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Environmental & Social Consultants

2018 GOLDEN SUN MOTH MONITORING REPORT

Yarralumla Equestrian Park

FINAL

April 2019

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Yarralumla Equestrian Park

FINAL

Prepared by
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on behalf of
Suburban Land Agency

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Executive Summary

Umwelt Australia Pty Ltd prepared this monitoring report on behalf of the ACT Government Suburban Land Agency to meet the 2018 annual reporting requirements of the Yarralumla Equestrian Park Offset Management Plan (RJPL 2014a, the OMP). This report fulfils the reporting requirements for golden sun moth (*Synemon plana*, GSM) monitoring at the YEP for year 5 as specified in the OMP.

Results

The key results of the 2018 monitoring program are:

- The spatial extent of NTG has not increased or declined. The extent of native pasture at the site has declined due to perennial exotic tussock grass invasion.
- While the total extent of GSM habitat has increased since 2013, the extent of moderate quality habitat has decreased. This is correlated with exotic perennial tussock grasses invading the site, and is indicative of a general decline in GSM habitat quality at the YEP.
- Floristic value scores and grassland ranking scores were close to or slightly below average in 2018.
- GSM habitat ranking scores continue to gradually decline at YEP.
- Record high numbers of flying moths were recorded in 2018. The timed traverse and rotational point count surveys indicated that the abundance of GSM in sampled areas were the highest observed since monitoring commenced in 2013. To date there has been no evidence of a decline in the GSM population at YEP despite substantial recent changes in grassland composition across the site.

The substantial increase in the distribution of perennial exotic tussock grasses such as African lovegrass and Chilean needle grass represents a major threat to the extent and condition of native grassland and moderate quality GSM habitat at YEP, and hence compliance with the offsetting requirement of the Commonwealth approval conditions. Weed control measures aimed at preventing future expansion of exotic tussock grasses into sensitive areas commenced in June 2018.

The findings of this monitoring report confirm that key threats to the offset detailed in the 2017 Yarralumla Equestrian Park monitoring report (SMEC 2018) have continued to increase.

Recommendations

The management recommendations outlined in the 2017 Yarralumla Equestrian Park monitoring report (SMEC 2018) relating to the maintenance and restoration of the offset remain relevant. The offset management plan should be reviewed and updated to incorporate a long term weed management strategy, specify effective management actions and define clear, practicable trigger thresholds.

Of critical priority, and requiring action independent of the management plan review process, weed control aimed at preventing expansion of African lovegrass, Chilean needle grass and serrated tussock in areas of NTG and native pasture should be continued as specified in the interim weed management plan (Umwelt 2018) until a long term weed management strategy is provided as part of the offset management plan review processes.

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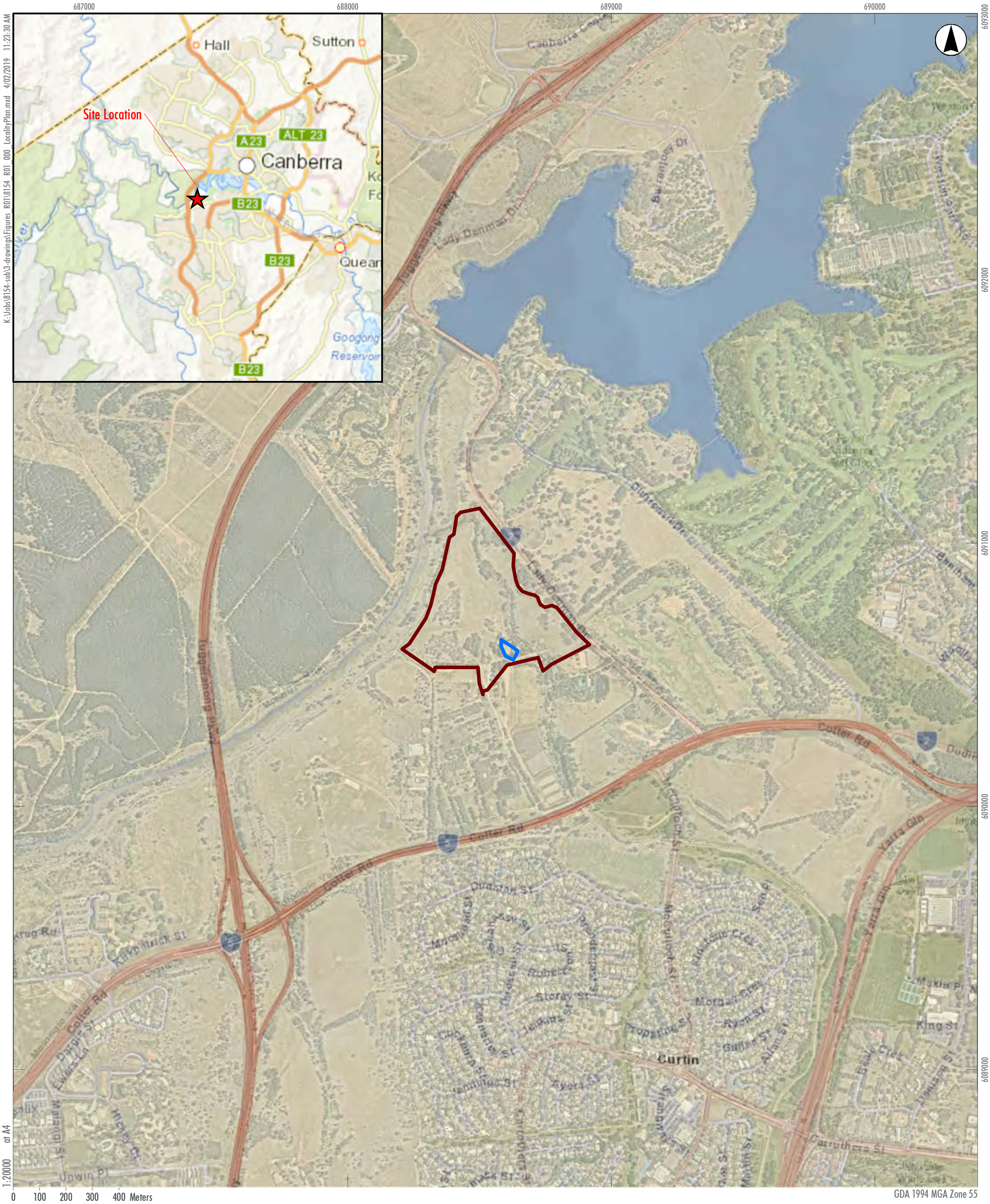
1.0 Introduction

Umwelt Environmental Pty Ltd prepared this monitoring report on behalf of the ACT Government Suburban Land Agency to meet the 2018 annual reporting requirements of the Yarralumla Equestrian Park Offset Management Plan (RJPL 2014a, the OMP). The OMP was prepared to meet specific offset requirements of the Commonwealth Department of Environment and Energy (DoEE) Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) approval decision (EPBC 2012/2692) for mixed-use development proposed for Campbell Section 5, Constitution Avenue, ACT.

The OMP details the requirement for ongoing monitoring of EPBC Act listed endangered Natural Temperate Grassland of the Southern Tablelands of NSW and the Australian Capital Territory, and the EPBC Act listed critically endangered golden sun moth (Synemon plana, GSM) populations at the Yarralumla Equestrian Park (YEP) offset area (RJPL 2014a). Subsequent to the approval, the listing of endangered Natural Temperate Grassland of the Southern Tablelands of NSW and the Australian Capital Territory has been revised under the EPBC Act, and areas within the ACT formerly within this community are now classified as the EPBC Act listed critically endangered Natural Temperate Grassland of the South- Eastern Highlands (Australian Government 2016). In this report, the former endangered ecological community and the revised critically endangered ecological community are collectively referred to as natural temperate grassland (NTG) except where a specific reference to the listed ecological community is required.

This report presents the results of monitoring surveys undertaken in November and December 2018 in the YEP offset area (see **Figure 1.1**). The results are briefly examined in relation to existing site information and the baseline year (i.e. year 0), year 1, year 2, year 3 and year 4 monitoring data collected during spring and summer from 2013 to 2017 (RJPL 2014b; RJPL 2015; SMEC 2016; SMEC 2017; SMEC 2018). The implications of results are considered in relation to impact thresholds identified in the OMP.



Legend

Yarralumla Equestrian Park Lady Pony Club

Yarralumla Equestrian Park Boundary

FIGURE 1.1

Locality Plan

Image Source: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, © OpenStreetMap contributors, and the GIS User Community Data source:

2.0 Methods

2.1 Regional GSM Information

The start of the GSM flying season was confirmed using known reference sites in the ACT and based on information from other consultants in the ACT, and Conservation Planning and Research, ACT Government (CPR). ACT researchers and consultants shared information regarding the timing and location of GSM sightings, particularly the start of the flying season, via email on a weekly basis during the GSM flying season.

2.2 Survey Area

The survey area comprised the YEP offset area defined in the OMP (RJPL 2014a) (**Figure 2.1**). Traverse routes were located, as defined in the OMP (RJPL 2014a) (**Figure 2.1**). Corrected locations for vegetation quadrats and point-count assessment reported in the year 0 baseline assessment report (RJPL 2014b) were used.

2.3 Revised Vegetation and GSM Habitat Assessment

Mapping of vegetation and potential GSM habitat areas presented in the OMP (RJPL 2014a) and the year 0 (i.e.2013), year 1 (i.e. 2014), year 2 (i.e. 2015) and year 3 (i.e. 2016) monitoring reports (RJPL 2014b; SMEC 2016, SMEC 2017) was reviewed by conducting a meandering traverse throughout the site, with close inspection of native pasture and NTG areas.

2.4 Native Pasture and Natural Temperate Grassland Monitoring

The condition of native pasture and NTG was assessed in twelve 4 m^2 quadrats located throughout the YEP offset area, as described in the year 0 (i.e. 2013) monitoring report (RJPL 2014b). Quadrats were qualitatively assessed using the NTG quality scale of Nash and Hogg (2013, Appendix E to the OMP (RJPL 2014a)). Nash and Hogg's (2013) criteria for the quality scale are based on criteria used for identifying NTG, as specified in the former Commonwealth listing advice for endangered Natural Temperate Grassland of the Southern Tablelands of NSW and the Australian Capital Territory (Australian Government 2011).

As specified in the OMP (RJPL 2014a), a modified version of Rehwinkel (2007) was used to quantitatively determine relative floristic value scores for native pasture and NTG within each quadrat (Appendices C and D of the OMP (RJPL 2014a)), consistent with ACT Government guidelines for assessing NTG (ACT Government 2010a). To ensure consistency and allow comparison with previous years, quadrats were assessed using the floristic value scores based on Rehwinkel (2007).

NTG condition was reviewed against criteria for the revised NTG community listing (Australian Government 2016). Threshold values for determining the classification of NTG were determined from Australian Government (2016). Floristic value scores referenced in these thresholds relate to the updated method of Rehwinkel (2015) and are not comparable to those based on Rehwinkel (2007).

To meet criteria for classification as NTG, the patch must be >0.1 hectares (e.g. 20 m x 50 m), within the defined region and altitude, and apparently naturally treeless or sparsely treed, and it must meet criterion A or B:

- Criterion A: contains a foliage cover of more than 50% Themeda triandra (Kangaroo Grass) or Poa labillardierei (River Tussock) – or Carex bichenoviana (Plains Sedge) if the patch is an ephemeral wetland

- Criterion B: contains a greater percentage cover of native plants (including annual and perennial species but not cryptogams) than of perennial exotic species (including weeds), AND in favourable sampling times (generally spring and early summer, and in non-drought affected seasons) it has:

    - at least 8 non-grass native species, or

    - at least 2 indicator species, or

    - a floristic value score of at least 5

    OR at other sampling times it has:

    - at least 4 non-grass native species, or

    - at least 1 indicator species, or

    - a floristic value score of at least 3.

Thresholds for favourable sampling times were applied.

Due to the modified sampling method applied to the detailed vegetation assessment (i.e. the use of 4 m x 4 m quadrats rather than 20 m x 20 m quadrats), failure of sites to meet one of the three floristic diversity thresholds does not indicate that the site does not meet thresholds for inclusion in the critically endangered NTG community.

Due to the absence of a minimum size criteria for the former EPBC Act listed endangered Natural Temperate Grassland of the Southern Tablelands of NSW and the Australian Capital Territory, the minimum size restriction was not considered as part of the thresholds when monitoring the extent of NTG at this site. Application of this threshold would result in artificial changes in the extent of NTG present.

2.5 GSM Flying Surveys

Flying GSM surveys were conducted in a manner consistent with the ACT Government (2010b) GSM survey guidelines and specifically according to the protocol outlined in the OMP (RJPL 2014a Appendix F). In conjunction with the required survey methods as specified in the OMP (RJPL 2014a) (i.e. rotational point counts, timed traverse) fixed transect surveys were conducted during the 2018/19 GSM flying season to improve consistency with GSM monitoring elsewhere in the ACT.

As specified in the OMP (RJPL 2014a), rotational point counts were conducted at the monitoring quadrats located throughout the YEP offset area according to the following protocol:

- Locate each of the quadrats used for the vegetation and habitat assessments using GPS

- While standing in the middle of each quadrat, count all GSM observed in and beyond the quadrat to approximately 20 m while rotating through 360^{o}

- Record GSM numbers on the Flying GSM survey data sheet (RJPL 2014a Appendix G)

- Wait 30 seconds

- Repeat Steps 2-4, nine more times
- Average the GSM count at each site and enter result on the flying GSM survey data sheet (RJPL 2014a Appendix G).

A timed traverse survey was undertaken, as specified in the OMP (RJPL 2014a Appendix F). During the 2013 baseline survey, the transect route indicated in Figure 5 of the OMP (RJPL 2014a) was confirmed as an appropriate route for the timed traverse survey. As specified in the OMP (RJPL 2014a), the following protocol was followed:

- Follow the mapped traverse identified in the OMP as closely as practicable
- Note the time when starting to walk the traverse
- Count all GSM observed while walking slowly and steadily along the traverse
- Note the time once the traverse is completed
- Record GSM numbers and times on the Flying GSM survey data sheet (RJPL 2014a Appendix G)
- Calculate the number of GSM observed per minute.

Timed transect surveys were conducted at 16 transects, each measuring 100 metres covering the main areas of grassland at YEP. The timed transect surveys were added to the survey program at YEP in 2018 to improve consistency with standard ACT Government GSM survey programs to allow standardised between-site analysis in flying moth numbers. The following protocol was followed:

- Follow the pre-defined 100 metre transects
- Note the time and weather conditions when starting to walk each transect
- Count all GSM observed while walking slowly and steadily along transects
- Note the end time of each transect survey
- Record data as per the ACT Government GSM Survey Protocol
- Calculate the number of GSM observed per minute.

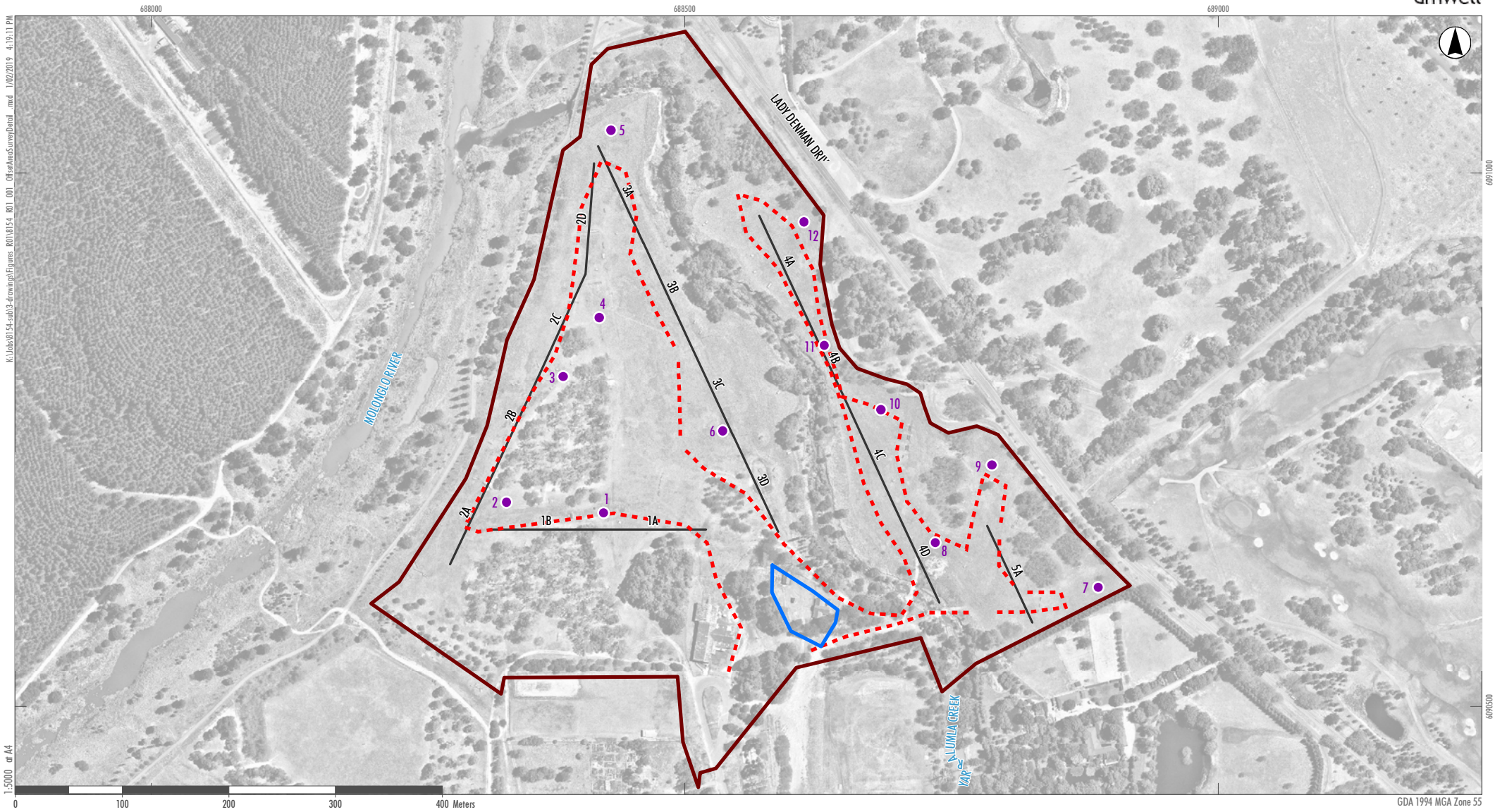
On-site weather data was recorded during all flying GSM field surveys. Incidental GSM observations were also recorded during other site visits and between surveys.

