Cessna 172, four seat, high-wing aircraft was flown along each transect at an indicated air speed of 60 – 70 knots. Two observers searched 250 m to the north and south of the transects using binoculars (12 x 50) to scan the landscape, with particular attention to wetlands, dams, creeks and drainage lines. Each observer had an aerial photograph of the site showing numbered transects and wetlands. For each Brolga or nest sighted the location was marked with a GPS and noted on a data sheet with the waypoint name, transect number, distance and direction from the transect and any notes such as whether the Brolga was in a pair, on a nest, or alone.

Detection of Brolga from an altitude of approximately 1,000 feet proved very difficult as they could not be readily distinguished from the grey coloured rocks and boulders that were scattered over most of the landscape. Whilst nests were easily identified from the air, it was difficult to determine whether the nest belonged to a Brolga or Swan. Aerial surveys have been useful in detecting Brolga in pre-construction surveys at wind farm sites when the aircraft is flown at an altitude of 500 ft above ground level. However, post-construction aerial surveys require a higher altitude to maintain a minimum vertical clearance of 500 ft above obstacles as required by Regulation 157 of the Civil Aviation Act 1988, As the highest point of the turbine blades were at 450 ft, the plane was required to fly no lower than 950 ft above ground level. This higher altitude, combined with the rocks and boulders scattered throughout the landscape, significantly reduced the ability to confidently detect Brolgas. The uncertainty of observations of Brolga or their nests from the aerial survey meant that the results were unreliable and subsequently discarded.

Wetland mapping undertaken by the Department of Sustainability and Environment was reviewed to identify potential Brolga habitats within the survey area, up to three km from the outermost turbines. Wetland mapping included the modelled distribution of wetlands predicted to occur in 1788 and also the current extent of wetlands as at 1994. Whilst many wetlands were inaccessible, being located on private property outside the wind farm boundary and were not visible from public roads, several discrepancies were found in the accuracy of the mapping during site inspections of those wetlands that were accessible and visible from the ground. Whilst most of the wetlands mapped as occurring in 1788 no longer exist due to extensive modification to the landscape from agricultural activities such as wetland drainage and pasture establishment, a number of these wetlands still exist but have not been

included in the 1994 wetland extent mapping. In addition, it was found that several other wetlands occur within the area which have not been included in either data set. These additional wetlands were mapped using ArcView GIS and included in assessments of potential Brolga habitat. Furthermore, the location and/or spatial extent of several wetlands mapped by DSE were found to be inaccurate. By reference to aerial photography and site inspections, a number of wetland polygons in the survey area were edited to produce a more accurate map of the spatial extent and distribution of wetlands. The distribution of wetlands and those surveyed for Brolga within the vicinity of the Macarthur Wind Farm are shown in Figure 3. The revised mapping is provided in Figure 3 as the 'wetlands surveyed' layer.

A total of 83 wetlands were visible from either within the wind farm or from public roads throughout the surrounding landscape. These varied in size and habitat quality from small shallow depressions to large permanently inundated wetlands. Each of these wetlands and surrounding paddocks were inspected on a weekly basis for the presence of Brolga from 26 October to 30 December 2016. The location of any Brolgas seen was recorded and mapped on an aerial photo of the site using ArcMap GIS software on a laptop computer. The date and time of the sighting along with notes of the individuals' activity at the time of observation was recorded in the attribute table corresponding to the mapped location. Each breeding pair was observed for a period of one hour using binoculars from a distance to minimise disturbance, with locations and observations of behaviour such as whether the birds were foraging, courting or nesting, recorded at five-minute intervals. Any Brolga observed in flight were closely watched, followed by vehicle if necessary, to examine their flight height and flight path, particularly in relation to their proximity to and behaviour near wind turbines. The flight path to the destination point was sketched on an aerial image of the site using ArcMap GIS and notes taken of their estimated altitude, flight duration and behaviour in close proximity to turbines where applicable. A map was produced using ArcMap to display the locations of each individual or pair of Brolgas during each observation and the path of any flights observed.

The habitat quality and extent of filling of the 83 accessible wetlands was assessed on 10 and 11 November 2016 to ascertain their suitability as potential breeding habitat for Brolga. Potential breeding habitat was defined as wetlands less than 0.5 m deep with at least 25% cover of aquatic vegetation suitable for nest construction and forage. The extent of filling was assessed by visually examining the extent of surface water in relation to the area of the wetland to determine an estimate of the percentage of its storage capacity categorised as either 'Dry', <25%, 25 – 50%, 50 – 75%, or > 75%. The field data sheet for the wetland condition assessment is provided in Appendix 1.

Limitations

Whilst all effort was made to locate all Brolgas during each survey, particularly those that had previously been located, this was not achieved on one occasion when a pair had moved from its previous location and was not found during the roaming survey. Much of the wind farm and surrounding land consists of stony rises and undulating terrain, which limits vehicle access and visibility across the landscape. Brolgas that could not be found may have been hidden in areas of undulating terrain. In addition, when Brolgas had disappeared from one area and others were seen elsewhere, unless the birds were banded and individuals could be identified, it could not be definitively determined that the same individuals were seen in a new location. Some individuals, however, had distinctive feather markings and/or colouration which assisted in identifying particular individuals and pairs.

As stipulated by the BAM Plan, the primary focus of this monitoring project was to document the occurrence of Brolga within the vicinity of the Macarthur Wind Farm and ascertain the likelihood of regular occurrence of Brolga in areas where they may collide with wind turbines. Given the large survey area and time taken to inspect all visible habitat areas, most time was spent undertaking roaming surveys searching for Brolga to determine the number of Brolga in the survey area, their use of habitat and spatial distribution rather than observing their behaviour and activity throughout the day. As such, observations of Brolga behaviour were usually limited to one hour per pair but additional observations were made when time permitted.

Figure 2. Aerial survey transects to survey Brolga within the vicinity of the Macarthur Wind Farm

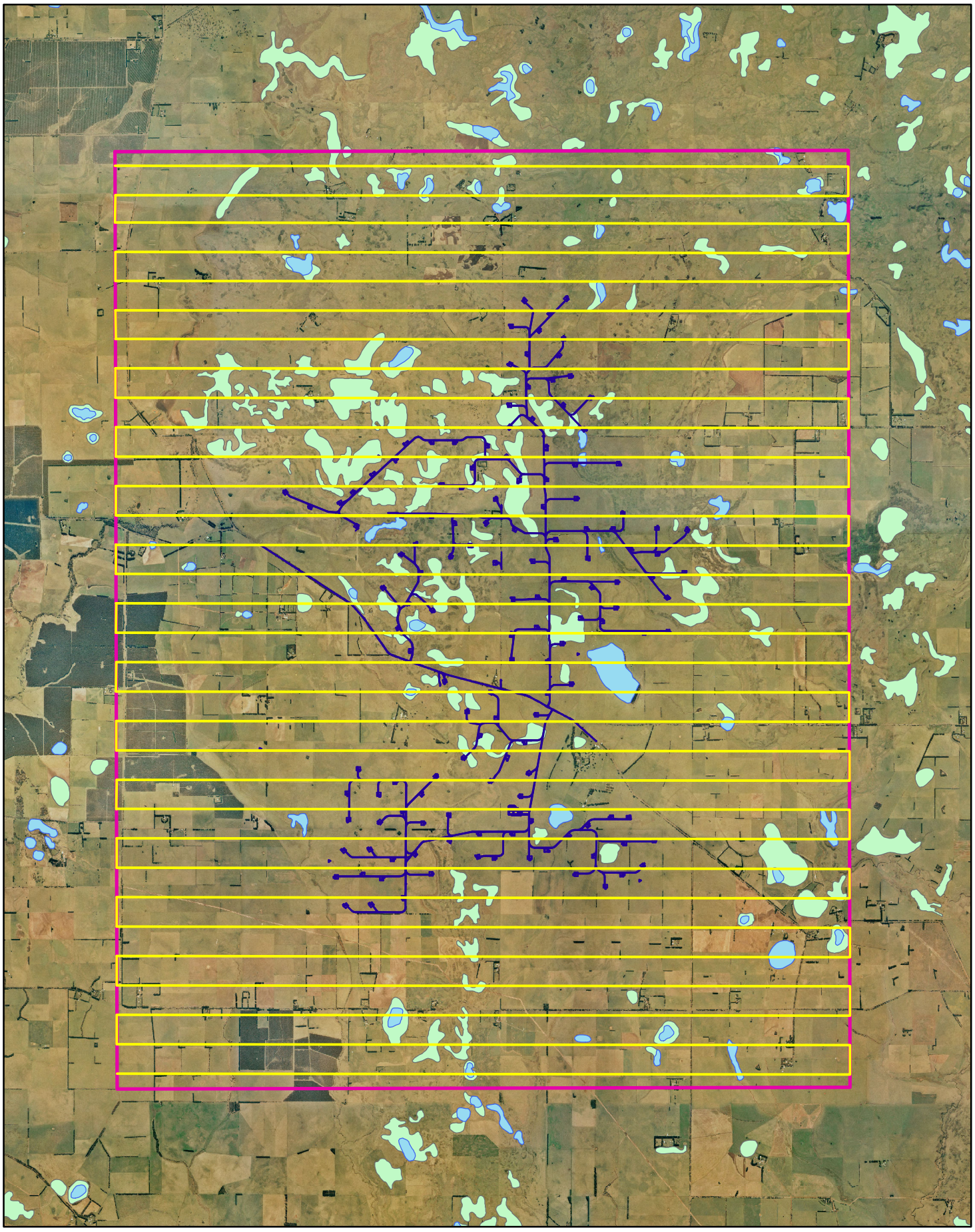
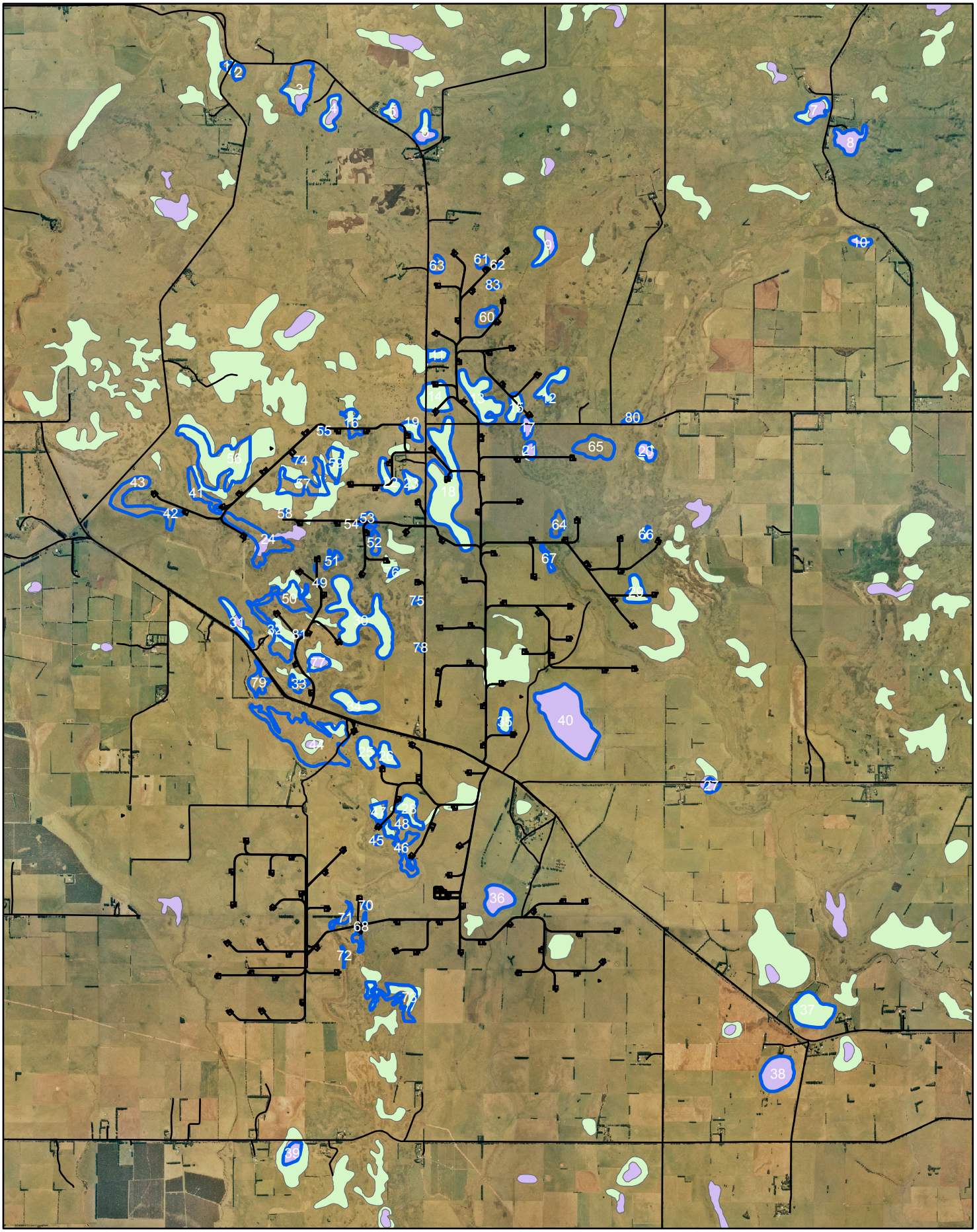