2.6 GSM Habitat Monitoring

As specified in the OMP (RJPL 2014a), a qualitative GSM habitat assessment was undertaken in each of the twelve monitoring quadrats using the GSM habitat quality scoring system of Hogg (2012, Appendix H of the OMP), which takes into consideration both grassland condition and GSM activity.

2.7 Meteorological Data

Meteorological data for Canberra Airport from 1 January 2013 to 31 December 2018 was obtained from the Bureau of Meteorology.



Legend

- Yarralumla Equestrian Park Lady Pony Club
- Yarralumla Equestrian Park Boundary
- Yarralumla Equestrian Park Meandering Traverse
- Indicative GSM Transects
- Plot Locations

FIGURE 2.1

Yarralumla Equestrian Park
Offset Area and Survey Details

Image Source: Nearmap (2018) Data source: Umwelt (2018)

3.0 Results

3.1 Regional GSM Information

Golden sun moth surveys commenced during the known local flight season, based on informal consultation with local specialists (including ACT and New South Wales Government ecologists and consultants). The first local records of the 2018 season were on 26 October in Jerrabomberra East, and the flying season was confirmed at numerous sites by early November (between 4 and 11 November). This is relatively early for the start of the local season and is likely a result of the hot and dry spring conditions. Sporadic and isolated flying moths were still being recorded in early January 2019; however, the local season appeared to be predominantly over by mid-December 2018.

3.2 Vegetation and GSM Habitat Mapping

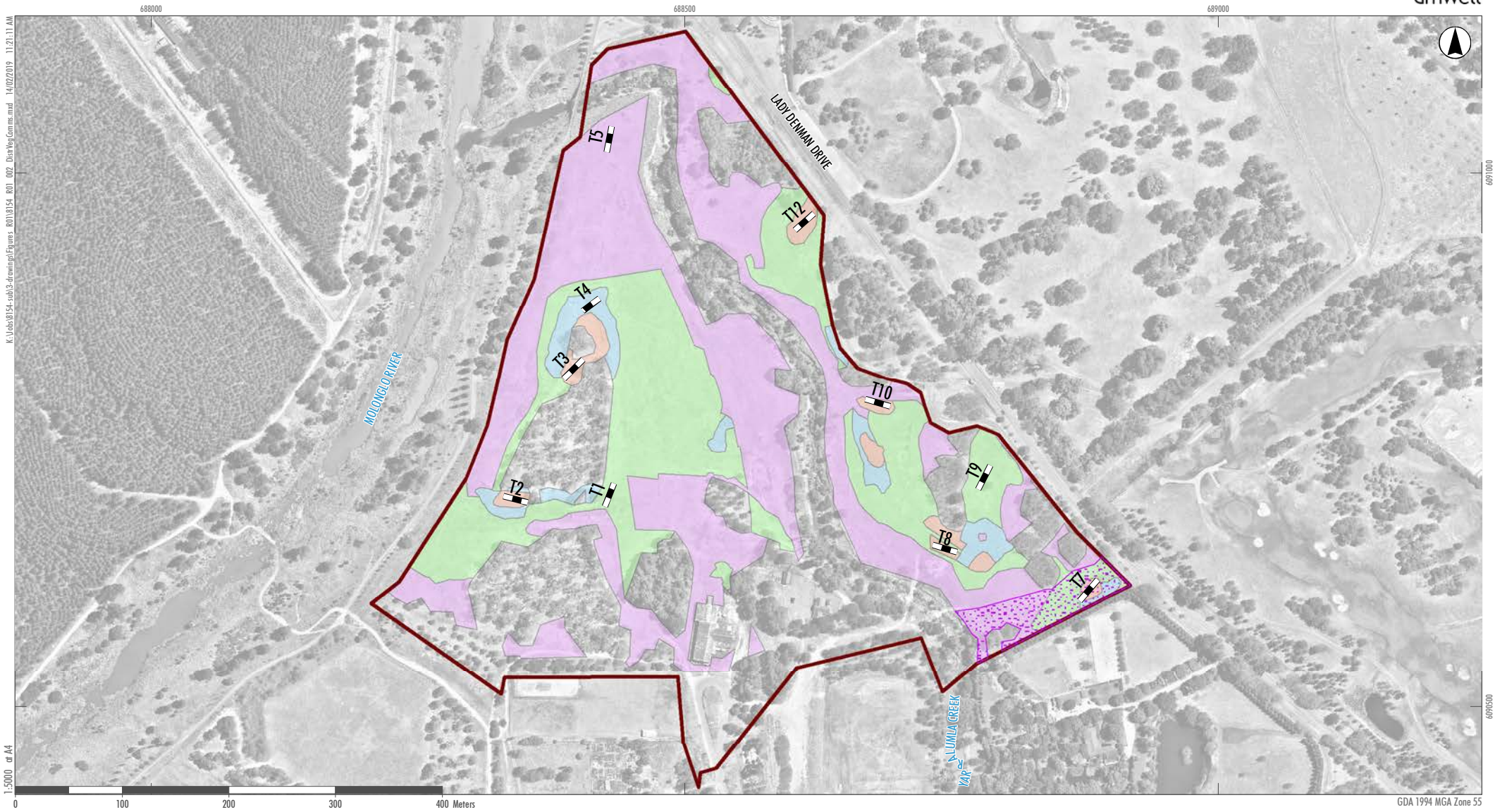
Vegetation mapping and GSM habitat mapping was conducted on 16 November. Figure 3.1 shows the distribution of vegetation communities mapped at YEP in 2018. Summaries of the areas of each vegetation community are shown in **Table 3.1**. The distribution of significant weeds at YEP is shown in **Figure 3.2**. Chilean needle grass (Nassella neesiana) and African lovegrass (Eragrostis curvula) occur in small to large patches throughout YEP. Isolated patches of serrated tussock (Nassella trichotoma) also occur in ten locations across YEP. Limited evidence of weed control was visible at the time of inspection. GSM habitat extent within YEP is summarised in **Table 3.2** and shown in **Figure 3.3**. Low to moderate quality GSM habitat persists across the majority of the grassland present at YEP.

Table 3.1 2018 summary of vegetation and land use mapping

Vegetation type / land use	2018 (ha)
Natural temperate grassland	0.5
Native pasture	0.7
Mixed native and exotic pasture	4.8
Exotic pasture	7.6
(Construction area)	0.0
(Non-grassland areas (e.g. buildings, riparian margins, woodland))	8.0
Total Project Area	**21.6**
Chilean needle grass	2.9
African lovegrass	2.7

Table 3.2 2018 summary of GSM habitat areas

GSM habitat area	2018 (ha)
Low quality	5.9
Low quality habitat dominated by Chilean needle grass	2.6
Moderate quality	1.1
High quality	0.0
Total	9.6



Legend

- Yarralumla Equestrian Park Boundary
- Vegetation Plots

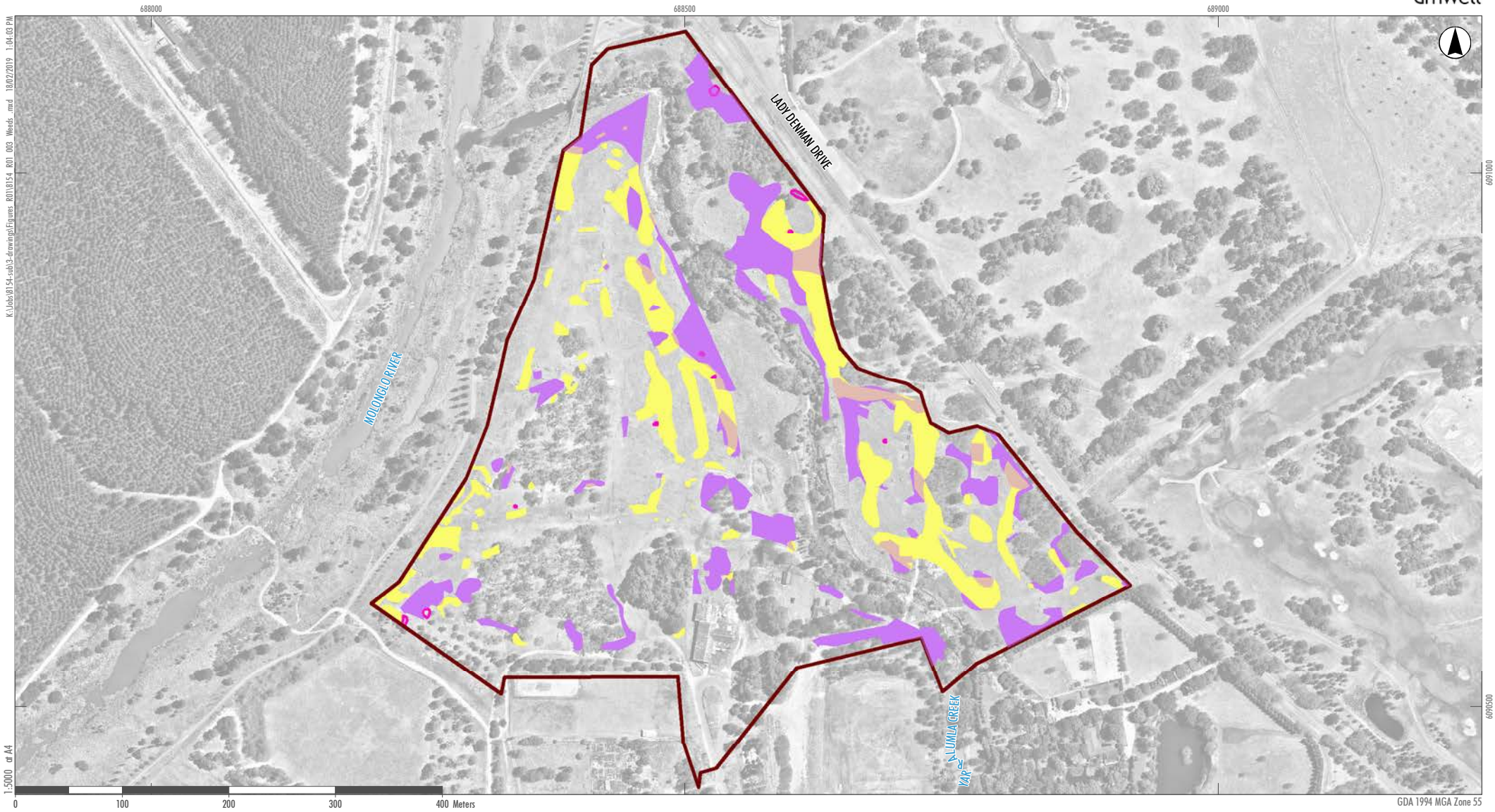
Vegetation Communities

- Exotic Pasture
- Mixed Native and Exotic Pasture
- Native Pasture
- Natural Temperate Grassland
- Mowed

Image Source: Nearmap (2018) Data source: Umwelt (2018)

FIGURE 3.1

Distribution of Vegetation Communities at Yarralumla Equestrian Park (2018)



Legend

- Yarralumla Equestrian Park Boundary

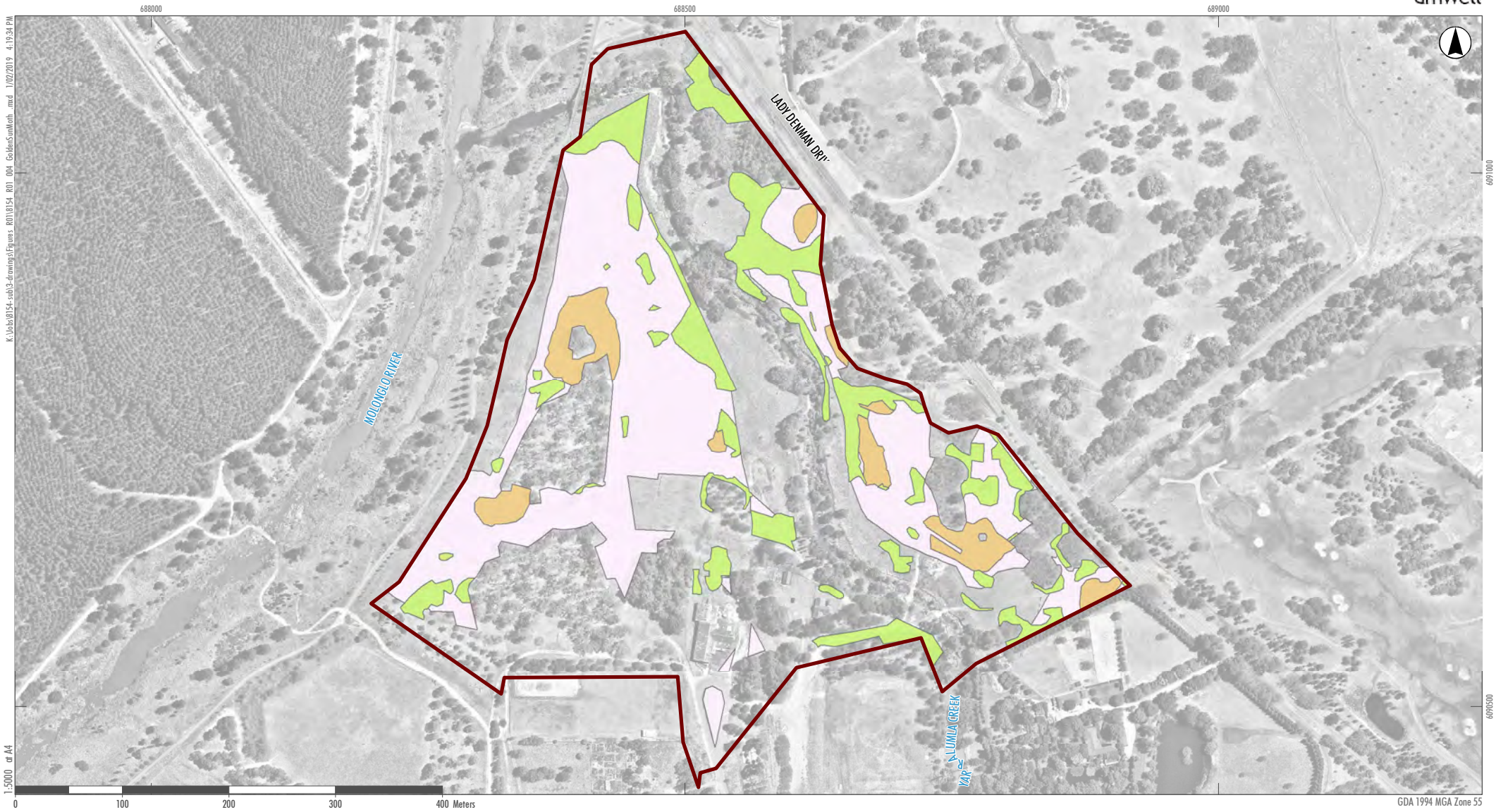
Weed Distribution

- Serrated Tussock
- African Love Grass
- Chilean Needle Grass
- Both African Love Grass and Chilean Needle Grass

Image Source: Nearmap (2018) Data source: Umwelt (2018)

FIGURE 3.2

Distribution of Serrated tussock, African lovegrass and Chilean Needle Grass at Yarralumla Equestrian Park (2018)



Legend

- Yarralumla Equestrian Park Boundary

Golden Sun Moth Habitat

- CNG Dominated GSM Habitat
- Medium Quality GSM Habitat
- Low Quality GSM Habitat

FIGURE 3.3

Distribution of Golden Sun Moth habitat at Yarralumla Equestrian Park (2018)

Image Source: Nearmap (2018) Data source: Umwelt (2018)

3.3 Native Pasture and Natural Temperate Grassland Monitoring

Grassland monitoring was conducted in spring conditions on 16 November 2018, following an extended dry period. Plant species, Braun-Blanquet abundance scores and a qualitative assessment of grassland quality based on the scale prepared by Nash and Hogg (2013) were recorded for each quadrat. **Table 3.3** presents a summary of the key vegetation quality indicators, including the quantitative site value score calculation based on Rehwinkel (2007) and qualitative grassland quality and GSM habitat quality scores. In 2017 and 2018, floristic value scores were also calculated according to Rehwinkel 2015, to facilitate consideration against criteria for inclusion in the revised NTG listing (**Table 3.3**). Data is presented in **Appendix A.**

To assess sites against criteria for inclusion in the revised EPBC Act-listed critically endangered natural temperate grassland community (Australian Government 2016), the updated floristic value score calculation described in Rehwinkel (2015) was applied, identifying grassland in quadrats 2, 3, 10 and 12 as NTG.