Figure 3. Distribution of wetlands and those surveyed for Brolga within the vicinity of the Macarthur Wind Farm.



3.0 RESULTS

3.1 Wetland habitat assessment

A total of 83 wetlands, ranging from small, shallow depressions to relatively deep permanent wetlands extending over several hectares, were assessed for potential Brolga breeding habitat and extent of filling (Figure 3). All other wetlands in the survey area were inaccessible being located on private property and were not visible from public roads.

A total of 45 of the 83 wetlands assessed were considered to be suitable breeding habitat for Brolga, including six wetlands known to be used for breeding by Brolga and three wetlands which were currently used by Brolga. All remaining wetlands were considered suitable only for foraging as they either lacked sufficient surface water for an adequate duration to successfully rear chicks to the fledging stage and/or lacked aquatic vegetation suitable for nest construction. Wetlands that were considered suitable breeding habitat for Brolga consisted of dense tussock grasses and aquatic vegetation and appeared as though they would sustain sufficient surface water throughout most of the breeding season. Wetlands assessed as potential Brolga breeding habitat and those known to be used by Brolga are depicted in Figures 4 - 6.

Wetlands assessed as potential Brolga breeding habitat varied substantially in habitat quality with many unlikely to be used for breeding due to their small areas but were included as potential Brolga breeding habitat as they provided adequate water and vegetation for nesting.

At the time of the wetland assessment on 10 and 11 November 2016, most of the 83 wetlands (54%) were dry or were estimated to be less than 25% of their surface water capacity (36%). Five wetlands (6%) were assessed to have between 25 and 50% of their surface water capacity, two wetlands had between 50 and 75%, whilst only one permanent wetland (Wetland 40), a deep dam of 57 ha, contained more than 75% of its storage capacity. Whilst this wetland may provide suitable Brolga breeding habitat in the shallower fringes where tussocks grasses and aquatic vegetation occur, most of the wetland is too deep for nesting. This wetland is most likely to be used for foraging, roosting or possibly flocking. Water levels within the 83 wetlands assessed are shown in Figures 7 – 9.

Figure 4. Wetlands assessed as potential Brolga breeding habitat and those known to be used by Brolga within the vicinity of the Macarthur Wind Farm.

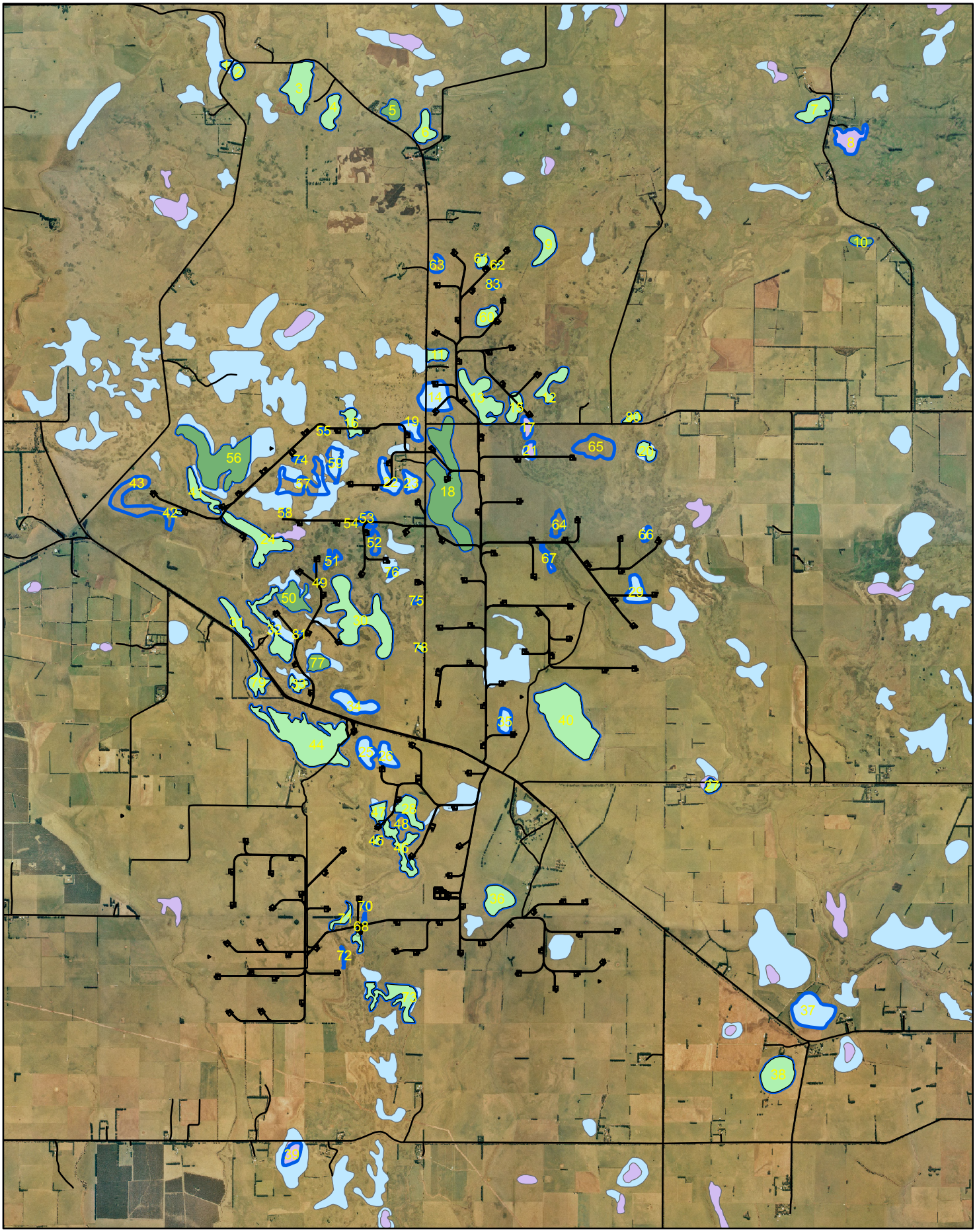


Figure 5. Wetlands assessed as potential Brolga breeding habitat and those known to be used by Brolga within the vicinity of the Macarthur Wind Farm - North section.

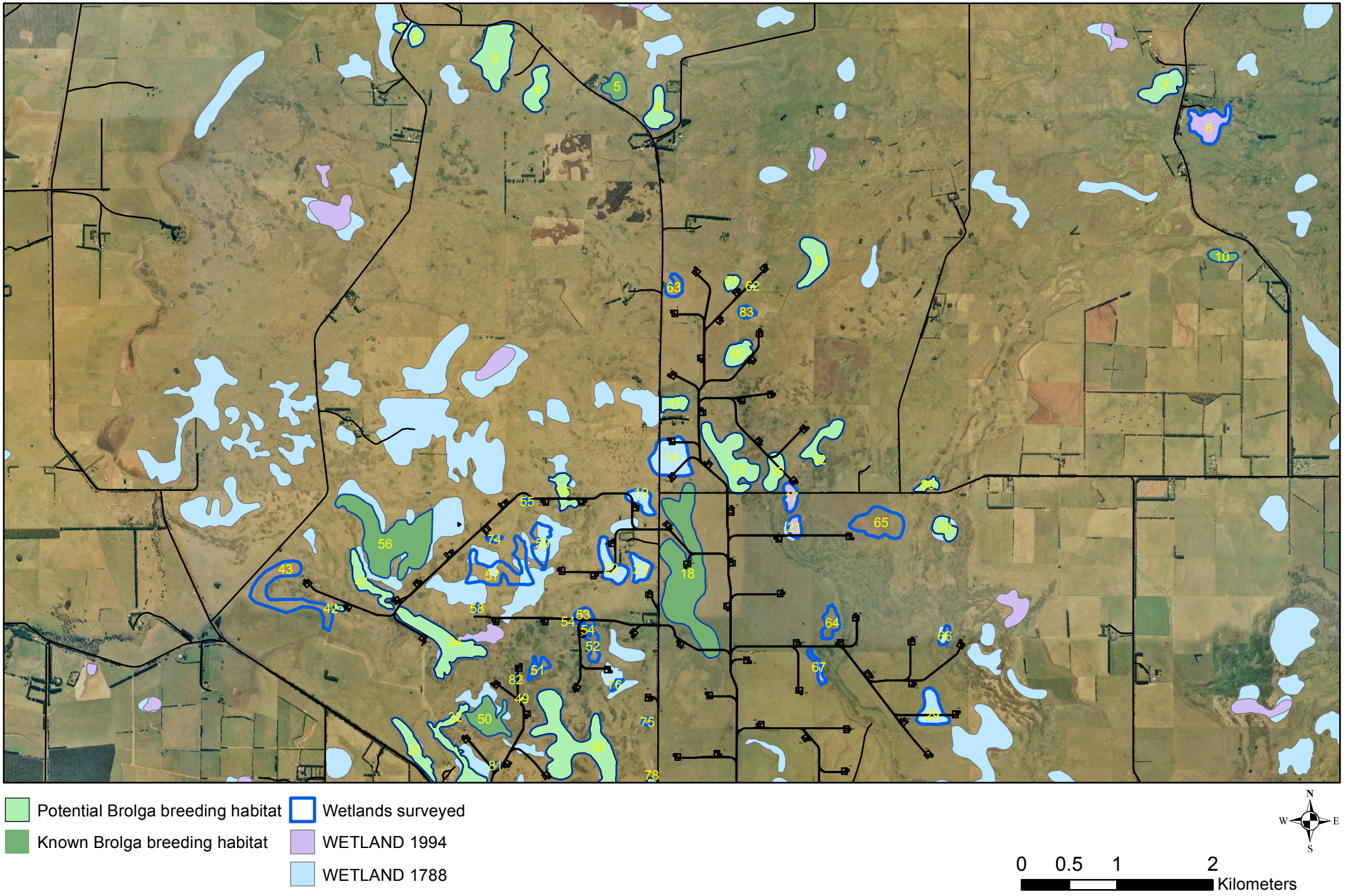


Figure 6. Wetlands assessed as potential Brolga breeding habitat and those known to be used by Brolga within the vicinity of the Macarthur Wind Farm - South section.