Assessment of the site against the updated criteria for the critically endangered community listings are shown in **Table 3.4**. Due to the need to maintain consistency with the OMP, quadrat sizes are smaller than the standard required for calculation of the floristic value scores. Thus, the potential for areas mapped as native pasture and an updated floristic value score of less than five is recorded, to meet the updated criteria for the revised critically endangered NTG ecological community cannot be excluded.

Table 3.3 2018 vegetation survey results

Quadrat	Number of native species	Number of exotic species	Number of significant weeds	Floristic value score (Rehwinkel 2007)	Floristic value score (Rehwinkel 2015)	Grassland quality score	GSM habitat quality score
1	2	10	1	0	0.22	N/A	1
2	8	5	1	1	5.33	4B	4
3	4	5	2	1	0.6	3B	4
4	0	3	0	0	0	N/A	1
5	2	11	3	0	0.2	N/A	1
6	5	9	4	1	2.35	5C	3
7	4	10	2	3	1.81	3B	3
8	3	7	1	3	3.73	5A	4
9	0	10	5	0	0	N/A	N/A
10	11	9	3	4	6.89	5C	5
11	6	9	2	1	4.3	N/A	1
12	7	7	2	4	5.98	5A	4

Table 3.4 Summarised assessment against Commonwealth criteria for the EPBC Act-listed natural temperate grassland critically endangered ecological community based on floristic data and site characteristics

Quadrat (Threshold)	Condition	Number of non grass native species (8)	Number of indicator species (2)	Floristic value score (5)	Meets natural temperate grassland criteria / comment
1	Mixed native and exotic	1	0	0.22	No
2	Native grassland	2	1	5.33	Yes
3	Native grassland	0	0	0.6	Yes
4	Native pasture	0	0	0	No
5	Exotic pasture	1	0	0.2	No
6	Native pasture	1	1	2.35	No
7	Native grassland	2	1	1.81	No
8	Native grassland	1	1	3.73	No
9	Mixed native and exotic	0	0	0	No
10	Native grassland	4	2	6.89	Yes
11	Mixed native and exotic	3	1	4.3	No
12	Native grassland	2	2	5.98	Yes

3.4 GSM Flying Surveys

All surveys were conducted between 11:00 and 13:30 on warm, sunny days with light winds. Point count survey data is presented in **Appendix B** and a complete list of GSM records is presented in **Appendix C** .

Table 3.5 Weather conditions during GSM flying moth surveys

Date	Temperature (ºC)	Last rainfall (mm)	Wind speed (km/h)	Cloud cover
13/11/18	28-29	9.8 (8 Nov)	Light (<11)	Scattered (<30%)
19/11/18	21-29	0.2 (16 Nov)	Light (<11)	Scattered (<30%)
26/11/18	19-22	1.0 (26 Nov)	Light (<11)	Fine

Eleven flying moth surveys were undertaken during the peak period of GSM activity in the ACT and are consequently valid representations of GSM activity levels at the YEP offset site. GSM activity observed during the traverse surveys was low-moderate (i.e. <10 moths per minute) during the first and last survey and moderate (i.e. 10-20 moths per minute) during the second survey based on the semi-

quantitative GSM site assessment method developed by David Hogg Pty Ltd (2010). The relatively continuous distribution of records along the traverse route and transects and at each of the rotational point survey sites demonstrates that GSM were flying across the majority of open areas in YEP during the 2018/19 flying season.

The locations of GSM records collected during the rotational point count and traverse surveys are shown in **Figure 3.4** and **Figure 3.5.** The results of the transect surveys are shown in **Figure 3.6**. A total of 461 GSM were recorded during the traverse survey on 13 November, 971 on 19 November and 217 on 26 November 2018.

Table 3.6 Summary of traverse survey results

Date	Survey	Start	Finish	Total Time (min)	Number of observations	Total GSM	Max GSM	GSM/ min
13/11/18	1	11:38	13:19	101	72	461	50	4.6
19/11/18	2	11:10	12.17	67	81	971	100	14.5
26/11/18	3	11:06	12:49	103	59	217	27	2.1

GSM were recorded at each of the 15 transects with the highest numbers occurring at transects 1A and 4C (**Table 3.7**). GSM numbers averaged across the three surveys corresponded with high activity levels (i.e. 60 or more moths per 100 metre of transect) at transect 1A, low activity levels (<6 per minute) at transect 3A and between low-moderate to moderate-high activity levels at the remaining sites.

Table 3.7 Summary of transect survey results

Transect	S1 Total GSM	S2 Total GSM	S3 Total GSM	Total GSM	Average GSM
1A	150	77	7	234	78.0
1B	60	37	6	103	34.3
2A	19	42	7	68	22.7
2B	8	26	2	36	12.0
2C	38	19	2	59	19.7
2D	23	15	0	38	12.7
3A	2	12	2	16	5.3
3B	18	57	1	76	25.3
3C	31	63	6	100	33.3
3D	32	61	3	96	32.0
4A	2	64	52	118	39.3
4B	42	53	22	117	39.0
4C	64	78	28	170	56.7
4D	2	45	1	48	16.0
5A	6	23	4	33	11.0

GSM were recorded at all rotational survey points with the highest numbers being recorded on 19 November 2019 at points one, two, six and ten (**Table 3.8**). GSM activity levels varied between rotational points from low to high based on the semi-quantitative GSM site assessment method abundance categories developed by David Hogg Pty Ltd (2010). The highest numbers of GSM were recorded at points 1, 10 and 11 whilst the lowest numbers were observed at points 4, 5 and 7.

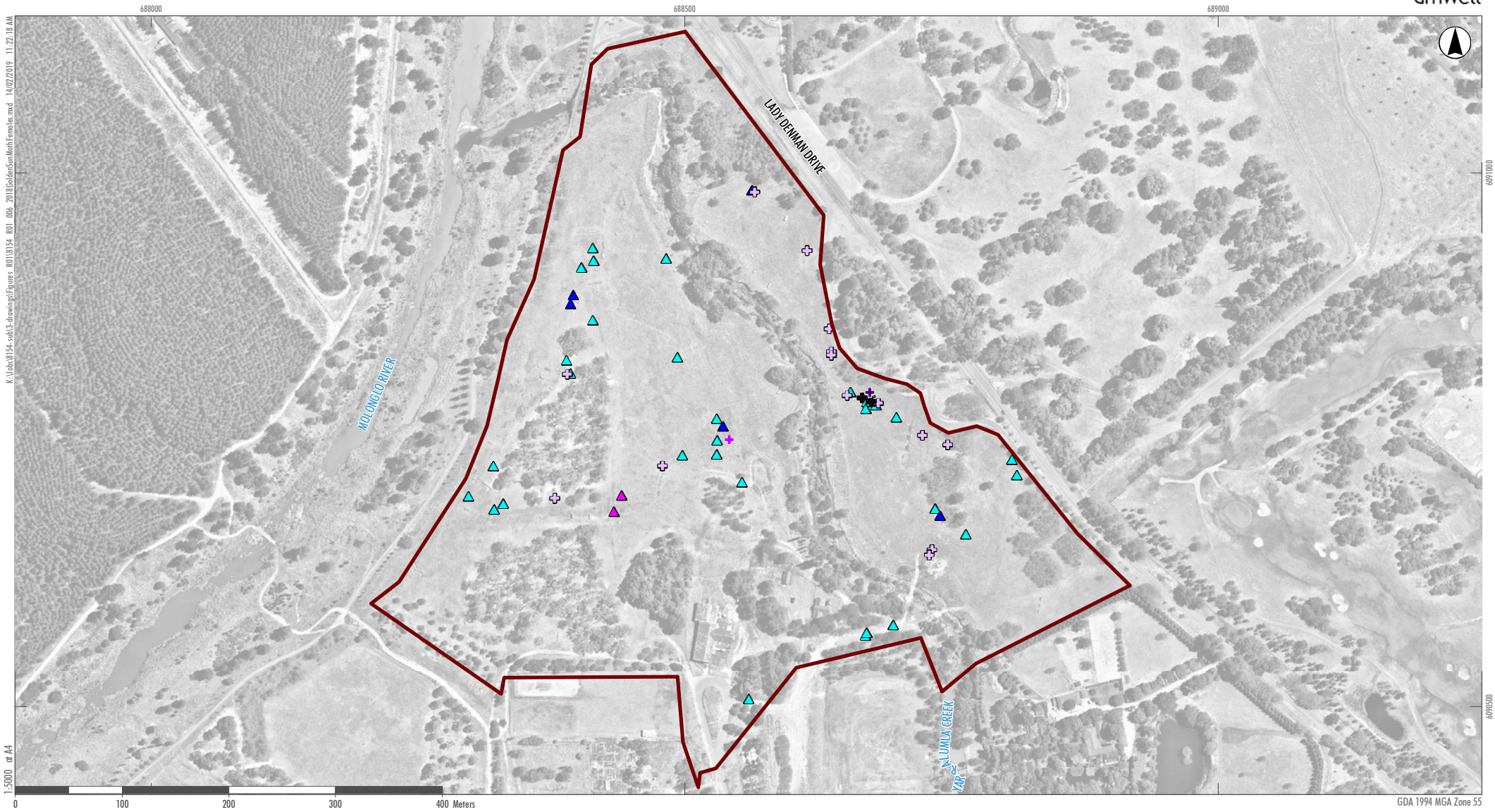
Table 3.8 Summary of rotational survey results

Point	Survey 1 Average	Survey 1 Max	Survey 2 Average	Survey 2 Max	Survey 3 Average	Survey 3 Max	Combined Average	Combined Max
1	2.1	6	46.9	65	1.6	3	16.9	65
2	0.9	3	27.9	40	3.5	7	10.8	40
3	0.3	1	8.6	14	0.9	3	3.3	14
4	0.3	2	3.5	9	0.1	1	1.3	9
5	0.3	2	3.4	9	0.5	3	1.4	9
6	6	12	25.2	38	1.3	4	10.8	38
7	0	0	5	9	0	0	1.7	9
8	4.2	15	20	33	0	0	8.1	33
9	0.3	3	6.9	10	0.6	2	2.6	10
10	3.1	7	40.8	63	2.4	5	15.4	63
11	0.7	3	12.8	19	40.9	62	18.1	62
12	0.3	1	6	9	9.4	23	5.2	23

Image Source: Nearmap (2018) Data source: Umwelt (2018)

FIGURE 3.4

Distribution of Golden Sun Moth records (traverse and rotational point surveys) at Yarralumla Equestrian Park (2018)



Legend

Yarralumla Equestrian Park Boundary

Golden Sun Moth Females	Pupa Cases
1	1 - 5
2	6 - 10
3	11 - 30

FIGURE 3.5

Distribution of Golden Sun Moth records (female moths and pupae cases) at Yarralumla Equestrian Park (2018)

Image Source: Nearmap (2018) Data source: Umwelt (2018)

FIGURE 3.6

Total Golden Sun Moth records
(100 metre transects)

Image Source: Nearmap (2018) Data source: Umwelt (2018)

3.5 Incidental Observations

Incidental observations of GSM are shown in **Figure 3.5**. Three female and two male GSM were observed during the vegetation assessment and fifteen female GSM were observed during the traverse surveys. A total of 24 pupa cases were recorded on 13 November 2018 and 15 on 19 November 2018 (cf. no pupa cases recorded at YEP during 2017).

3.6 GSM Habitat Monitoring

GSM habitat ranking scores (Nash and Hogg 2013) for each quadrat are presented in **Table 3.9**. Quadrat 9 did not meet thresholds for classification as GSM habitat.

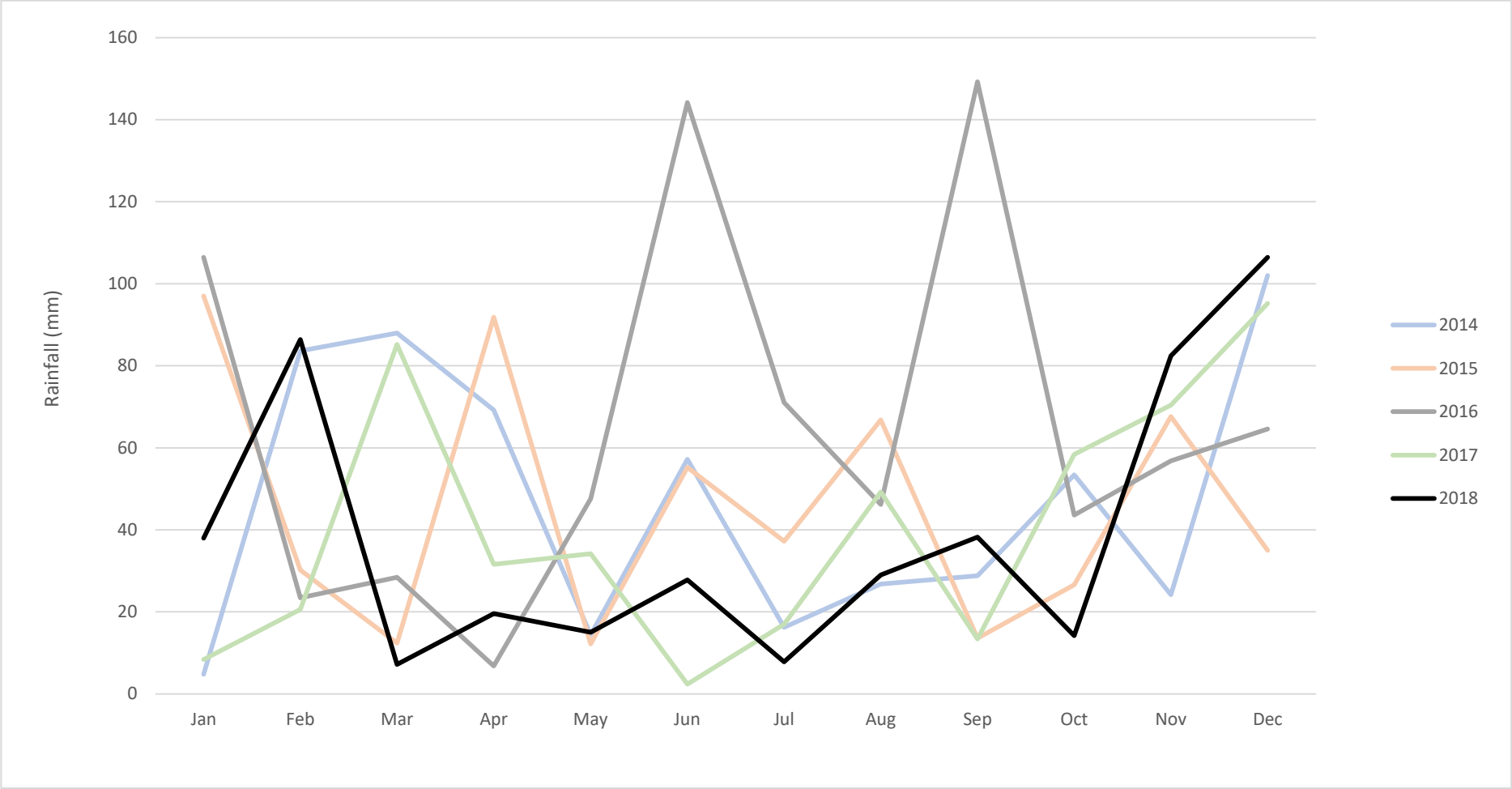
Table 3.9 GSM habitat ranking score (2018)

Quadrat	GSM Habitat Ranking Score
1	1
2	4
3	4
4	1
5	1
6	3
7	3
8	4
9	N/A
10	5
11	1
12	4

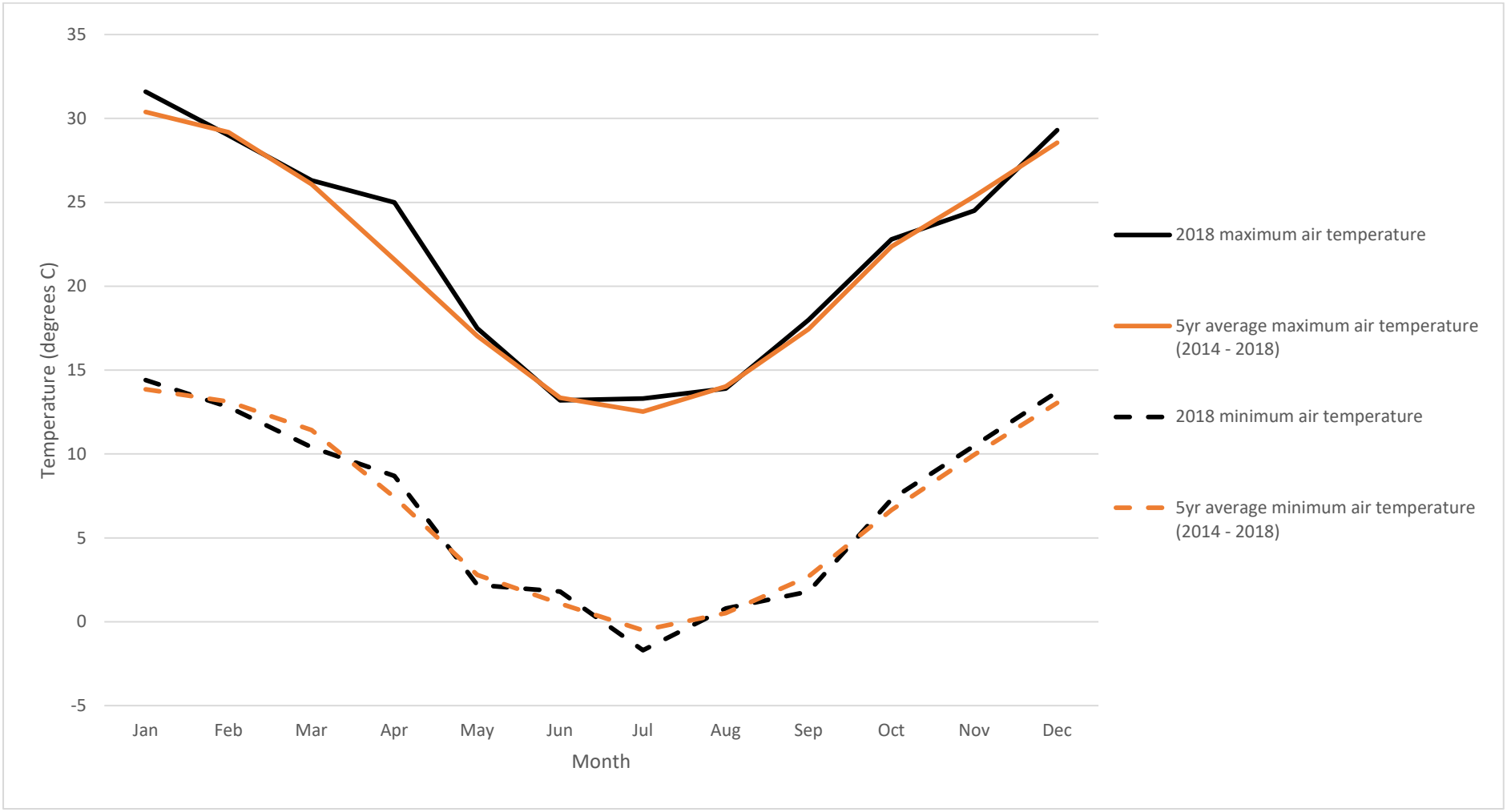
3.7 Meteorological Data

Where applicable survey data is interpreted with reference to summarised meteorological data for the season. Monthly rainfall and average daily maximum and minimum air temperatures (2014-2018) are presented in **Graph 3.1** and **Graph 3.2** respectively. Total rainfall during the months leading up to the GSM 2018 flying season (i.e. June to October: 117.0 mm) was far lower than the 10-year average (i.e. 229.6 mm) and slightly lower than during the same period in 2017 (i.e. 140.4 mm). Rainfall during the 2018 flying season (i.e. November / December: 188.8 mm) was higher than the 10-year average (i.e. 149.6 mm) and slightly higher than during the same period in 2017 (i.e. 165.5 mm).

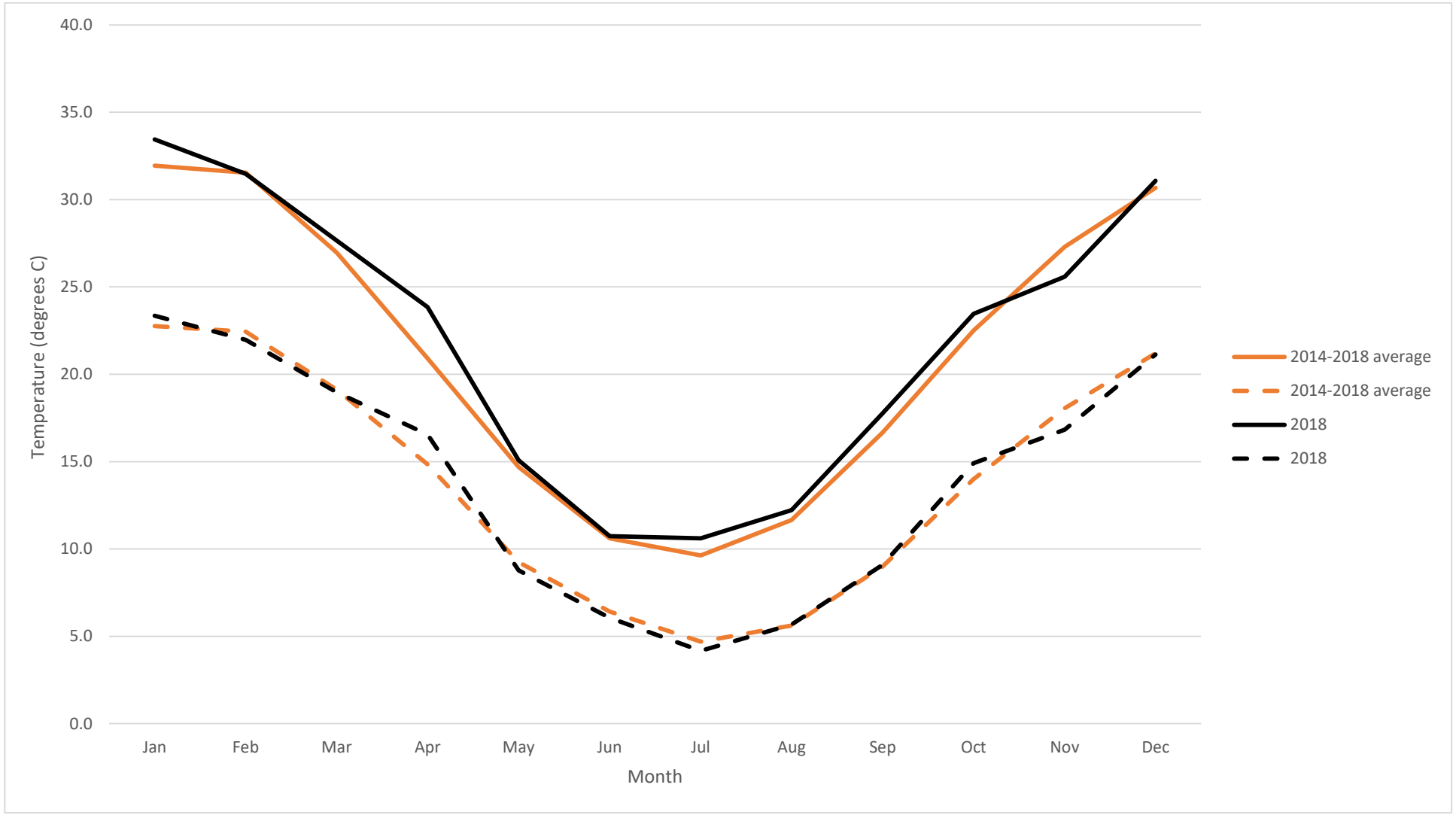
Monthly average daily maximum and minimum soil temperatures recorded at 10 cm depth for 2014-2018 is presented in **Graph 3.3**. **Graph 3.4** shows daily maximum soil temperature and **Graph 3.5** shows daily precipitation leading up to and during the past five GSM flying seasons (i.e. October to December). All relevant meteorological data from 2014 to 2018 are presented in **Appendix D** and **Appendix E.** All meteorological data presented in this report were recorded at the Canberra Airport (i.e. site 070351).



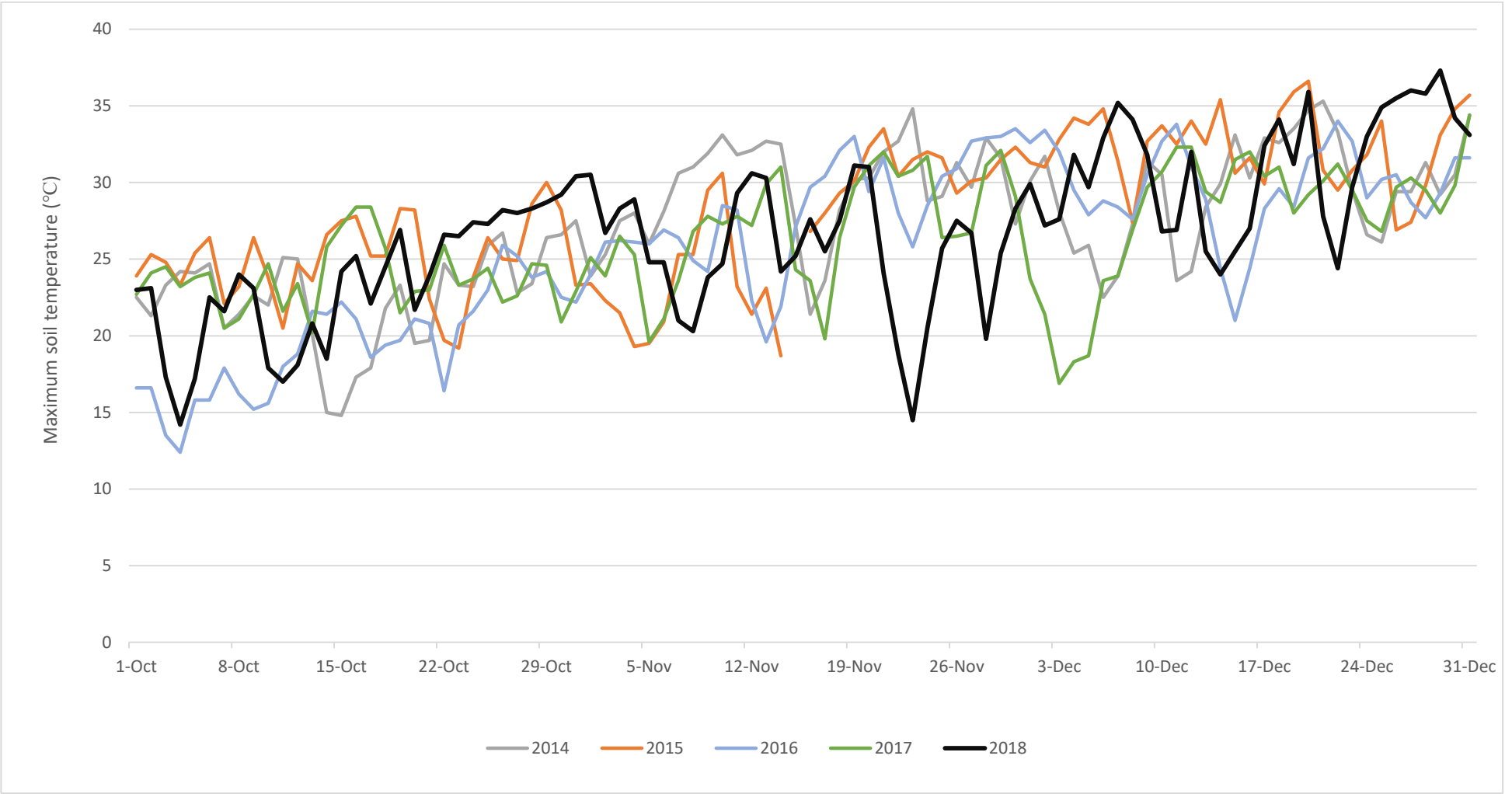
Graph 3.1 Monthly rainfall at Canberra Airport (2014-2018)



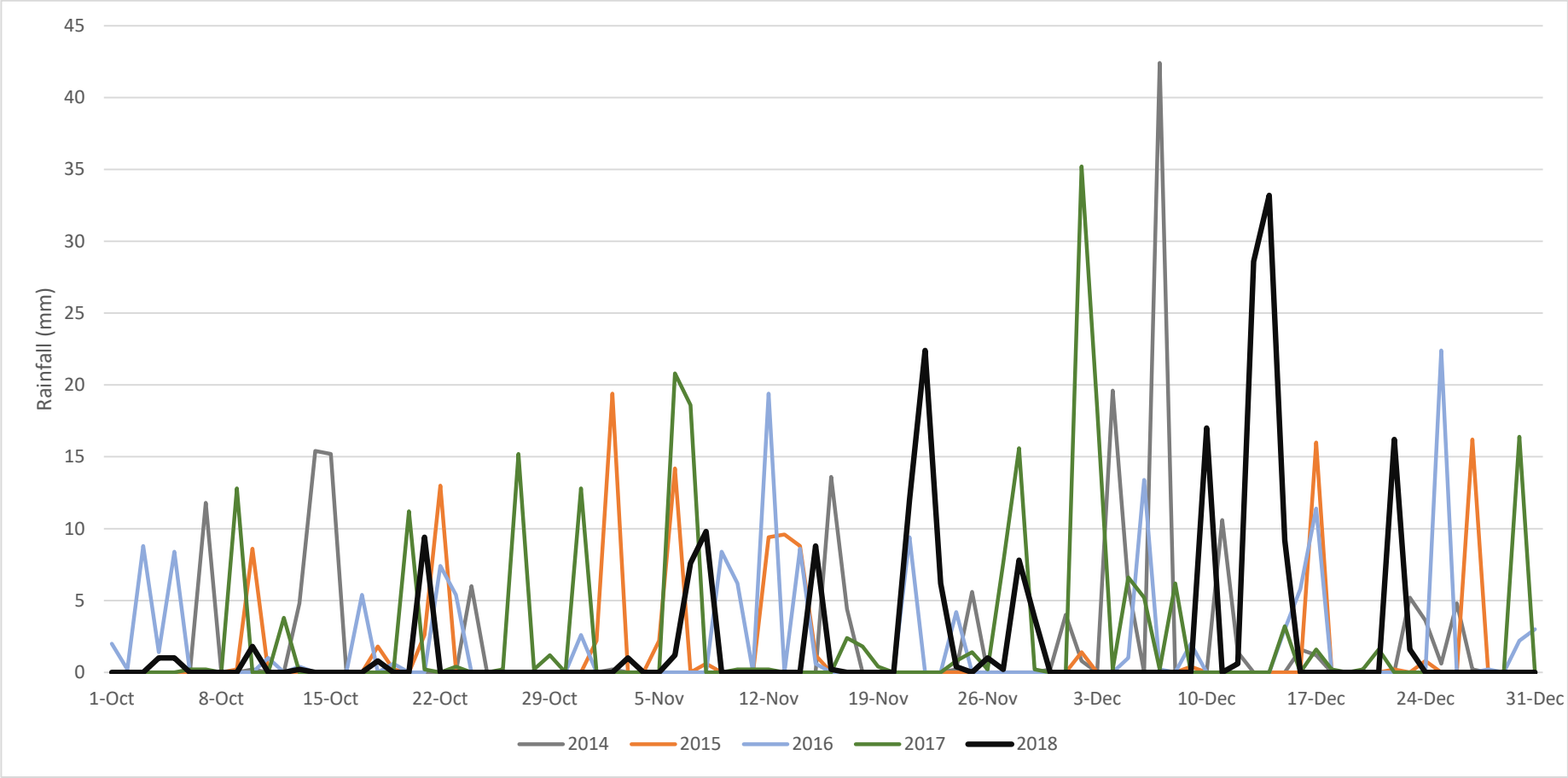
Graph 3.2 Monthly average daily maximum and minimum air temperature at Canberra Airport (2014-2018)



Graph 3.3 Monthly average daily maximum and minimum soil temperature at 10 cm depth at Canberra Airport (2018 vs 2014-2018 average)



Graph 3.4 Maximum daily soil temperature at Canberra Airport leading up to and during the GSM flying period (1 October – 31 December, 2014-2018)



Graph 3.5 Daily rainfall at Canberra Airport leading up to and during the GSM flying period (1 October – 31 December, 2014-2018)

4.0 Discussion and Analysis

4.1 Vegetation and GSM Habitat

Changes in the distribution and extent of vegetation types and land uses reported in the OMP (RJPL 2014a), and year 0 (RJPL 2014b), year 1, year 2, year 3 and year 4 monitoring reports (RJPL 2015; SMEC 2016, SMEC 2017, SMEC 2018) to 2018 are summarised in **Table 4.1.** Trends in the extent of NTG and other grassland types within YEP are shown in **Graph 4.1**.