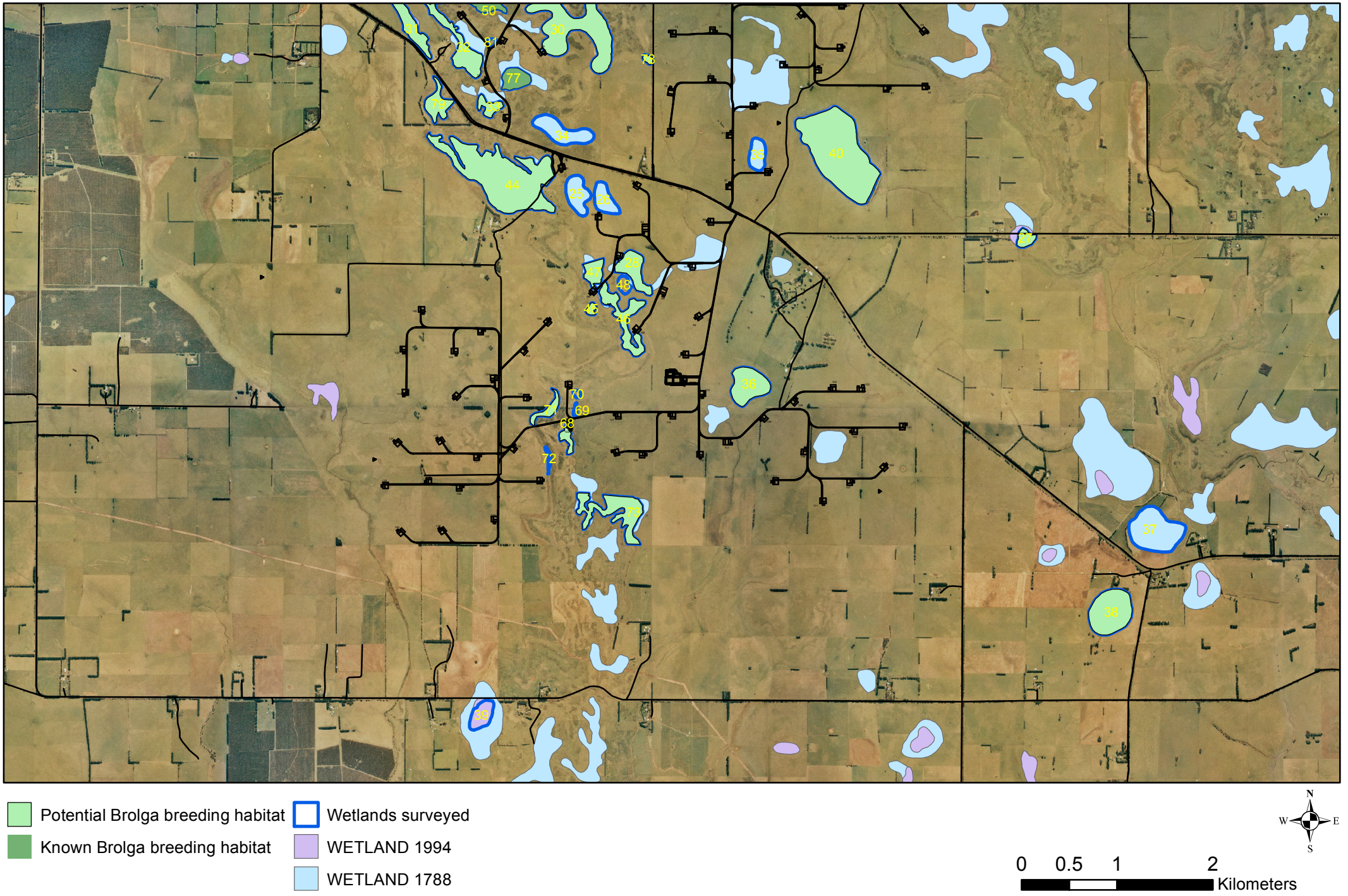


Figure 7. Extent of filling of wetlands surveyed as at 10 - 11 November 2016

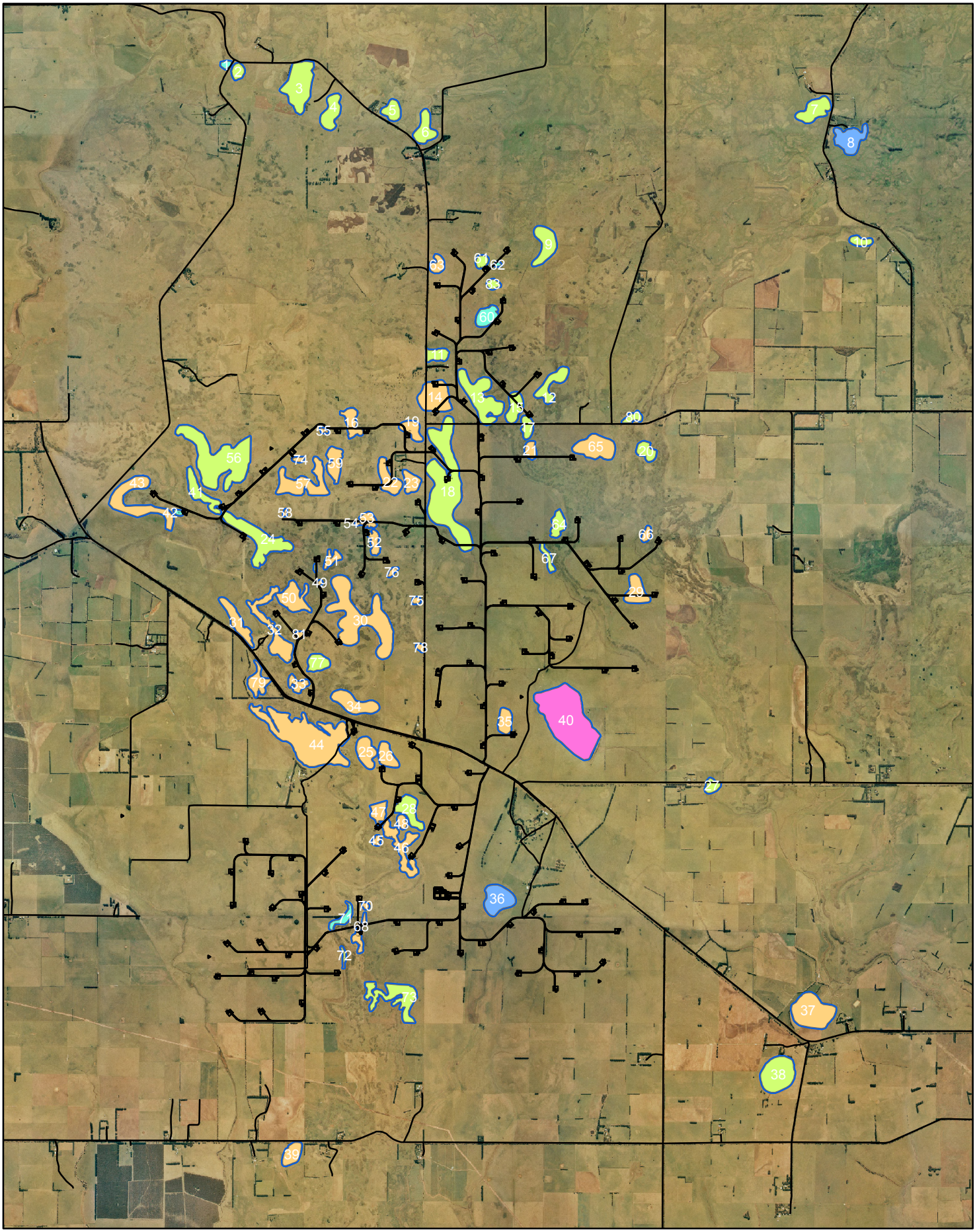


Figure 8. Extent of filling of wetlands surveyed as at 10 - 12 November 2016 - North section

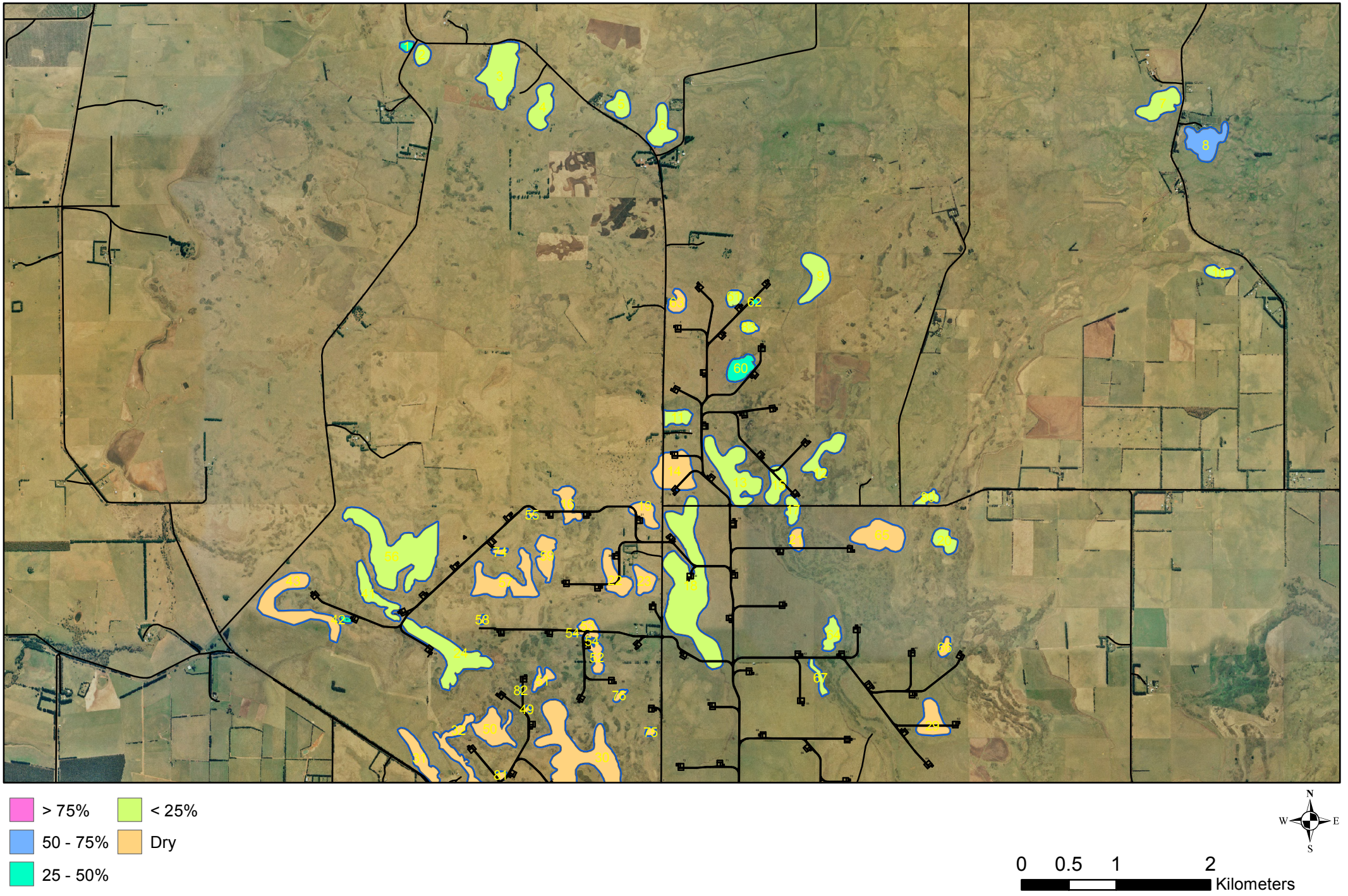
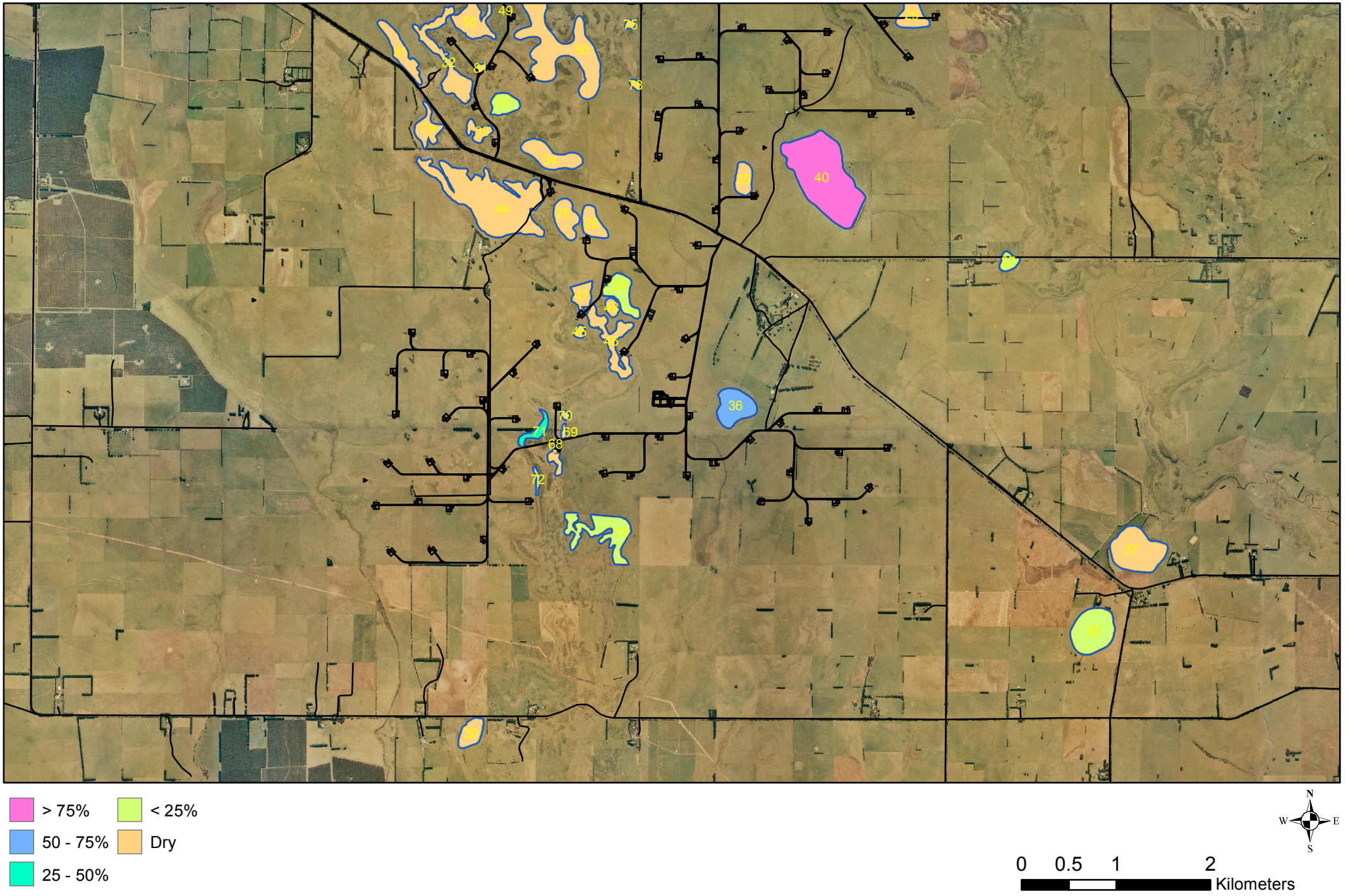


Figure 9. Extent of filling of wetlands surveyed as at 10 - 12 November 2016 - South section



3.2 Brolga abundance and habitat utilisation

During the breeding season of 2016 a total of seven Brolgas, consisting of three pairs and one chick, were found within 3 km of the wind farm. All utilised wetland habitats within the wind farm for most of the season. The following illustrates the locations and habitats in which these Brolgas were found and describes observations of behavioural activity.

Brolga pair 1

The first pair of Brolga, hereafter referred to as Brolga pair 1, were first seen foraging in and around Wetland 28 near Turbine #96 on 26 October. These birds were positively identified from distinctive feather markings and colouration as those that were first seen on the wind farm in 2012 with two chicks and which attempted nesting again during the following breeding seasons of 2013 and 2014. Maintenance staff of Vestas advised that this pair were seen nesting earlier in the season at Wetland 77, the same wetland where they attempted breeding in 2013, but again were unsuccessful and abandoned the nest.

During the next survey on 5 November 2016 this Brolga pair were found foraging in Wetland 18 near Turbine #20, approximately 4.6 km north of their previous location. The pair were observed for one hour recording their locations and behavioural activity at five-minute intervals. Both birds were seen to be foraging in and around the drain where surface water was still present during all 12 observations.

These birds were next seen on 11 November foraging in Wetland 13, approximately 1 km north-east of their previous location. Only one observation was recorded during this survey.

Neither bird was seen during the next roaming survey on 17 November but were found during the following survey on 25 November foraging in Wetland 18 near Turbine 30. Their activity was observed over one hour and were seen to be foraging during all 13 observations. This pair was not seen in any subsequent surveys. The observed locations of Brolga pair 1 during each survey are shown in Figure 10.

Brolga pair 2

This pair of Brolgas were first found on 26 October 2016 in Wetland 56 approximately 400m west of Turbine #34. They were observed to accompany a chick which appeared to be relatively well developed and was estimated to be approximately two months of age.

These Brolgas were found at the same wetland during the following survey on 5 November and were observed over one hour to record observations of activity every five minutes. All three birds were recorded to be foraging and walking around the area during all 13 observations.

This family of Brolgas were again seen foraging in Wetland 56 on 11 November but during the following survey on 17 November they were found to have left the wetland and had moved to Wetland 3, approximately 5 km north of their previous location.

On 25 November, all three birds were again found foraging at Wetland 3. Observations of activity over one hour showed all three birds walked slowly around and foraged during all 13 observations. These Brolgas were not found again during any subsequent survey. The observed locations of Brolga pair 2 during each survey are shown in Figure 11.

Brolga pair 3

During the first roaming survey on 26 October, a lone adult Brolga was observed foraging in Wetland 9 approximately 500m east of Turbine #1. However, during the next survey on 5 November, this Brolga was accompanied by a partner, both of which mostly walked around foraging in the southern section of the wetland. Behavioural observations over one hour determined that most time was spent foraging (85%) although both were observed to stand still and appeared to be resting during two of the 13 observations recorded.

Both Brolga were again found foraging in the same wetland during the next survey on 11 November but only one location was recorded during this survey.

On 17 November, the pair of Brolgas were observed foraging in close proximity to the drain and fence line which intersect the wetland. Both were initially found on the western side of the fence but were observed to fly approximately 180m south where one landed just over the other side of the fence whilst the other turned back towards the north and landed near its previous location but on the eastern side of the fence. Observations of these flights found that both were less than one minute and were at an altitude of approximately 2m above ground level. Following these flights each bird foraged separately in the wetland approximately 150m apart. Both birds were recorded foraging in all observations of activity other than when they were observed flying,

During the next survey on 25 November, only one of the Brolgas was found. This Brolga was observed foraging in Wetland 83, approximately 900m south-west of its previous location. After 20 minutes of observation, this Brolga was observed to fly a distance of approximately 1 km, returning to Wetland 9 where it continued walking around and foraging. The partner of this Brolga was not seen in the area but may have been obscured from view in dense tussock grasses. During all observations of this Brolga pair there was no indication of any attempted breeding. These Brolgas were not found again during any subsequent survey. The observed locations and flight paths of Brolga pair 3 during each survey are shown in Figure 12.