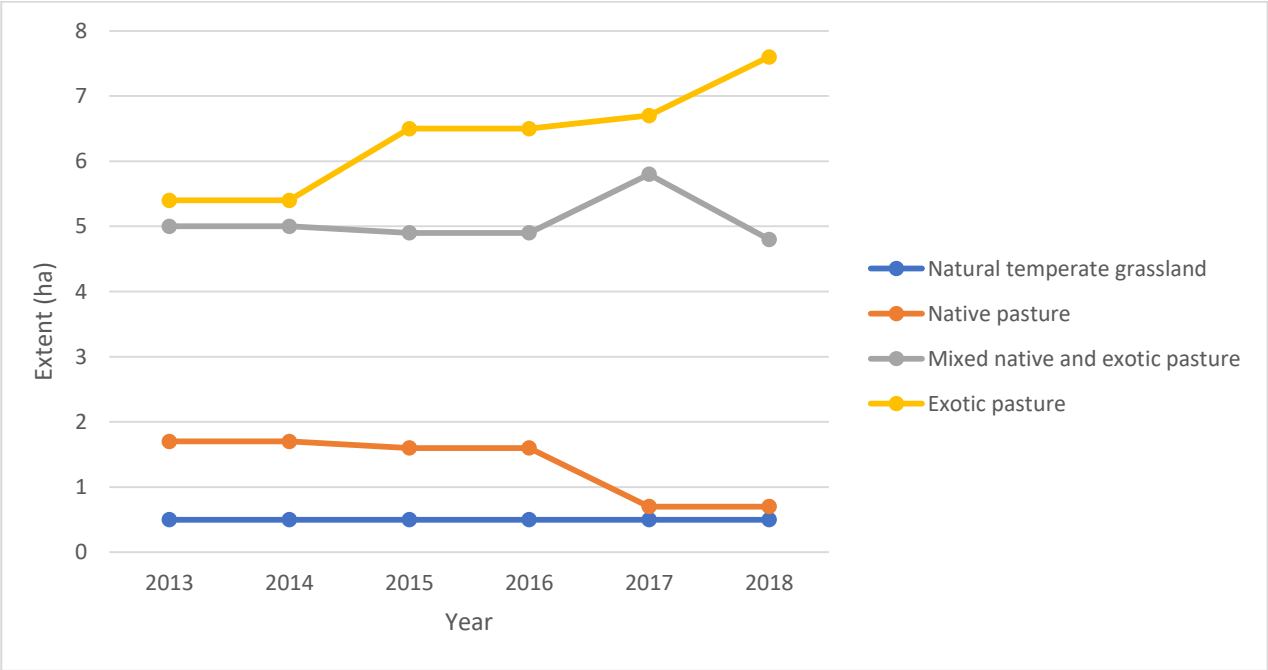
While the extent of NTG has remained stable since 2013, the extent of native dominated pasture has declined substantially (i.e. more than halved). The decline in native pasture area in recent years is attributable to the invasion of native pasture areas by perennial exotic tussock grasses, particularly African lovegrass and Chilean needle grass, resulting in the reclassification of substantial areas as mixed native and exotic pasture. The extent of exotic pasture increased by 0.9 hectares between 2017 and 2018, corresponding to a reduction in the extent of mixed native and exotic pasture.

Trends in the extent of significant perennial grassy weeds (i.e. Chilean needle grass and African lovegrass) are shown in **Graph 4.2**. The coverage of African lovegrass at YEP increased by 29% between November 2017 and November 2018 from 2.1 hectares – 2.7 hectares following an 86% increase in the 12 months leading up to November 2017. Large tracts of African lovegrass are now dominant across much of the central and eastern parts of YEP threatening existing areas of NTG (**Figure 3.2**). Chilean needle grass patches supporting GSM are located in the north and east of the YEP, and along the edge of the access track to the west of Yarralumla Creek in the south of the YEP (**Figure 3.2**). The coverage of Chilean needle grass has increased by 133% and 61% since 2013 and 2017 respectively (**Table 4.1).** The 1.1 hectare increase in the extent of Chilean needle grass between November 2017 and November 2018 represents the largest recorded annual increase in coverage of this species since monitoring commenced in 2013.

Table 4.1 Revised vegetation and land use mapping compared with 2013 and 2017

Vegetation type / land use	2013 (ha)	2014 (ha)	2015 (ha)	2016 (ha)	2017 (ha)	2018 (ha)	Change since 2013 (ha) (%)	Change since 2017 (ha) (%)
Natural temperate grassland	0.5	0.5	0.5	0.5	0.5	0.5	0	0
Native pasture	1.7	1.7	1.6	1.6	0.7	0.7	-1.0 (-58%)	0
Mixed native and exotic pasture	5.0	5.0	4.9	4.9	5.8	4.8	-0.2 (-4%)	-1 (-17%)
Exotic pasture	5.4	5.4	6.5	6.5	6.7	7.6	NA	+0.9 (+13%)
(Construction area)	0.8	0.8	0	0	0	0	NA	NA
(Non-grassland areas (e.g. buildings, riparian margins,	8.0	8.0	8.0	8.0	8.0	8.0	NA	NA
Total Project Area	**21.6**	**21.6**	**21.6**	**21.6**	**21.6**	**21.6**	NA	**NA**

Vegetation type / land use	2013 (ha)	2014 (ha)	2015 (ha)	2016 (ha)	2017 (ha)	2018 (ha)	Change since 2013 (ha) (%)	Change since 2017 (ha) (%)
Chilean needle grass	1.2	1.2	1.1	1.4	1.8	2.9	+1.6 (+133%)	+1.1 (+61%)
African lovegrass	**0**	**0**	0	0.3	2.1	2.7	+2.7 (N/A)	+0.6 (29%)

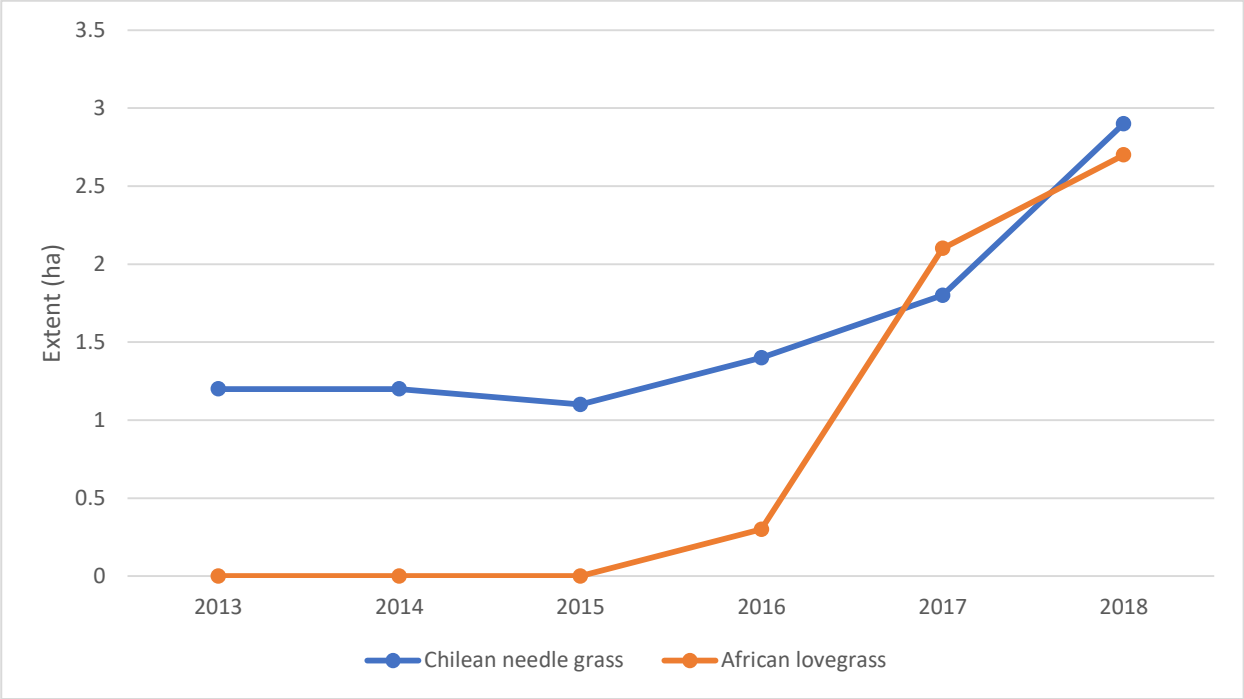


Graph 4.1 Change in grassland extent at Yarralumla Equestrian Park (2013-2018)

Spot spraying treatment of serrated tussock and African love-grass with selective flupropanate herbicide was undertaken by ACT Government on two occasions in June and November 2018 (**Table 4.2**). Herbicide treatment focussed on removing scattered tussocks within areas of native grassland and native pasture. While impacts of weed control on targeted species was not evident at the time of the inspection due to the slow-acting nature of the flupropanate herbicide, impacts of weed control (i.e. dead tussocks and reduced living tussock density) were observed within treated areas during site inspection in March 2019. As the focus of weed control has been on areas less densely infested, weed control actions taken to date are unlikely to change the mapped extent of exotic tussock grasses, but may reduce future expansion.

Table 4.2 Weed control measures implemented during 2018 (based on information provided by Sport and Recreation Facilities; Transport Canberra and City Services Directorate)

Date	Treatment	Target Species	Person Hours
23 June 2018	Spot-spray, flupropanate	Serrated tussock; African lovegrass	18
1 November 2018	Spot-spray, flupropanate	Serrated tussock; African lovegrass	21

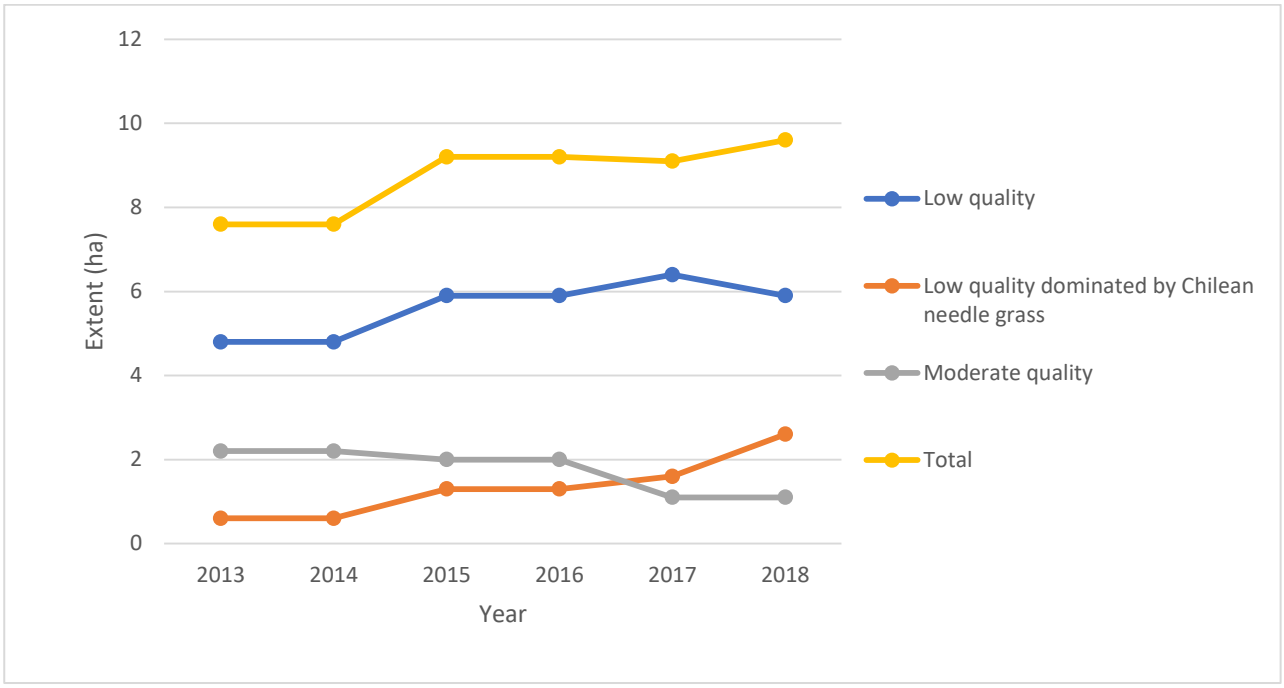


Graph 4.2 Change in extent of African lovegrass and Chilean needle grass at Yarralumla Equestrian Park (2013-2018)

GSM habitat extent reported in the OMP (RJPL 2014a) and the year 0 (i.e. 2013) (RJPL 2014b), year 1 (RJPL 2015), year 2 (SMEC 2016), year 3 (SMEC 2017) and year 4 (SMEC 2018) monitoring reports are compared in Table 4.3**.** Changes in the extent of GSM habitat in the period 2013 to 2017 are shown in **Graph 4.3.** Overall, the extent of GSM habitat has increased since 2013 due to a 2 hectare increase in the extent of low quality habitat dominated by Chilean needle grass. The total extent of GSM habitat at YEP in 2018 (i.e. 9.6 hectares) was higher than the total mapped extent during 2017 (i.e. 9.1 hectares) due to the reclassification of areas of 'low quality' GSM habitat to 'low quality habitat dominated by Chilean needle grass' GSM habitat. The extent of 'moderate quality' GSM habitat has halved due to an increase in perennial exotic grass cover associated with invasion by Chilean needle grass and African lovegrass with the most severe reduction occurring between 2016 and 2017 (Table 4.3).

Table 4.3 Revised 2018 GSM habitat areas compared with 2013-2017

GSM habitat area	2013 (ha)	2014(ha)	2015 (ha)	2016 (ha)	2017(ha)	2018 (ha)	Change since 2013 (ha)
Low quality	4.8	4.8	5.9	5.9	6.4	5.9	+1.1
Low quality dominated by Chilean needle grass	0.6	0.6	1.3	1.3	1.6	2.6	+2.0
Moderate quality	2.2	2.2	2.0	2.0	1.1	1.1	-1.1
High quality	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**7.6**	**7.6**	**9.2**	**9.2**	**9.1**	**9.6**	**+2.0**



Graph 4.3 Change in GSM habitat extent at Yarralumla Equestrian Park (2013-2018)

The extent of native grassland and moderate quality GSM habitat has been reduced by the substantial expansion of Chilean needle grass and African lovegrass at YEP since 2016. From November 2017 to November 2018 the extent of Chilean needle grass increased by 61% following an increase of 50% during the preceding 12 month period. The extent of African lovegrass increased by 39% from November 2017 to November 2018 following a 600% increase from 2016 to 2017. Further expansion of the distribution of these species at YEP has high potential to impact the patches of NTG at YEP, potentially causing the loss of the native ecological communities. Weed control during the 2018 season within areas of native grassland and native pasture did not change mapped extent of weed infestations but may result in reduced expansion of targeted exotic pasture grasses within areas dominated by native species.

4.2 Native Pasture and Natural Temperate Grassland Monitoring

Floristic scores and grassland ranking scores for each survey season are shown in **Table 4.4** and **Table 4.5** respectively. Three quadrats, i.e. quadrats 1, 5 and 9 were not located within predominantly native vegetation, consistent with previous years. A high level of inter-annual variability in floristic value scores is present within each monitoring quadrat which is the result of variable seasonal conditions and survey timing.

In 2018, no quadrats had a floristic value score of four or greater, down from two quadrats in 2017 and seven quadrats in 2016. Four quadrats achieved a floristic value score of 0 in 2018 compared with six quadrats in 2017, three in 2016, four in 2015, three in 2014 and two in 2013. Floristic value scores were lower than the 2013 – 2017 average at eight quadrats, equal to the average at two quadrats and higher than average at the remaining two quadrats. Exotic species richness was greater than native species richness in each of the twelve monitoring quadrats. At least one significant weed species was recorded in all but one of the quadrats.