Figure 10. Observed locations of Brolga pair 1 during the breeding season of 2016

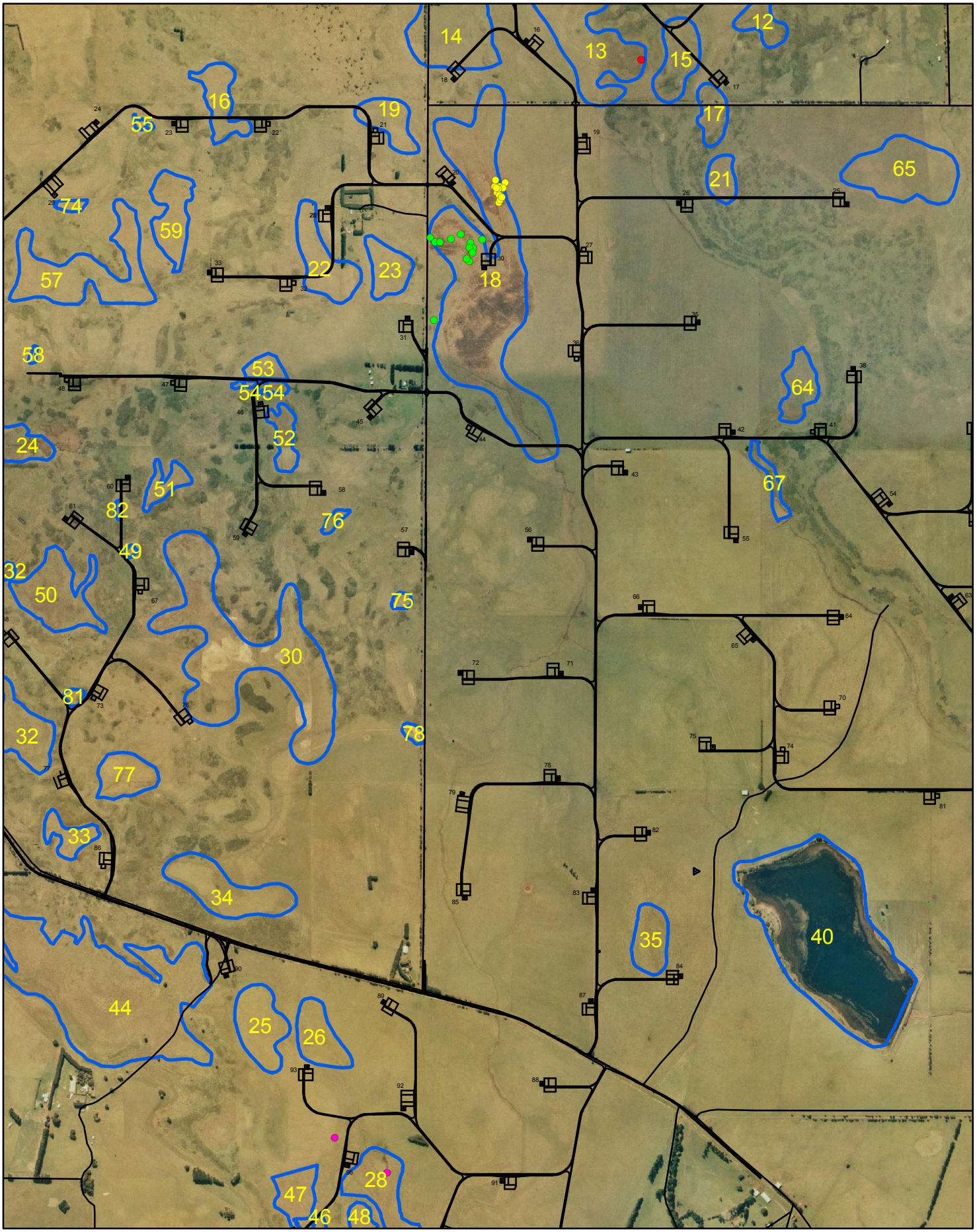


Figure 11. Observed locations of Brolga pair 2 during the breeding season of 2016

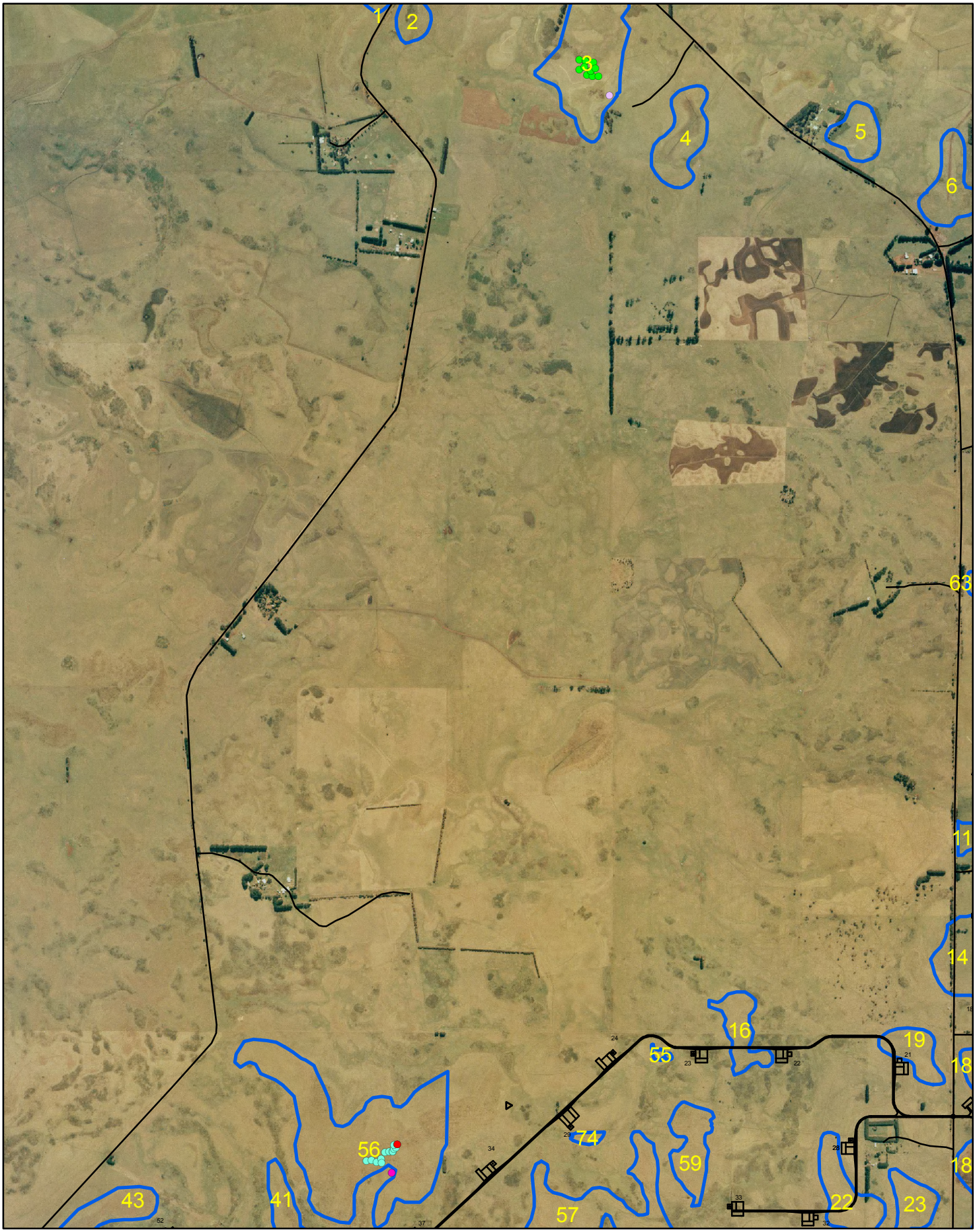
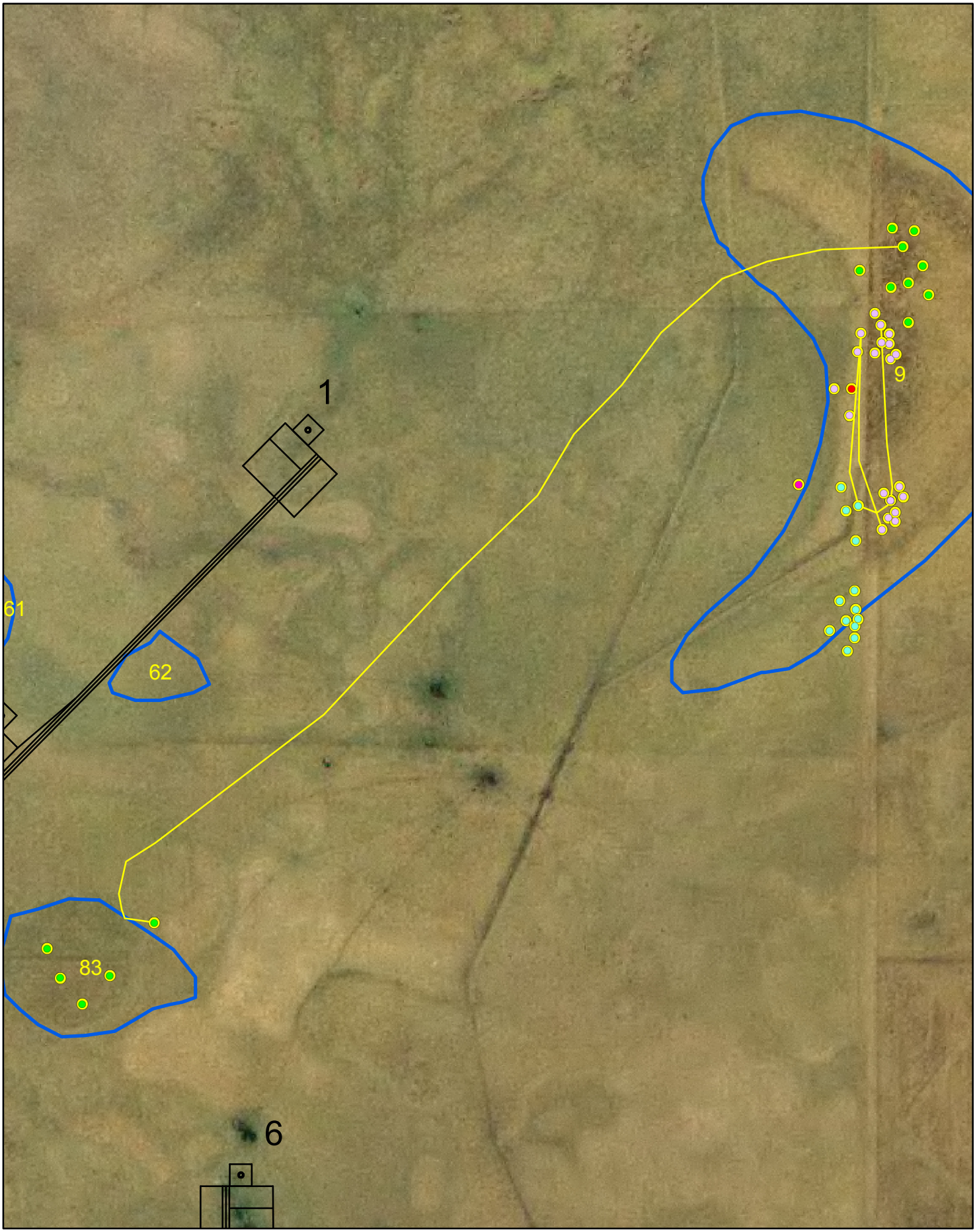


Figure 12. Observed locations of Brolga pair 3 during the breeding season of 2016



3.3 Impact of wet and dry climatic conditions on Brolga abundance and habitat utilisation

The Planning Permit for the Macarthur Wind Farm requires an assessment of the impact of wet and dry climatic conditions on the Brolgas' usage of habitat within the wind farm and close surrounds. Rainfall records from the Macarthur weather monitoring station since 1936 (Appendix 1) show that on average, the wettest months occur from May through to the end of October when average rainfall exceeds 70 mm in all months compared to less than 60 mm in the months from November through to the end of April (Table 1). These periods were respectively defined as 'wet' and 'dry' seasons for the purposes of examining the climatic conditions and the impact on brolga use of the wind farm, particularly in relation to the extent of wetland filling during the wet season. It is during the wettest months from May to October that cumulative rainfall would contribute mostly to the level of wetland filling and would be particularly relevant to Brolga utilisation of the wetland habitats.