Table 4.4 Summary of floristic value scores (2013-2018)

Quadrat	Site floristic value score 2013	Site floristic value score 2014	Site floristic value score 2015	Site floristic value score 2016	Site floristic value score 2017	Site floristic value score 2018
1	0	0	0	0	0	0
2	4	7	1	7	1	1
3	7	4	2	1	2	1
4	2	2	1	5	0	0
5	1	0	0	1	0	0
6	4	8	1	5	0	1
7	1	5	1	0	2	3
8	2	2	0	11	5	3
9	0	0	0	0	0	0
10	2	5	1	5	2	4
11	4	4	1	5	0	1
12	6	14	1	9	5	4
Average	2.75	4.25	0.75	3.83	1.42	1.5

Note: During data review, 2016 data for quadrat 4 and quadrat 5 appeared to have been switched. This table has been updated to reflect the correct data.

The average floristic value score in 2018 was similar to that recorded the previous year but lower than the 2013-2018 average. Floristic value scores recorded at YEP show a high level of inter-annual variation, and, on average, exhibit a marginal and non-significant decline across the site since 2013 (SMEC 2018). Inter-annual variation in grassland composition and structure (and hence, site floristic scores) at YEP can be strongly influenced by rainfall during the months leading up to each annual vegetation survey. For example, rainfall during winter and spring 2016 was well above average in Canberra (i.e. 511 mm cf. average of 296 mm), which led to favourable conditions for exotic grassland species that following spring / summer (SMEC 2017). Rainfall in Canberra during winter and spring of both 2017 (SMEC 2018) and 2018 was far lower than average and could therefore have led to poorer than average growing conditions at YEP during the sampling period in both years. The high level of inter-annual variation is likely attributable to variation in seasonal conditions.

Table 4.5 Summary of grassland ranking scores assessment (2013 - 2018)

Quadrat	Grassland ranking score 2013	Grassland ranking score 2014	Grassland ranking score 2015	Grassland ranking score 2016	Grassland ranking score 2017	Grassland ranking score 2018
1	N/A	N/A	N/A	N/A	N/A	N/A
2	4C	5A	3A	3A	4B	4B
3	5C	4A	4C	1	4A	3B
4	4C	3A	1	4C	3B	1
5	N/A	N/A	N/A	1	N/A	N/A
6	4C	4A	3B	4B	4A	5C
7	4C	3A	3B	N/A	4A	3B
8	5C	3A	N/A	4B	5B	5A
9	N/A	N/A	N/A	N/A	N/A	N/A
10	4C	4A	1	3A	4A	5C
11	4C	4A	2	3A	1	N/A
12	5C	5A	1	4A	5B	5A

Note: During data review, 2016 data for quadrat 4 and quadrat 5 appeared to have been switched. This table has been updated to reflect the correct data.

Note: In application of the Grassland Quality Score, there has been inconsistency in the consideration of the presence of threatened species. In this case, it has been assumed that the grassland quality score refers to threatened flora species and the presence of GSM is consequently not considered in the application of the scale. This contrasts with the approach applied in 2013, but is consistent with that applied in 2014. Application of the scale in 2015 and 2016 appears inconsistent in the treatment of the presence of GSM.

Grassland ranking scores in 2018 were similar to 2017 though scores for certain sites were closer to the record low values recorded in 2015. Most notably, the consistent year-year reduction in the grassland ranking score of quadrat 11 from 4C in 2013 to 1 in 2017 continued in 2018 with the quadrat being assigned N/A. Overall, grassland ranking scores also indicate a slight decline in grassland condition at the monitoring points (SMEC 2018). NTG ranking scores have not increased on average or at any site since 2013, and a decrease was noted at some sites. Whether this is indicative of declining trend in grassland condition is unclear due to the high level of variability from year to year. Some inter-annual variation in habitat ranking scores is likely due to the subjective nature of this ranking and varying seasonal conditions are also likely to influence scores.

Declines in vegetation condition at YEP are associated with the invasion of perennial exotic tussock grasses, as outlined in **Section 4.1.**

4.3 GSM Habitat Monitoring

GSM habitat value scores recorded in 2018 ranged between N/A (i.e. no GSM habitat) and 5 (Moderate quality NTG habitat with very low numbers of GSM) (**Table 4.6**). Eleven of the monitoring quadrats were determined to have some GSM habitat value, due to the presence of potential host species and GSM activity. The average 2018 GSM habitat quality score of 2.8 is lower than the 2013-2018 average (i.e. 3.3). The variation in GSM habitat scores between the years is likely attributable to variation in seasonal conditions and GSM density. The steady reduction in GSM habitat scores at quadrats 11 and four during the monitoring period has likely been driven by the expansion of exotic perennials at such locations.

Table 4.6 GSM habitat quality scores (2013-2018)

Quadrat	GSM habitat quality score 2013	GSM habitat quality score 2014	GSM habitat quality score 2015	GSM habitat quality score 2016	GSM habitat quality score 2017	GSM habitat quality score 2018
1	2	2	1	1	2	1
2	5	5	4	4	5	4
3	6	6	6	4	5	4
4	4	4	3	4	4	1
5	1	1	1	1	1	1
6	3	5	4	3	3	3
7	2	4	2	1	2	3
8	4	2	2	3	4	4
9	0	N/A	N/A	N/A	N/A	N/A
10	3	5	4	3	5	5
11	4	5	5	3	3	1
12	4	5	4	3	4	4

The average GSM habitat quality score in 2018 was slightly lower than the 2013-2018 average. The number of quadrats that were determined to contain GSM habitat remained steady at 11 quadrats. Quadrats four and 11 which have experienced a gradual decline in habitat quality since 2013 both scored a record low of one in 2018. This is likely a function of the invasion of perennial exotics during the past five years.

Overall, average GSM habitat ranking scores have demonstrated a slight decline at YEP since monitoring began in 2013 (SMEC 2018) however whether this is indicative of a declining trend in grassland condition is unclear due to the high level of inter-annual variation. Some inter-annual variation in habitat ranking scores is likely due to the subjective nature of this ranking. Varying seasonal conditions may also influence scores. Declines in GSM habitat ranking scores, independent of seasonal variation and the subjectivity of assessment, are likely to be due to perennial exotic grasses invading native grassland areas.

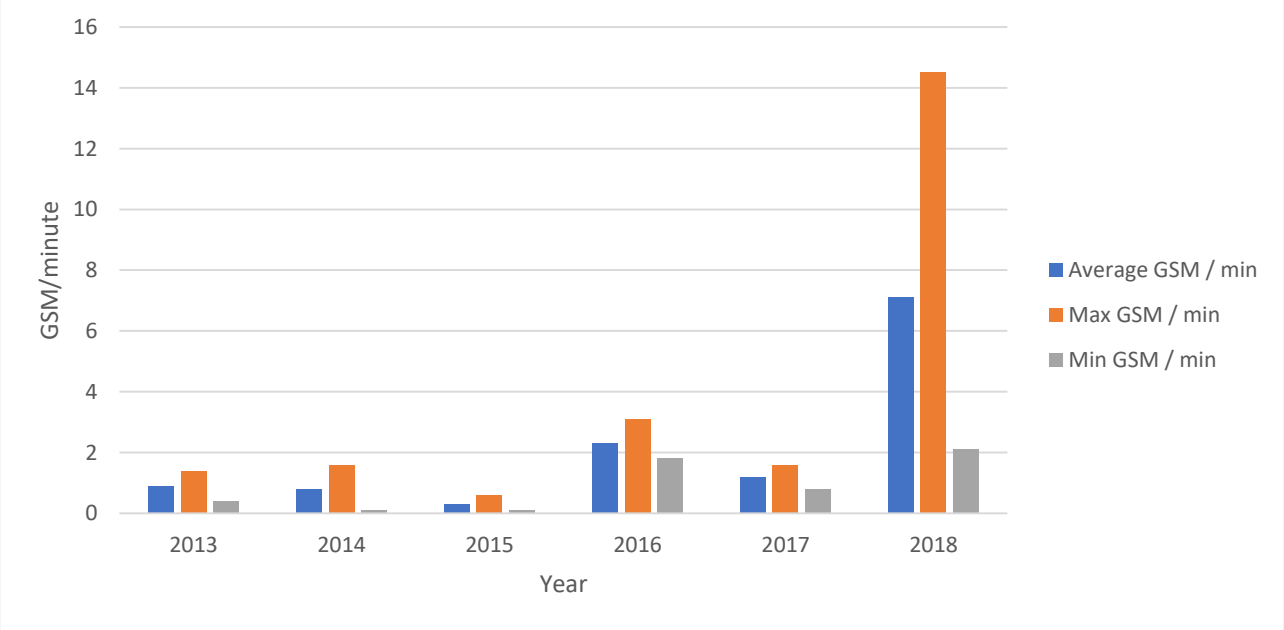
4.4 GSM Flying Surveys

Trends in GSM numbers over the monitoring period (2013-2018), as measured by the timed traverse surveys and rotational point counts are presented in **Table 4.7** and **Table 4.8** respectively.

Record numbers of GSM were observed during the timed traverse surveys conducted in November 2018 (Table 4.7**, Graph 4.4**). The average total number of GSM observed along the traverse across each survey during 2018 was 549.7 compared with less than 100 in 2013, 2014, 2015 and 2017 and 277 in 2016. The average number of GSM observed per minute during 2018 (i.e. 7.1) is far higher than the 2013 - 2017 average of 1.1 GSM/minute.

Table 4.7 GSM traverse survey results (2013-2018)

Year	Average GSM numbers Total GSM	Average GSM numbers Max number GSM	Average GSM numbers Average GSM / min	Average GSM numbers Max GSM / min	Average GSM numbers Min GSM / min
2013	64.0	8.3	0.9	1.4	0.4
2014	74.3	9.7	0.8	1.6	0.1
2015	25.7	3.7	0.3	0.6	0.1
2016	277.0	92.0	2.3	3.1	1.8
2017	87.0	8.3	1.2	1.6	0.8
2018	549.7	971	7.1	14.5	2.1



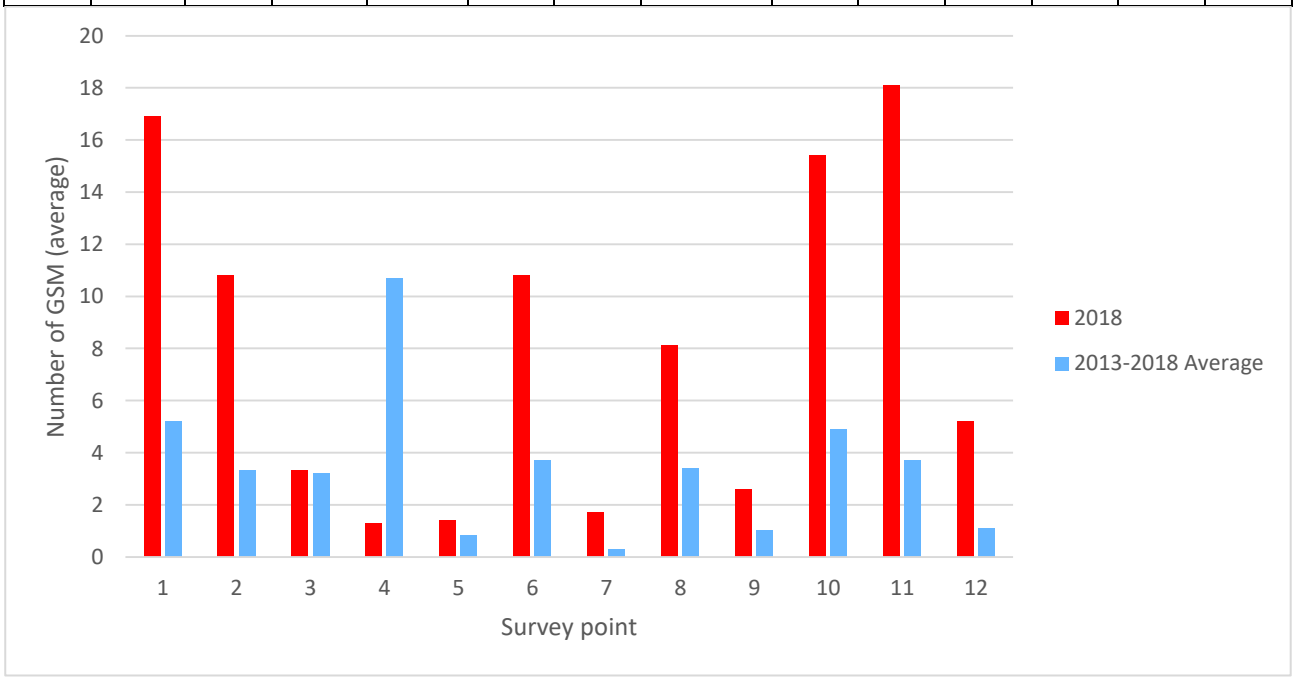
Graph 4.4 Comparison of yearly GSM traverse survey results (2013-2018)

GSM were recorded at all 12 rotational survey sites during 2018. This is the first instance of this since monitoring began at YEP in 2013. The average number of GSM recorded during the rotational point

surveys in 2018 was higher than the 2013-2018 average at all sites except site 4 where relatively high numbers of GSM were observed prior to 2017 (**Table 4.8, Graph 4.5)**. Higher than average numbers of moths were recorded at points 1, 2, 6, 10 and 11 during 2018.

Table 4.8 Average and maximum numbers of GSM at rotational survey sites (2013-2018)

Point	Average (1DP)2013	Average (1DP)2014	Average (1DP)2015	Average (1DP)2016	Average (1DP)2017	Average (1DP)2018	Average (1DP) 13 18 Av.	Maximum 2013	Maximum 2014	Maximum 2015	Maximum 2016	Maximum 2017	Maximum 2018
1	2.1	3.4	1.7	2.2	5.0	**16.9**	5.2	6	14	3	8	24	**65**
2	2.3	2.3	2.4	0.5	1.2	**10.8**	3.3	7	7	5	2	4	**40**
3	3.0	6.3	2.3	3.6	0.7	**3.3**	3.2	8	20	5	14	3	**14**
4	3.9	8.9	5.6	43.2	1.5	**1.3**	10.7	14	26	9	129	12	**9**
5	0.4	0.6	0.4	1.7	0	**1.4**	0.8	5	2	1	7	1	**9**
6	0.8	1.9	3.8	4.4	0.5	**10.8**	3.7	4	5	6	13	3	**38**
7	0.1	0.0	0.0	0	0	**1.7**	0.3	1	1	0	0	0	**9**
8	0.2	0.0	0.0	12.1	0.2	**8.1**	3.4	3	0	0	51	1	**33**
9	0.0	0.8	1.3	1.4	0	**2.6**	1.0	0	2	3	4	1	**10**
10	0.1	0.7	1.2	11.8	0.1	**15.4**	4.9	1	2	3	46	1	**63**
11	0.2	0.7	1.1	2.1	0.2	**18.1**	3.7	2	1	1	7	2	**62**
12	0.0	0.5	0.0	0.5	0.2	**5.2**	1.1	1	1	0	6	2	**23**



Graph 4.5 Average number of GSM recorded during rotational point counts (2018 vs 2013-2018 average)

The combined data from the six years of monitoring to date confirms that GSM activity has remained widespread throughout open areas of YEP though with high inter-annual variability in GSM abundance. Record numbers of GSM were recorded at YEP during November 2018 during the rotational point count surveys and the timed traverse surveys. During 2018 GSM were recorded at all rotational survey points for the first time since monitoring began in 2013 and the number of GSM recorded per minute during the timed traverse surveys was over three times greater than the previous maximum GSM/minute rate recorded in 2016.

The difference between the GSM activity levels between years, in particular, the huge spike in numbers in 2016 in 2018, at YEP is likely due to inter-annual variation in GSM abundance as a result of inter-annual climatic and site condition variability, but may also be influenced by the high variability in GSM flying levels between days, and the inability to obtain a representative sample of GSM flying levels over three survey days. Regression analysis indicates a statistically significant correlation between pre-flying season rainfall and GSM flying activity at YEP (SMEC 2018).

5.0 Compliance with the Offset Management Plan

5.1 Survey Requirements

NTG and GSM monitoring surveys were conducted according to the methods specified in the OMP (RJPL 2014a). Quadrats were located at co-ordinates specified in the 2013 monitoring report (RJPL 2014b), which are consistent with Figure 5 of the OMP (RJPL 2014a), rather than at the incorrect co- ordinates reported in Appendix B of the OMP. In addition, to improve comparability with ACT Government monitoring at other offset sites, additional transect based sampling was implemented.

It is recommended that transect based monitoring be implemented in future surveys.

5.2 Reporting Requirements

The OMP (RJPL 2014a) requires that annual monitoring reports:

- provide and assess the monitoring data for the previous twelve months against the previous monitoring results
- conclude whether or not there has been a lack of increase or a decline in GSM population numbers in the YEP due to equestrian activities, taking into account regional population trends and local ecological conditions
- conclude whether or not there has been no improvement or a decline in GSM habitat, and NTG quality and extent in the YEP due to equestrian activities, taking into account local ecological conditions.

The preparation of this report fulfils the reporting requirements for year 5, as specified in the OMP (RJPL 2014a).

5.3 Management Response

The recommended management responses detailed in the 2017 Yarralumla Equestrian Park Offset Report remain pertinent and are unchanged at present (SMEC 2018). Spot-spraying of African lovegrass and serrated tussock with selective herbicide within areas of native pasture and NTG commenced in 2018, as specified in the interim weed management plan (Umwelt 2018). Recommendations relating to control of exotic tussock grasses, also including Chilean needlegrass, remain a high priority at the site to avoid further degradation of native grassland. Interim weed control measures design to reduce expansion of exotic tussock grasses within areas of native pasture and NTG should be implemented until an updated OMP is prepared addressing a long term weed management strategy.

5.4 Impact Thresholds

The OMP (RJPL 2014a) includes a variety of ongoing management actions derived from the approval conditions. Subsequent active management responses are also identified should specified adverse impact response thresholds be met or exceeded. Four impact thresholds triggered in 2018 are outlined in the 2017 Yarralumla Equestrian Park Offset Report (SMEC 2018). Whilst no statistical analyses were conducted following the 2018 surveys, the findings of the 2018 Yarralumla Equestrian Park Offset Report relating to

impact thresholds were consistent with those reported in the 2017 Yarralumla Equestrian Park Offset Report, namely:

- There has been no increase in the spatial extent of NTG and/or GSM habitat nor has there been an increase in native grassland and NTG floristic value scores over at least three consecutive years.

- There has been no increase in NTG ranking scores or GSM habitat ranking scores over at least three consecutive seasons.

- There has been no decline in flying moth numbers over at least three consecutive seasons. Though record numbers of GSM were recorded in 2018, the high degree of stochasticity (both inter- and intra-annual) in GSM numbers means that it remains unclear whether this species is undergoing a long-term increase at Yarralumla Equestrian Park.

  Based on the above, a review of the offset management plan is triggered, consistent with the 2018 report. Statistical analysis, in addition to that completed in the 2017 report (SMEC, 2018), was not considered warranted, as preliminary conclusions on the thresholds were consistent with the 2018 and statistical significance would be unlikely to be achieved due to the stochastic variation observed.

6.0 Conclusions and Recommendations

Results

The key results of the 2018 monitoring program are:

- The spatial extent of NTG has not increased or declined. The extent of native pasture at the site has declined due to perennial exotic tussock grass invasion.
- While the total extent of GSM habitat has increased since 2013, the extent of moderate quality habitat has decreased. This is correlated with exotic perennial tussock grasses invading the site, and is indicative of a general decline in GSM habitat quality at the YEP.
- Floristic value scores and grassland ranking scores were close to or slightly below average in 2018.
- GSM habitat ranking scores continue to gradually decline at YEP.
- Record high numbers of flying moths were recorded in 2018. The timed traverse and rotational point count surveys indicated that the abundance of GSM in sampled areas were the highest observed since monitoring commenced in 2013. To date there has been no evidence of a decline in the GSM population at YEP despite substantial recent changes in grassland composition across the site.

The substantial increase in the distribution of perennial exotic tussock grasses such as African lovegrass and Chilean needle grass represents a major threat to the extent and condition of native grassland and moderate quality GSM habitat at YEP, and hence compliance with the offsetting requirement of the Commonwealth approval conditions. Weed control measures aimed at preventing future expansion of exotic tussock grasses into sensitive areas commenced in June 2018.

The findings of the 2018 monitoring report confirm that the key threats to the offset detailed in the 2017 Yarralumla Equestrian Park monitoring report (SMEC 2018) have continued to increase. Specifically, the failure to achieve any improvements in the extent or condition of natural temperate grassland or golden sun moth habitat trigger a review of the management plan consistent with the 2017 monitoring report (SMEC 2018).

Recommendations

The management recommendations outlined in the 2017 Yarralumla Equestrian Park monitoring report (SMEC 2018) relating to the maintenance and restoration of the offset remain relevant. The offset management plan should be reviewed and updated to incorporate a long term weed management strategy, specify effective management actions and define clear, practicable trigger thresholds.

Of critical priority, and requiring action independent of the management plan review process, is control of perennial exotic tussock grasses, specifically African lovegrass, Chilean needle grass and serrated tussock. Invasion by these species is threatening the extent, integrity and condition of NTG and GSM habitat at the YEP. Weed control measures aimed at preventing future expansion of these exotic tussock grasses should be continued as specified in the interim weed management plan (Umwelt 2018) until a long term weed management strategy is provided as part of the offset management plan review processes.

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APPENDIX A

2018 vegetation and habitat survey data

Scientific Name	Common Name	E/N*	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Plant Status
Native Grasses															
Austrostipa bigeniculata	tall spear grass	N	2	5	4			4				4	2	3	
Austrostipa scabra	rough speargrass	N		3	1				6	4		3	1	5	
Bothriochloa macra	redleg grass	N		3	1			4	5			5	4	6	
Carex sp.	carex sp.	N													
Elymus scabra	*wheat grass*	N		1								1		2	
Panicum effusum	hairy panic	N		3	1		1	4				2			
Rytidosperma caespitosum	*tall wallaby grass*	N		3						1		3		3	
Rytidosperma carphoides	short wallaby grass	N						2				4			
Rytidosperma sp.	wallaby grass	N	1						3	2					
Themeda australis	kangaroo grass	N								5					
Native forbs															
Acaena ovina	sheep's burr	N													
Chrysocephalum apiculatum	yellow buttons	N		4				2				4	3	4	
Euchiton sp.	cudweed sp.	N													
Erodium crinitum	blue storkskbill	N	1												

Scientific Name	Common Name	E/N*	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Plant Status
Lomandra bracteata	mat-rush sp.	N													
Lomandra filiformis subsp. coriacea	mat-rush sp.	N													
Lomandra multiflora	mat-rush sp.	N							1			1		2	
Oxalis sp.														1	
Rumex brownii	swamp dock	N													
Wahlenbergia communis	tufted bluebell	N		2								2	1		
Wahlenbergia luteola	bluebell sp.	N										1			
Wurmbea dioica	early Nancy														
Exotic grasses															
Aira sp.	hairgrass	E													
Avena sp.	oats	E	2			1	1	2	3	1	4	2	3		
Briza minor	shivery grass	E													
Bromus catharticus	prairie grass	E	3			6									
Bromus diandrus	ripgut brome	E													
Bromus hordeaceus	soft brome	E	4		2		2	3	3	4	2	3	2	2	
Bromus spp.	bromes	E													
Dactylis glomerata	cocksfoot	E	5	2	4			1							

Scientific Name	Common Name	E/N*	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Plant Status
Eragrostis curvula	African lovegrass	E	1	3	1		2	4	5	4	6	4	7	2	ACT C; WoNS
Festuca arundinacea	tall fescue	E						2			1		4		
Hordeum sp.	barley sp.	E													
Lolium perenne	perennial ryegrass	E													
Nassella neesiana	Chilean needle grass	E			1		6	5			3	3			ACT P, C; WoNS
Paspalum dilatatum	paspalum	E						1	1		4	2		1	
Nassella trichotoma	serrated tussock	E													ACT P, C; WoNS
Phalaris aquatica	tall phalaris	E					1				4				
Poa annua	annual meadow grass	E													
Poa bulbosa	bulbous bluegrass	E							1				1		
Sporobolus africanus	Parramatta grass	E											3		
Vulpia sp.	rat's tail fescue	E					3	3	3	3					
Exotic forbs															
Arctotheca calendula	Cape weed	E													
Cathamus lanatus	saffron thistle	E													
Centaurium sp.	centaury sp.	E													

Scientific Name	Common Name	E/N*	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Plant Status
Cerastium glomeratum	mouse-ear chickweed	E					1								
Chondrilla juncea	skeleton weed	E					4			3	3	2			
Echium vulgare	viper's bugloss	E													
Erodium botrys	stork's bill sp.	E													
Erodium cicutarium	common storksbill	E	2												
Hirschfeldia incana	hairy mustard	E		1		4			1						
Hypericum perforatum	St John's wort	E		2							3	3	1	2	ACT C
Hypochaeris glabra	flatweed	E													
Hypochaeris radicata	flatweed	E		2			1		2	3	2	2	4	5	
Malva sp.	mallow sp.	E													
Medicago sp.	medick	E	3												
Moenchia erecta	erect chickweed	E													
Oenothera glazioviana	large-flowered evening-primrose	E													
Paronychia brasiliana	Brazilian whitlow	E												2	
Petrorhagia nanteuilii	proliferous pink	E							2						

Scientific Name	Common Name	E/N*	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Plant Status
Plantago lanceolata	narrow leaf plantain	E	5	4	2		1	1	2	4		2	4	4	
Rumex brownii	hooked dock	E					1		1	1			2		
Spergularia rubra	red sand-spurrey	E													
Tolpis barbarta	yellow hawkweed	E													
Tragopogan sp.		E	2												
Trifolium arvensis	haresfoot clover	E					1								
Trifolium campestre	hop trefoil	E													
Trifolium sp.	clover	E									2				
Trifolium subterraneum	subterranean clover	E	2												

* E – Exotic, N - Native

APPENDIX B

2018 flying GSM survey data (rotational point survey)

Date	Survey	Quadrat	Quadrat 1	Quadrat 2	Quadrat 3	Quadrat 4	Quadrat 5	Quadrat 6	Quadrat 7	Quadrat 8	Quadrat 9	Quadrat 10	Total	Average
13/11/2018	1	1	2	0	3	3	6	4	0	1	1	1	21	2.1
13/11/2018	1	2	3	0	1	1	2	0	0	0	2	0	9	0.9
13/11/2018	1	3	0	0	1	0	0	1	1	0	0	0	3	0.3
13/11/2018	1	4	0	0	0	2	1	0	0	0	0	0	3	0.3
13/11/2018	1	5	0	0	0	0	2	1	0	0	0	0	3	0.3
13/11/2018	1	6	1	9	12	11	2	9	10	2	3	1	60	6
13/11/2018	1	7	0	0	0	0	0	0	0	0	0	0	0	0
13/11/2018	1	8	7	15	0	3	4	4	4	2	1	2	42	4.2
13/11/2018	1	9	3	0	0	0	0	0	0	0	0	0	3	0.3
13/11/2018	1	10	7	5	0	2	2	1	4	3	4	3	31	3.1
13/11/2018	1	11	0	1	3	0	1	0	1	0	0	1	7	0.7
13/11/2018	1	12	0	0	0	1	0	0	1	1	0	0	3	0.3
19/11/2018	2	1	34	32	65	45	52	51	45	45	41	59	469	46.9
19/11/2018	2	2	36	25	33	28	36	22	21	19	19	40	279	27.9
19/11/2018	2	3	11	7	10	14	8	5	6	7	5	13	86	8.6
19/11/2018	2	4	2	2	0	6	2	9	4	4	1	5	35	3.5
19/11/2018	2	5	3	6	0	6	5	1	9	3	1	0	34	3.4
19/11/2018	2	6	30	27	19	24	31	38	16	29	20	18	252	25.2
19/11/2018	2	7	5	3	7	8	9	5	4	2	4	3	50	5
19/11/2018	2	8	25	8	16	26	27	15	33	19	20	11	200	20
19/11/2018	2	9	4	10	8	8	8	7	6	4	9	5	69	6.9
19/11/2018	2	10	37	33	63	61	38	25	29	36	37	49	408	40.8
19/11/2018	2	11	19	17	9	15	11	15	8	10	8	16	128	12.8

Date	Survey	Quadrat	Quadrat 1	Quadrat 2	Quadrat 3	Quadrat 4	Quadrat 5	Quadrat 6	Quadrat 7	Quadrat 8	Quadrat 9	Quadrat 10	Total	Average
19/11/2018	2	12	5	7	8	5	9	6	5	5	9	1	60	6
26/11/2018	3	1	2	1	2	2	3	2	1	0	3	0	16	1.6
26/11/2018	3	2	4	4	2	1	7	7	5	1	1	3	35	3.5
26/11/2018	3	3	3	1	0	0	2	1	2	0	0	0	9	0.9
26/11/2018	3	4	0	0	0	0	0	0	0	1	0	0	1	0.1
26/11/2018	3	5	0	0	0	0	3	0	1	1	0	0	5	0.5
26/11/2018	3	6	0	1	3	0	4	1	1	2	1	0	13	1.3
26/11/2018	3	7	0	0	0	0	0	0	0	0	0	0	0	0
26/11/2018	3	8	0	2	1	0	1	0	1	1	0	0	6	0.6
26/11/2018	3	9	3	4	2	0	5	2	1	2	1	4	24	2.4
26/11/2018	3	10	35	39	62	45	53	34	62	23	20	36	409	40.9
26/11/2018	3	11	23	10	18	12	4	6	7	5	6	3	94	9.4
26/11/2018	3	12	1	2	1	1	2	0	3	0	2	3	15	1.5

APPENDIX C

2018 GSM observations

Date	Survey	X	Y	Number of GSM	Sex/Pupae Case	Survey Type
13/11/2018	1	688518.7	6090495	1	Male	TRAVERSE
13/11/2018	1	688546.8	6090550	3	Male	TRAVERSE
13/11/2018	1	688532.5	6090619	5	Male	TRAVERSE
13/11/2018	1	688527	6090639	3	Male	TRAVERSE
13/11/2018	1	688528.5	6090643	25	Male	TRAVERSE
13/11/2018	1	688530.6	6090665	10	Male	TRAVERSE
13/11/2018	1	688497	6090670	3	Male	TRAVERSE
13/11/2018	1	688472.3	6090675	15	Male	TRAVERSE
13/11/2018	1	688442.2	6090678	40	Male	TRAVERSE
13/11/2018	1	688388.2	6090671	10	Male	TRAVERSE
13/11/2018	1	688363.1	6090675	20	Male	TRAVERSE
13/11/2018	1	688339.6	6090670	15	Male	TRAVERSE
13/11/2018	1	688307.5	6090653	2	Male	TRAVERSE
13/11/2018	1	688276.6	6090628	3	Male	TRAVERSE
13/11/2018	1	688302	6090711	5	Male	TRAVERSE
13/11/2018	1	688323.8	6090720	3	Male	TRAVERSE
13/11/2018	1	688342	6090757	2	Male	TRAVERSE
13/11/2018	1	688352.5	6090787	3	Male	TRAVERSE
13/11/2018	1	688376	6090802	3	Male	TRAVERSE
13/11/2018	1	688378.4	6090824	5	Male	TRAVERSE
13/11/2018	1	688381.3	6090849	10	Male	TRAVERSE
13/11/2018	1	688393	6090877	6	Pupae Case	TRAVERSE
13/11/2018	1	688393	6090877	3	Male	TRAVERSE
13/11/2018	1	688395.3	6090886	6	Pupae Case	TRAVERSE
13/11/2018	1	688400.2	6090896	20	Male	TRAVERSE
13/11/2018	1	688414.5	6090918	8	Male	TRAVERSE
13/11/2018	1	688414.5	6090918	5	Pupae Case	TRAVERSE
13/11/2018	1	688413.6	6090930	3	Pupae Case	TRAVERSE
13/11/2018	1	688413.6	6090930	5	Male	TRAVERSE
13/11/2018	1	688416.6	6090949	3	Male	TRAVERSE
13/11/2018	1	688423.8	6090984	1	Male	TRAVERSE
13/11/2018	1	688460.9	6090966	2	Male	TRAVERSE
13/11/2018	1	688465.5	6090952	1	Male	TRAVERSE
13/11/2018	1	688478.2	6090905	2	Male	TRAVERSE
13/11/2018	1	688494.4	6090902	7	Male	TRAVERSE
13/11/2018	1	688490.8	6090866	5	Male	TRAVERSE