To determine whether wet or dry climatic conditions occurred during the wet seasons of 2013 and 2014, the total rainfall recorded at Macarthur from May to October in each of these years was compared to the mean total rainfall during this period of 469.5 mm (Table 2). Rainfall from May to October of 2013 totalled 556.6 mm which was 87.1 mm above the average rainfall for this period whilst rainfall during the wet season of 2014 totalled 358.4 mm, being 111.1 mm less than the average rainfall for this period (Figure 13). Such variation from the mean rainfall was considered adequate to define the winter and spring of 2014 as 'dry' climatic conditions however, rainfall for the wet season of 2013 was not considered sufficient to be considered 'wet' climatic conditions. Rainfall from May to October 2016, however, totalled 609.9 mm, 140.4 mm higher than the average rainfall for this period. Such rainfall was considered sufficient to be characterised as 'Wet' climatic conditions.

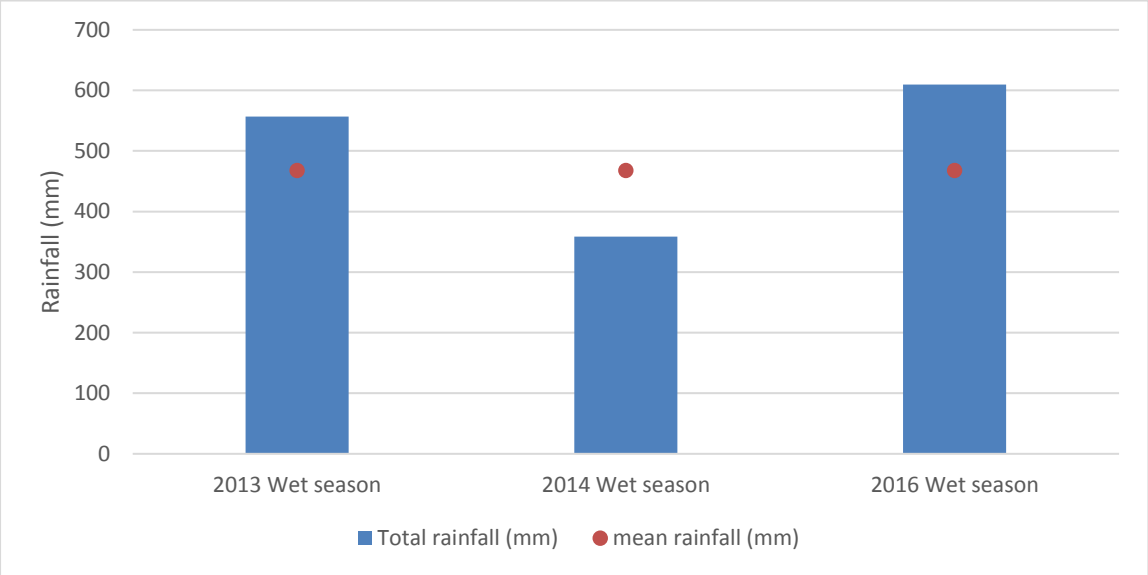
Table 1. Monthly rainfall (mm) at Macarthur.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2013	7.4	13.8	18.6	28.8	86.6	72.0	86.4	145.8	46.8	119.0	89.8	44.8	759.8
2014	19.0	19.4	42.1	71.6	85.2	98.0	61.3	63.6	29.7	20.6	17.2	24.2	524.9
2016	28.6	38.8	26.4	37.2	90.0	86.4	120.6	78.9	147.0	87.0	28.6	36.6	806.1
Mean since 1936	35.3	32.4	43.6	56.3	71.4	72.7	86.4	91.1	77.2	70.7	58.3	48.9	753.0

Table 2. Monthly rainfall (mm) at Macarthur from May to October (wet season).

Year	May	Jun	Jul	Aug	Sep	Oct	Total
2013	86.6	72.0	86.4	145.8	46.8	119.0	556.6
2014	85.2	98.0	61.3	63.6	29.7	20.6	358.4
2016	90.0	86.4	120.6	78.9	147.0	87.0	609.9
Mean since 1936	71.4	72.7	86.4	91.1	77.2	70.7	469.5

Figure 13. Mean and total rainfall during wet seasons (May – October) of 2013, 2014 and 2016 at Macarthur.



Figures 14 and 15 show the locations of all observations of Brolga within the vicinity of the Macarthur Wind Farm during the breeding seasons of 2014 and 2016. A total of 11 Brolgas, consisting of five pairs and one juvenile, were observed within the vicinity of the wind farm during the breeding season of 2014 compared to seven Brolga (3 pairs and 1 juvenile) in 2016. However, as roaming surveys in 2016 did not commence until late October, other Brolga may have utilised the area earlier in the season but vacated prior to the survey commencing. During 2014, two of the five Brolga pairs were observed to utilise wetland habitats on the wind farm only for a short period of time, one of which was seen on only one occasion and neither pair was seen after 8 July 2014. The other three Brolga pairs utilised the area for between one to four months and none were seen after the end of October 2014. In contrast, the three Brolga pairs that were observed utilising the wind farm site in 2016 all remained in the area until the end of November.

In 2014, two of the Brolga pairs constructed nests and attempted to breed but neither was successful at producing offspring to the fledging stage. One pair of Brolga hatched two chicks, one died soon after hatching possibly due to exposure to cold weather and the other was most likely taken by a predator at approximately 4 weeks of age. The other Brolga pair was observed to be incubating at least one egg during late July but had abandoned the nest by 6 August. During the breeding season of 2016 at least two pairs attempted to breed on the wind farm site, one of which successfully raised a chick to the fledging stage. There may, however, have been other attempts at breeding earlier in the season which were not detected due to the late commencement of the surveys.

It appears that the abundance of Brolga utilising wetland habitats on the wind farm and surrounding area does not vary substantially between ‘wet’ and ‘dry’ climatic conditions but the duration in which they occupy these habitats is longer.

Figure 14. Observed locations of Brolgas during the breeding seasons of 2014 and 2016 - North section

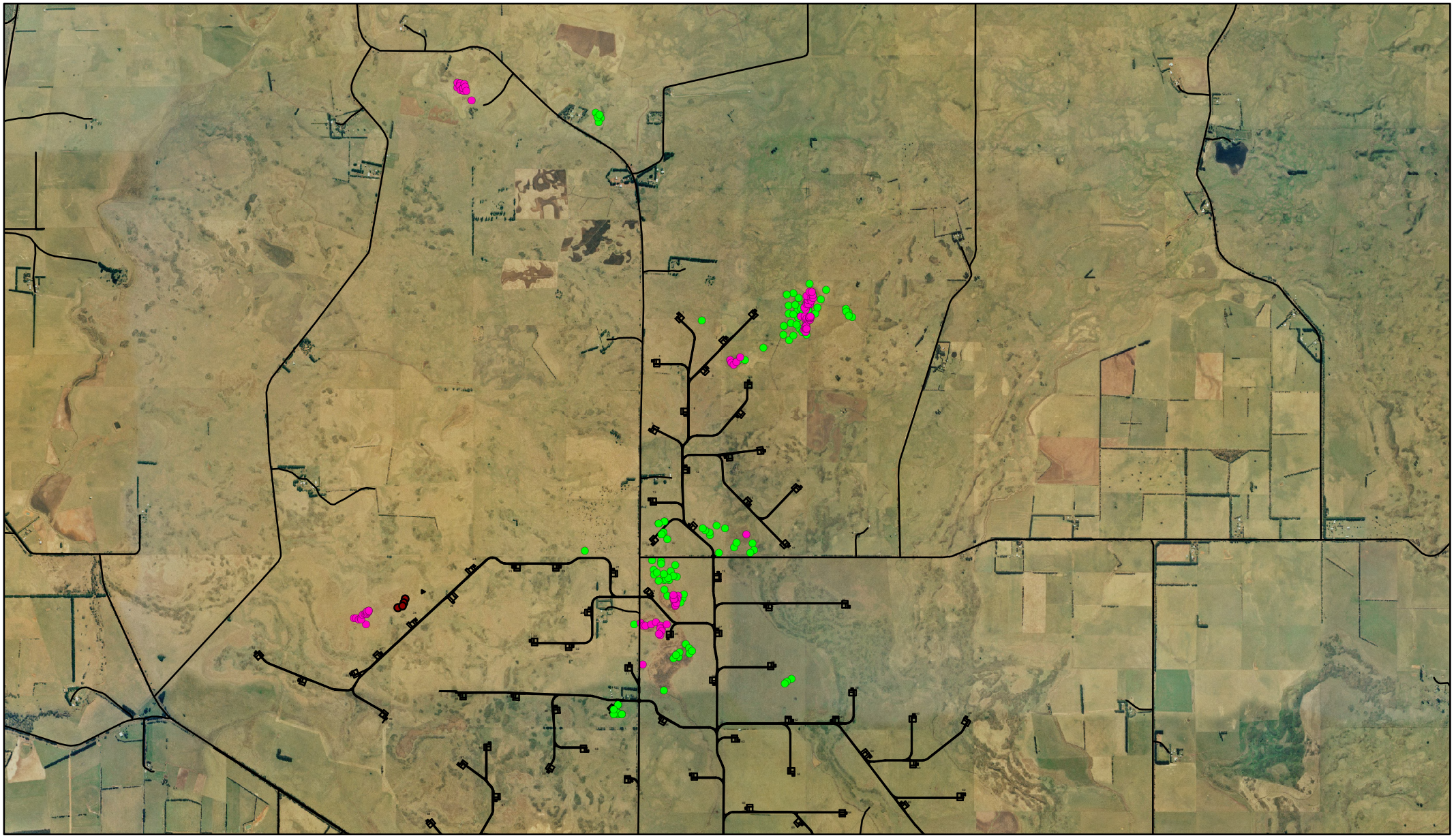
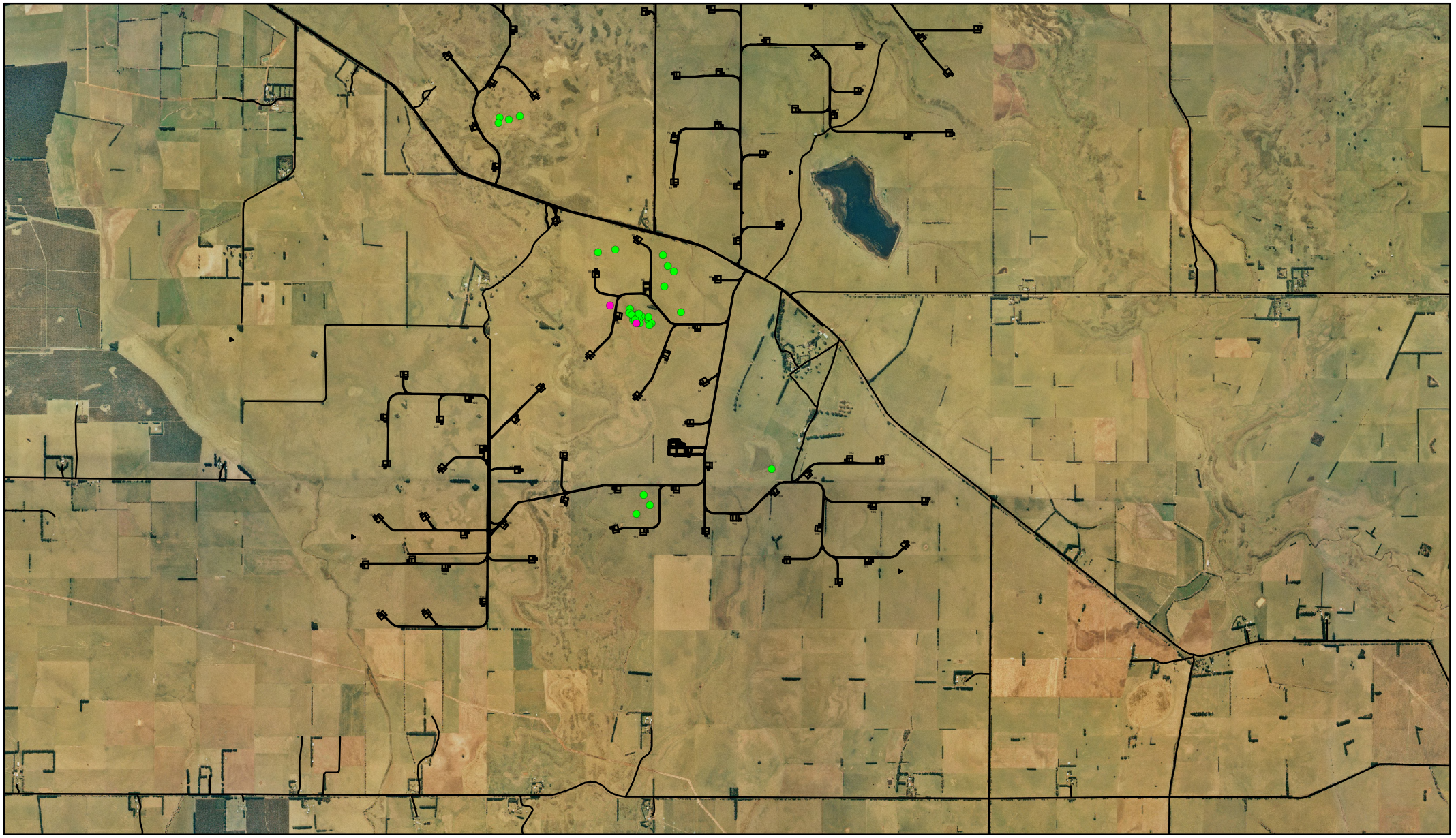


Figure 15. Observed locations of Brolgas during the breeding seasons of 2014 and 2016 - South section



4.0 DISCUSSION

Suitable breeding habitat for Brolga generally consists of shallow freshwater wetlands, less than 0.5m deep, with adequate cover of herbs, tussock grasses and sedges to provide material for nest construction (Merchant and Higgins 1993). There are a number of wetlands within the vicinity of the Macarthur Wind Farm which provide potential breeding habitat for Brolgas. During the current breeding season, three pairs of Brolgas were observed to utilise wetland habitats on the wind farm. One of these pairs produced and raised a chick to fledging stage and left the site in late November when the family migrated back to flocking sites. Breeding was attempted by one of the other Brolga pairs but was unsuccessful. Other attempts at breeding on the wind farm and surrounding wetlands may have occurred earlier in the season but were not detected due to the late commencement of roaming surveys, or at other wetlands which were not included in the survey due to their remote location on private property. Breeding habitats selected by Brolga on the Macarthur Wind Farm were typically relatively large wetlands, well vegetated with tussock grasses and sedges, and sustained surface water for a longer period than most other wetlands.

As Brolgas are known to use the same breeding sites throughout consecutive breeding seasons (Merchant and Higgins 1993), and usually defend these territories, it is likely that those observed during the current survey were the same individuals that occurred on the site in previous years including 2014. This may explain why the abundance of Brolga did not increase despite a greater extent of wetland filling during wet climatic conditions. Due to the widespread flooding across south-west Victoria in September 2016, those that use breeding habitats elsewhere in their range would have also had abundant surface water and suitable habitat for breeding. It is only if breeding habitat elsewhere was limited compared to at the wind farm or through population growth that the abundance of Brolga would be expected to increase at the Macarthur Wind Farm when juveniles disperse from their parents and establish their own home range.

At the time of the wetland habitat assessment on 10 and 11 November, 90% of wetlands assessed had less than 25% of their estimated storage capacity, most of which were dry. Ideally, this assessment should have occurred much earlier in the season when water levels were greatest. Of the 83 wetlands assessed, 45 were considered potential breeding habitat for Brolga as they contained abundant vegetation suitable for nest construction and appeared as though they would hold surface water for an adequate duration, even if some were dry at the time of the assessment.

The use of habitat by Brolga for breeding is largely determined by habitat quality, particularly by the amount of surface water present in wetlands. In the current survey, Brolgas were only found in wetlands that contained at least some surface water. In years of high winter/spring rainfall more surface water is present in wetlands for a longer period of time. Adequate surface water in wetlands throughout the length of the breeding season is an important factor contributing to the survival of Brolga chicks. Surface water not only deters some predators from approaching but also provides an abundance of food such as frogs, snails and insects as well as maintaining soft underlying soils in which Brolga can more easily forage for worms and vegetable matter such as tubers. This abundance of food enables chicks to develop well to fledging age when they can then accompany their parents to

flocking sites. The longer duration in which Brolgas were present at the wind farm in 2016 compared to in 2014 would primarily be due to the extended period in which surface water was present in wetlands.

The turbines of the wind farm do not appear to deter Brolgas from utilising existing habitat. The Brolga nest constructed on the wind farm during the 2014 breeding season was located approximately 200m from a turbine and Brolgas were observed on several occasions to forage within 100m from turbines. It has been suggested that wind turbines may create partial barriers to the movements of birds, forcing them to travel further and thereby increase their energy requirements (Drewitt and Langston 2006). Whilst Brolgas have only occasionally been observed in flight, the turbines did not appear to significantly obstruct their flight paths. On two occasions Brolgas were observed to fly at low altitude below the rotor-swept area of the turbine and on another occasion were seen to deliberately avoid the turbines when flying at altitudes within the rotor-swept area, diverting their course slightly to fly between turbines. The Brolgas seemed well aware of the turbine blades and consciously avoided these areas but appeared comfortable to fly between turbines.

The main potential impact of the wind farm on the local Brolga population is mortality arising from the collision with turbines or powerlines. Although a number of Brolgas use the wind farm site, the risk of collision with turbines seems relatively low considering their use is primarily only during the breeding season when they spend most of their time either foraging or incubating eggs and the frequency of flights is very low, typically less than two flights per day (Arnol *et.al*. 1984). During the current survey, Brolgas were observed to be foraging in almost all observations of behaviour, other than two observations of resting and three small flights. All flights were below 2 m in altitude and were less than 1 minute in duration. The overhead powerlines which run through the wind farm from Gerrigerrup-Minhamite Road to the Tarrone substation, approximately 12 km south of the wind farm may also pose a potential collision risk to Brolgas. Whilst Brolgas have been known to collide with power lines (Goldstraw and Du Guesclin 1991), Brolgas at the Macarthur wind farm have been observed to avoid collision by flying low underneath the powerlines. It is expected that the risk of collision with the high voltage powerlines of the Macarthur wind farm will be relatively low as these powerlines consist of several heavy gauge lines which are highly visible.

This Brolga monitoring project has determined that the Macarthur Wind Farm and surrounding landscape provides important breeding habitat for a number of Brolgas. The risk of collision with the blades of turbines appears to be very low considering the low frequency of flights, and apparent avoidance behaviour of Brolga when flying near turbines. The Macarthur Wind Farm does not appear to have had any detrimental impact on the local Brolga population, either from the direct impact with turbines or displacement from habitat.

5.0 REFERENCES

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Monthly Rainfall (millimetres)

MACARTHUR (POST OFFICE)

Station Number: 090055 · State: VIC · Opened: 1936 · Status: Open · Latitude: 38.03°S · Longitude: 142.00°E · Elevation: 80 m

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1936	70.4	0.8	30.1	50.2	30.5	81.5	77.0	128.7	52.9	87.2	22.1	105.8	737.2
1937	71.8	44.7	28.0	21.8	83.4	21.7	69.8	75.5	79.1	74.9	21.4	75.7	667.8
1938	32.5	52.7	24.1	61.0	39.0	118.5	53.6	51.2	39.4	28.1	32.8	36.3	569.2
1939	7.1	32.4	15.3	97.6	51.5	83.9	51.5	184.2	83.2	86.4	89.5	34.3	816.9
1940	70.1	29.4	24.5	81.1	56.2	53.1	105.1	41.8	35.6	28.8	78.0	51.0	654.7
1941	107.9	24.2	115.5	56.4	46.6	69.6	99.7	83.5	129.3	46.6	28.8	24.7	832.8
1942	42.7	29.7	34.8	39.0	157.0	57.8	100.3	118.4	94.6	29.8	62.0	45.5	811.6
1943	19.0	48.8	16.5	94.2	68.8	80.4	123.6	111.5	85.6	50.6	52.5	12.4	763.9
1944	19.1	43.9	14.7	83.7	114.0	33.3	75.5	24.6	52.8	93.7	34.3	70.2	659.8
1945	53.4	98.0	16.6	15.5	79.4	52.9	58.2	112.1	72.7	93.2	75.0	46.2	773.2
1946	101.5	101.4	472.7	32.5	52.9	78.8	119.3	84.7	82.1	49.5	29.4	57.5	1262.3
1947	25.5	28.1	127.9	48.3	30.8	92.9	123.0	85.6	54.3	88.3	61.2	55.4	821.3
1948	35.6	6.5	29.2	105.4	83.0	44.8	72.4	81.0	68.9	133.1	55.3	47.7	762.9
1949	33.8	80.8	26.1	21.0	69.3	61.2	58.4	45.8	45.5	157.6	112.6	19.5	731.6
1950	19.9	28.2	14.9	40.7	31.2	28.7	67.7	53.9	85.1	57.0	32.5	28.2	488.0
1951	24.1	50.7	1.3	116.3	138.0	60.9	127.5	128.1	42.7	98.2	46.5	60.2	894.5
1952	85.9	36.4	17.9	97.9	109.9	135.0	70.8	111.4	111.8	59.9	158.2	47.6	1042.7
1953	34.4	5.8	6.1	40.9	72.6	115.6	111.4	107.9	85.1	69.2	133.9	51.0	833.9
1954	30.5	27.3	24.3	93.6	52.5	90.2	65.9	53.0	84.4	70.2	72.1	30.5	694.5
1955	9.2	61.0	20.9	86.7	90.3	108.3	83.3	157.2	58.3	56.6	48.3	66.1	846.2
1956	34.2	3.0	55.8	87.5	58.1	121.7	75.4	133.8	57.8	91.5	51.4	51.1	821.3
1957	3.4	75.4	55.6	60.9	91.9	33.7	31.4	82.6	108.2	88.4	84.6	71.7	787.8
1958	20.2	62.1	33.2	25.3	123.2	52.2	107.7	129.3	69.4	92.6	53.1	24.6	792.9
1959	47.7	31.8	74.3	10.9	20.2	54.8	56.7	87.3	60.4	28.8	19.6	120.8	613.3
1960	34.2	80.5	45.5	113.2	115.2	60.2	91.8	81.1	137.1	75.5	77.5	19.9	931.7
1961	6.6	14.0	11.5	120.0	60.2	71.3	86.6	64.4	55.8	58.3	19.1	53.8	621.6
1962	16.7	36.8	33.7	23.4	90.6	95.2	36.9	68.8	52.5	94.7	25.1	29.0	603.4
1963	87.7	7.9	32.8	8.3	122.0	54.9	100.4	55.3	83.6	22.4	24.7	7.0	607.0
1964	18.4	51.9	32.2	39.8	70.6	104.7	169.0	82.2	92.3	89.2	74.1	65.7	890.1
1965	6.6	2.1	32.6	65.6	110.8	32.4	105.0	55.5	64.2	15.7	81.5	44.6	616.6
1966	27.5	27.8	41.5	60.6	35.4	43.6	139.2	96.6	75.6	48.1	48.3	113.8	758.0
1967	14.0	25.9	20.9	9.5	27.1	14.8	95.8	95.4	30.7	14.7	24.6	83.6	457.0
1968	4.3	16.6	35.8	69.3	147.5	91.9	87.6	115.9	49.9	116.7	91.2	25.4	852.1
1969	18.8	104.8	36.5	48.0	88.5	14.1	66.0	84.2	101.2	77.8	67.5	47.3	754.7
1970	61.7	5.6	74.8	74.4	71.9	59.9	98.7	162.4	51.2	40.4	82.5	87.9	871.4
1971	46.7	28.1	56.1	123.2	148.8	83.3	50.7	96.8	73.6	117.6	117.3	77.8	1020.0
1972	69.1	69.3	31.8	80.1	28.8	38.8	107.7	74.9	36.6	49.2	69.1	3.3	658.7
1973	17.5	91.2	60.7	67.5	76.3	73.1	68.2	78.8	101.8	140.3	50.8	51.8	878.0
1974	36.4	20.6	33.8	71.2	55.6	30.2	154.2	77.0	105.6	70.2	50.0	55.0	759.8
1975	18.4	8.8	88.4	32.2	91.2	63.8	131.4	125.6	91.8	201.6	80.8	15.6	949.6
1976	13.8	32.0	32.2	42.0	43.6	91.2	33.4	126.8	102.8	157.0	75.4	55.0	805.2
1977	38.0	18.0	50.6	45.8	78.6	140.0	75.8	44.4	49.0	32.0	99.4	22.2	693.8
1978	18.6	24.6	33.0	76.2	99.8	60.9	137.8	116.6	111.4	65.0	90.4	57.2	891.5
1979	21.4	12.0	27.0	59.7	39.2	46.8	49.4	94.2	118.4	89.2	92.4	27.1	676.8
1980	55.0	2.4	0.6		64.8	67.8	66.8	59.8	78.0	86.0	46.0	35.7	
1981	42.6	10.0	14.8	15.0	84.6	93.4	135.6	135.0	45.4	52.0	24.8	14.6	667.8
1982	37.0	3.0	56.4	37.8	64.0	58.6	38.0	12.6	51.4	45.8	14.4	22.8	441.8
1983	32.3	0.0	174.4	85.0	117.2	74.0	100.3	98.7	132.8	41.2	78.2	14.6	948.7

Quality control: 12.3 Done & acceptable, *12.3* Not completed or unknown

Monthly Rainfall (millimetres)

MACARTHUR (POST OFFICE)

Station Number: 090055 · State: VIC · Opened: 1936 · Status: Open · Latitude: 38.03°S · Longitude: 142.00°E · Elevation: 80 m

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1984	18.0	7.8	110.8	36.2	34.0	42.0	108.0	87.5	136.0	52.9	69.8	34.4	737.4
1985	12.0	8.8	56.3	56.6	78.2	116.6	72.4	81.8	58.5	84.0	77.4	154.0	856.6
1986	26.4	10.6	11.4	71.6	92.1	67.4	108.2	96.0	80.6	123.2	29.8	103.4	820.7
1987	46.0	35.6	25.0	27.4	152.6	75.8	46.6	62.2	36.2	50.5	35.8	85.2	678.9
1988	42.0	24.6	42.6	26.6	51.5	105.3	66.3	84.7	71.6	70.1	76.2	46.2	707.7
1989	19.4	28.0	36.3	40.4	62.8	82.4	88.2	103.4	77.4	113.0	35.0	34.2	720.5
1990	5.6	71.4	40.6	31.8	17.4	93.4	83.8	142.4	90.8	68.4	39.8	35.6	721.0
1991	71.2	2.4	34.2	29.4	21.4	118.2	103.8	123.2	101.4	24.6	62.6	47.8	740.2
1992	19.4	33.6	37.2	121.6	56.2	101.2	85.4	121.4	134.8	94.0	133.4	48.6	986.8
1993	13.0	19.0	40.0	8.0	36.2	74.8	51.6	117.4	120.9	89.0	45.6	91.4	706.9
1994	47.0	14.0	1.6	64.0	82.2	54.6	58.2	56.8	97.6	74.8	54.4	37.0	642.2
1995	26.6	23.8	60.8	135.6	61.0	77.8	113.2	72.8	71.2	20.2	33.6	50.6	747.2
1996	57.6	15.6	30.6	74.0	13.8	91.6	125.0	115.2	121.2	58.0	21.2	29.4	753.2
1997	48.6	8.4	15.8	29.4	81.4	39.4	49.5	72.2	83.4	40.6	81.2	13.6	563.5
1998	28.6	29.0	13.8	63.2	35.2	106.2	80.0	35.8		60.6	51.8	24.4	
1999	16.8	61.2		21.2	63.8	44.6	38.5	69.5	65.4		68.4	63.8	
2000	27.8	12.4	14.6	67.7	129.3	50.2	94.0		114.2	104.6	40.8	25.0	
2001	9.2	16.0	49.1	65.1		54.4	42.3	185.3	61.2	162.0	91.0	50.6	
2002	32.2		21.4	32.4	48.8	97.4	109.0	54.6	78.6	62.6	47.0	40.4	
2003	36.4	53.6	65.2	25.2	39.4	118.0	73.6	102.2	73.2		39.2	42.8	
2004	44.4	38.2	57.2	46.6	43.6	158.2	103.4		*72.2*			65.4	
2005	35.8	83.0	14.0	27.4	21.8	72.2	41.6	78.0	64.8	50.8	38.6		
2006		44.0	25.2	63.3	48.1	24.0	82.8	34.2	70.8	21.3	24.6	21.0	
2007	105.4		27.8	46.4	116.2	71.4	111.6	79.4	74.8	37.6	134.6	31.8	
2008	18.2	32.0	33.0	40.4	40.2	42.0	120.0		49.0	16.0	56.0	131.6	
2009	3.8	0.0	30.4	54.6	44.8	54.6	109.4	101.6	92.2		42.8	37.4	
2010	11.6	46.4	32.6	56.6		65.2	77.0	166.6	87.0	75.3	47.6	127.2	
2011	110.7	43.6	63.4	103.8	63.8	65.8		57.6	38.0	72.7	34.8	23.8	
2012	23.2	15.2	51.2	19.2	87.4	107.0	106.4	111.6	46.7	27.4	24.4	22.2	641.9
2013	7.4	13.8	18.6	28.8	86.6	72.0	86.4	145.8	46.8	119.0	89.8	44.8	759.8
2014	19.0	19.4	42.1	71.6	85.2	98.0	61.3	36.6	29.7	20.6	17.2	24.2	524.9
2015	68.6	13.6	20.2	47.6	71.4	67.8	86.4	58.2	53.6	5.0	32.9	19.2	544.5
2016	28.6	38.8	26.4	37.2	90.0	86.4	*120.6*	*78.9*	*147.0*	*87.0*	*28.6*	*36.6*	806.1

Quality control: 12.3 Done & acceptable, *12.3* Not completed or unknown

Monthly Rainfall (millimetres)

MACARTHUR (POST OFFICE)

Station Number: 090055 · State: VIC · Opened: 1936 · Status: Open · Latitude: 38.03°S · Longitude: 142.00°E · Elevation: 80 m

Statistics for this station calculated over all years of data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean	35.3	32.4	43.6	56.3	71.4	72.7	86.4	91.1	77.2	70.7	58.3	48.9	753.0
Lowest	3.4	0.0	0.6	8.0	13.8	14.1	31.4	12.6	29.7	5.0	14.4	3.3	441.8
5th percentile	6.6	2.4	11.1	14.8	21.8	28.7	38.5	36.5	36.6	19.4	21.1	14.6	529.8
10th percentile	9.0	5.1	14.5	21.2	30.7	33.7	49.1	49.6	45.1	23.7	24.6	19.5	586.3
Median	28.6	28.0	32.6	52.4	68.8	71.3	85.9	84.7	74.2	69.2	51.6	45.2	754.0
90th percentile	70.5	72.2	66.1	98.5	118.2	115.6	123.7	134.2	118.7	118.2	91.3	88.2	913.1
95th percentile	88.4	83.8	111.0	116.5	138.9	118.5	135.7	158.0	132.9	143.6	118.1	114.2	977.5
Highest	110.7	104.8	472.7	135.6	157.0	158.2	169.0	185.3	147.0	201.6	158.2	154.0	1262.3

Statistics calculated over the period 1961-1990

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean	29.3	26.7	44.5	53.3	76.9	69.6	90.3	89.3	76.9	76.2	59.7	50.1	747.1
Lowest	4.3	0.0	0.6	8.3	17.4	14.1	33.4	12.6	30.7	14.7	14.4	3.3	441.8
5th Percentile	6.1	2.2	11.4	11.7	27.9	21.7	37.4	49.3	36.4	18.7	21.6	10.4	515.6
10th percentile	6.6	2.9	14.5	21.7	33.5	32.2	45.7	55.5	44.5	31.0	24.7	14.6	606.3
Median	20.4	19.3	34.8	48.0	74.1	69.6	87.9	86.1	76.5	69.2	68.3	45.4	737.4
90th percentile	55.7	69.5	76.2	81.1	124.6	104.8	137.9	127.6	112.1	124.9	91.3	89.4	902.9
95th percentile	65.8	82.3	100.7	106.0	148.2	111.5	147.4	139.1	126.3	149.5	96.2	109.1	949.2
Highest	87.7	104.8	174.4	123.2	152.6	140.0	169.0	162.4	136.0	201.6	117.3	154.0	1020.0

1) Calculation of statistics

Summary statistics, other than the Highest and Lowest values, are only calculated if there are at least 20 years of data available.

2) Gaps and missing data

Gaps may be caused by a damaged instrument, a temporary change to the site operation, or due to the absence or illness of an observer.

3) Further information

http://www.bom.gov.au/climate/cdo/about/about-rain-data.shtml.