Date	Survey	X	Y	Number of GSM	Sex/Pupae Case	Survey Type
13/11/2018	1	688508.6	6090834	3	Male	TRAVERSE
13/11/2018	1	688514.2	6090812	6	Male	TRAVERSE
13/11/2018	1	688517.5	6090782	3	Male	TRAVERSE
13/11/2018	1	688530	6090770	15	Male	TRAVERSE
13/11/2018	1	688530	6090770	1	Pupae Case	TRAVERSE
13/11/2018	1	688535.8	6090763	9	Pupae Case	TRAVERSE
13/11/2018	1	688545.2	6090742	10	Male	TRAVERSE
13/11/2018	1	688553.5	6090710	7	Male	TRAVERSE
13/11/2018	1	688553.7	6090710	1	Pupae Case	TRAVERSE
13/11/2018	1	688571.6	6090691	6	Male	TRAVERSE
13/11/2018	1	688592.5	6090680	3	Male	TRAVERSE
13/11/2018	1	688596.2	6090661	3	Male	TRAVERSE
13/11/2018	1	688695.2	6090576	5	Pupae Case	TRAVERSE
13/11/2018	1	688702.3	6090575	2	Male	TRAVERSE
13/11/2018	1	688751.2	6090618	1	Male	TRAVERSE
13/11/2018	1	688732.7	6090641	2	Male	TRAVERSE
13/11/2018	1	688686.1	6090702	2	Male	TRAVERSE
13/11/2018	1	688674.3	6090736	6	Male	TRAVERSE
13/11/2018	1	688662.5	6090759	10	Male	TRAVERSE
13/11/2018	1	688663.5	6090776	50	Male	TRAVERSE
13/11/2018	1	688655.2	6090795	20	Male	TRAVERSE
13/11/2018	1	688655.2	6090795	1	Pupae Case	TRAVERSE
13/11/2018	1	688640.5	6090811	12	Male	TRAVERSE
13/11/2018	1	688629.6	6090839	3	Male	TRAVERSE
13/11/2018	1	688612	6090866	2	Male	TRAVERSE
13/11/2018	1	688597	6090898	1	Male	TRAVERSE
13/11/2018	1	688579.2	6090929	1	Male	TRAVERSE
13/11/2018	1	688559	6090984	1	Male	TRAVERSE
13/11/2018	1	688612.5	6090942	1	Male	TRAVERSE
13/11/2018	1	688614.5	6090927	1	Female	TRAVERSE
13/11/2018	1	688620.2	6090900	1	Male	TRAVERSE
13/11/2018	1	688638.9	6090840	1	Male	TRAVERSE
13/11/2018	1	688668.9	6090797	12	Male	TRAVERSE
13/11/2018	1	688694.8	6090780	3	Male	TRAVERSE
13/11/2018	1	688722.9	6090754	1	Female	TRAVERSE
13/11/2018	1	688724.2	6090723	2	Male	TRAVERSE

Date	Survey	X	Y	Number of GSM	Sex/Pupae Case	Survey Type
13/11/2018	1	688734.7	6090685	3	Male	TRAVERSE
13/11/2018	1	688734.7	6090685	2	Pupae Case	TRAVERSE
13/11/2018	1	688739.4	6090679	7	Pupae Case	TRAVERSE
13/11/2018	1	688745.6	6090670	8	Male	TRAVERSE
13/11/2018	1	688745.7	6090669	8	Male	TRAVERSE
13/11/2018	1	688763.7	6090662	1	Pupae Case	TRAVERSE
13/11/2018	1	688775.2	6090661	2	Male	TRAVERSE
13/11/2018	1	688791.2	6090672	1	Male	TRAVERSE
13/11/2018	1	688811.4	6090717	1	Pupae Case	TRAVERSE
13/11/2018	1	688783.9	6090738	1	Male	TRAVERSE
13/11/2018	1	688773.7	6090718	1	Male	TRAVERSE
13/11/2018	1	688786.6	6090680	2	Male	TRAVERSE
13/11/2018	1	688844.9	6090591	1	Male	TRAVERSE
13/11/2018	1	688794.9	6090599	1	Male	TRAVERSE
13/11/2018	1	688772.3	6090595	1	Male	TRAVERSE
13/11/2018	1	688669.1	6090567	2	Pupae Case	TRAVERSE
13/11/2018	1	688678.9	6090783	2	Pupae Case	TRAVERSE
13/11/2018	1	688681.3	6090784	1	Female	TRAVERSE
13/11/2018	1	688637.6	6090833	1	Female	TRAVERSE
13/11/2018	1	688637.4	6090829	1	Female	TRAVERSE
13/11/2018	1	688746.7	6090745	1	Female	TRAVERSE
13/11/2018	1	688806.5	6090731	4	Pupae Case	TRAVERSE
13/11/2018	1	688530.3	6090749	2	Pupae Case	TRAVERSE
13/11/2018	1	688541.6	6090750	2	Female	TRAVERSE
13/11/2018	1	688497.6	6090736	2	Pupae Case	TRAVERSE
13/11/2018	1	688479.2	6090725	1	Female	TRAVERSE
13/11/2018	1	688440.9	6090698	20	Pupae Case	TRAVERSE
13/11/2018	1	688433.3	6090683	30	Pupae Case	TRAVERSE
13/11/2018	1	688329.7	6090690	2	Pupae Case	TRAVERSE
13/11/2018	1	688392.7	6090812	1	Pupae Case	TRAVERSE
13/11/2018	1	688389	6090824	3	Pupae Case	TRAVERSE
13/11/2018	1	688413.4	6090862	4	Pupae Case	TRAVERSE
13/11/2018	1	688424	6090681	2.1	M	POINT COUNT (AVERAGE)
13/11/2018	1	688333	6090691	0.9	M	POINT COUNT (AVERAGE)
13/11/2018	1	688387	6090809	0.3	M	POINT COUNT

Date	Survey	X	Y	Number of GSM	Sex/Pupae Case	Survey Type
						(AVERAGE)
13/11/2018	1	688421	6090864	0.3	M	POINT COUNT (AVERAGE)
13/11/2018	1	688431	6091040	0.3	M	POINT COUNT (AVERAGE)
13/11/2018	1	688534	6090760	6	M	POINT COUNT (AVERAGE)
13/11/2018	1	688888	6090612	0	M	POINT COUNT (AVERAGE)
13/11/2018	1	688735	6090654	4.2	M	POINT COUNT (AVERAGE)
13/11/2018	1	688789	6090726	0.3	M	POINT COUNT (AVERAGE)
13/11/2018	1	688685	6090779	3.1	M	POINT COUNT (AVERAGE)
13/11/2018	1	688631	6090838	0.7	M	POINT COUNT (AVERAGE)
13/11/2018	1	688612	6090954	0.3	M	POINT COUNT (AVERAGE)
16/11/2018		688421.5	6090681	5	Male	INCIDENTAL
16/11/2018		688445.2	6090726	3	Male	INCIDENTAL
16/11/2018		688389.7	6090811	1	Female	INCIDENTAL
16/11/2018		688731.9	6090647	1	Female	INCIDENTAL
16/11/2018		688729.3	6090642	1	Female	INCIDENTAL
19/11/2018	2	688531.8	6090505	3	Male	TRAVERSE
19/11/2018	2	688540.9	6090536	5	Male	TRAVERSE
19/11/2018	2	688543.5	6090587	15	Male	TRAVERSE
19/11/2018	2	688517.5	6090625	5	Male	TRAVERSE
19/11/2018	2	688527.1	6090648	5	Male	TRAVERSE
19/11/2018	2	688530.1	6090667	25	Male	TRAVERSE
19/11/2018	2	688508	6090681	100	Male	TRAVERSE
19/11/2018	2	688481	6090687	50	Male	TRAVERSE
19/11/2018	2	688457.5	6090694	5	Male	TRAVERSE
19/11/2018	2	688426.5	6090688	20	Male	TRAVERSE
19/11/2018	2	688392.5	6090686	8	Male	TRAVERSE
19/11/2018	2	688377.9	6090695	1	Female	TRAVERSE
19/11/2018	2	688381.3	6090692	45	Male	TRAVERSE
19/11/2018	2	688347.6	6090695	12	Male	TRAVERSE
19/11/2018	2	688322.1	6090684	20	Male	TRAVERSE

Date	Survey	X	Y	Number of GSM	Sex/Pupae Case	Survey Type
19/11/2018	2	688321.2	6090685	5	Pupae Case	TRAVERSE
19/11/2018	2	688302.6	6090692	7	Male	TRAVERSE
19/11/2018	2	688297.1	6090697	1	Pupae Case	TRAVERSE
19/11/2018	2	688310.1	6090719	8	Male	TRAVERSE
19/11/2018	2	688320.3	6090725	3	Pupae Case	TRAVERSE
19/11/2018	2	688333.4	6090745	2	Male	TRAVERSE
19/11/2018	2	688375.3	6090801	3	Male	TRAVERSE
19/11/2018	2	688382.1	6090818	2	Male	TRAVERSE
19/11/2018	2	688379.8	6090849	4	Male	TRAVERSE
19/11/2018	2	688386.2	6090873	3	Male	TRAVERSE
19/11/2018	2	688396.6	6090894	10	Male	TRAVERSE
19/11/2018	2	688403.2	6090912	3	Pupae Case	TRAVERSE
19/11/2018	2	688403.3	6090911	7	Male	TRAVERSE
19/11/2018	2	688400.8	6090944	4	Male	TRAVERSE
19/11/2018	2	688402.6	6090967	2	Male	TRAVERSE
19/11/2018	2	688417.1	6090980	3	Male	TRAVERSE
19/11/2018	2	688423.3	6091015	1	Male	TRAVERSE
19/11/2018	2	688438	6091029	1	Male	TRAVERSE
19/11/2018	2	688453.3	6090988	1	Male	TRAVERSE
19/11/2018	2	688464.5	6090960	5	Male	TRAVERSE
19/11/2018	2	688470.1	6090936	10	Male	TRAVERSE
19/11/2018	2	688482.4	6090920	5	Pupae Case	TRAVERSE
19/11/2018	2	688482.9	6090920	15	Male	TRAVERSE
19/11/2018	2	688475.9	6090900	6	Male	TRAVERSE
19/11/2018	2	688484.9	6090881	7	Male	TRAVERSE
19/11/2018	2	688486.2	6090853	3	Male	TRAVERSE
19/11/2018	2	688490.7	6090835	23	Male	TRAVERSE
19/11/2018	2	688493.2	6090827	1	Pupae Case	TRAVERSE
19/11/2018	2	688495.4	6090811	15	Male	TRAVERSE
19/11/2018	2	688507.1	6090787	8	Male	TRAVERSE
19/11/2018	2	688517.3	6090774	8	Male	TRAVERSE
19/11/2018	2	688528.8	6090741	35	Male	TRAVERSE
19/11/2018	2	688529.9	6090736	1	Pupae Case	TRAVERSE
19/11/2018	2	688538.4	6090725	19	Male	TRAVERSE
19/11/2018	2	688553.5	6090704	6	Male	TRAVERSE
19/11/2018	2	688565.9	6090689	13	Male	TRAVERSE

Date	Survey	X	Y	Number of GSM	Sex/Pupae Case	Survey Type
19/11/2018	2	688582.5	6090671	12	Male	TRAVERSE
19/11/2018	2	688598.2	6090654	8	Male	TRAVERSE
19/11/2018	2	688657.2	6090596	2	Male	TRAVERSE
19/11/2018	2	688697.5	6090575	30	Male	TRAVERSE
19/11/2018	2	688716	6090647	35	Male	TRAVERSE
19/11/2018	2	688691.7	6090685	5	Male	TRAVERSE
19/11/2018	2	688683.8	6090718	8	Male	TRAVERSE
19/11/2018	2	688668.9	6090754	50	Male	TRAVERSE
19/11/2018	2	688648.5	6090791	30	Male	TRAVERSE
19/11/2018	2	688634.4	6090815	17	Male	TRAVERSE
19/11/2018	2	688621.2	6090841	10	Male	TRAVERSE
19/11/2018	2	688594.8	6090893	11	Male	TRAVERSE
19/11/2018	2	688582.5	6090912	12	Male	TRAVERSE
19/11/2018	2	688566.9	6090934	5	Male	TRAVERSE
19/11/2018	2	688552.4	6090967	4	Male	TRAVERSE
19/11/2018	2	688560.1	6090987	16	Male	TRAVERSE
19/11/2018	2	688563	6090984	9	Pupae Case	TRAVERSE
19/11/2018	2	688565.3	6090982	1	Female	TRAVERSE
19/11/2018	2	688579.1	6090975	5	Male	TRAVERSE
19/11/2018	2	688602.3	6090957	3	Male	TRAVERSE
19/11/2018	2	688610.9	6090934	14	Male	TRAVERSE
19/11/2018	2	688615.3	6090914	4	Male	TRAVERSE
19/11/2018	2	688624.6	6090879	7	Male	TRAVERSE
19/11/2018	2	688631.5	6090855	4	Male	TRAVERSE
19/11/2018	2	688639.5	6090837	13	Male	TRAVERSE
19/11/2018	2	688678.8	6090793	18	Male	TRAVERSE
19/11/2018	2	688698.6	6090771	2	Pupae Case	TRAVERSE
19/11/2018	2	688698.3	6090771	15	Male	TRAVERSE
19/11/2018	2	688722.1	6090754	3	Male	TRAVERSE
19/11/2018	2	688720.9	6090710	7	Male	TRAVERSE
19/11/2018	2	688731.6	6090688	15	Male	TRAVERSE
19/11/2018	2	688743.1	6090669	25	Male	TRAVERSE
19/11/2018	2	688768.7	6090668	2	Male	TRAVERSE
19/11/2018	2	688773.5	6090692	3	Male	TRAVERSE
19/11/2018	2	688803.7	6090671	1	Male	TRAVERSE
19/11/2018	2	688808	6090641	3	Male	TRAVERSE

Date	Survey	X	Y	Number of GSM	Sex/Pupae Case	Survey Type
19/11/2018	2	688844.1	6090608	2	Male	TRAVERSE
19/11/2018	2	688883.8	6090609	3	Male	TRAVERSE
19/11/2018	2	688844	6090590	3	Male	TRAVERSE
19/11/2018	2	688792.4	6090589	2	Male	TRAVERSE
19/11/2018	2	688655.1	6090559	15	Male	TRAVERSE
19/11/2018	2	688652.2	6090791	1	Female	TRAVERSE
19/11/2018	2	688666.2	6090789	1	Female	TRAVERSE
19/11/2018	2	688670.5	6090785	1	Pupae Case	TRAVERSE
19/11/2018	2	688674.9	6090786	1	Female	TRAVERSE
19/11/2018	2	688674.9	6090786	1	Pupae Case	TRAVERSE
19/11/2018	2	688673.4	6090794	3	Female	TRAVERSE
19/11/2018	2	688673.4	6090794	5	Pupae Case	TRAVERSE
19/11/2018	2	688669.4	6090779	3	Pupae Case	TRAVERSE
19/11/2018	2	688635.4	6090854	1	Female	TRAVERSE
19/11/2018	2	688670.6	6090569	4	Pupae Case	TRAVERSE
19/11/2018	2	688560.1	6090507	2	Pupae Case	TRAVERSE
19/11/2018	2	688424	6090681	46.9	M	POINT COUNT (AVERAGE)
19/11/2018	2	688333	6090691	27.9	M	POINT COUNT (AVERAGE)
19/11/2018	2	688387	6090809	8.6	M	POINT COUNT (AVERAGE)
19/11/2018	2	688421	6090864	3.5	M	POINT COUNT (AVERAGE)
19/11/2018	2	688431	6091040	3.4	M	POINT COUNT (AVERAGE)
19/11/2018	2	688534	6090760	25.2	M	POINT COUNT (AVERAGE)
19/11/2018	2	688888	6090612	5	M	POINT COUNT (AVERAGE)
19/11/2018	2	688735	6090654	20	M	POINT COUNT (AVERAGE)
19/11/2018	2	688789	6090726	6.9	M	POINT COUNT (AVERAGE)
19/11/2018	2	688685	6090779	40.8	M	POINT COUNT (AVERAGE)
19/11/2018	2	688631	6090838	12.8	M	POINT COUNT (AVERAGE)
19/11/2018	2	688612	6090954	6	M	POINT COUNT (AVERAGE)

Date	Survey	X	Y	Number of GSM	Sex/Pupae Case	Survey Type
26/11/2018	3	688547.7	6090586	1	Male	TRAVERSE
26/11/2018	3	688520.5	6090651	1	Male	TRAVERSE
26/11/2018	3	688479.6	6090683	1	Male	TRAVERSE
26/11/2018	3	688466.2	6090686	2	Male	TRAVERSE
26/11/2018	3	688452	6090688	1	Male	TRAVERSE
26/11/2018	3	688397.2	6090684	1	Male	TRAVERSE
26/11/2018	3	688377.7	6090684	1	Male	TRAVERSE
26/11/2018	3	688344.3	6090683	1	Male	TRAVERSE
26/11/2018	3	688303.2	6090703	1	Male	TRAVERSE
26/11/2018	3	688317.9	6090727	1	Male	TRAVERSE
26/11/2018	3	688325.9	6090743	2	Male	TRAVERSE
26/11/2018	3	688343	6090778	2	Male	TRAVERSE
26/11/2018	3	688385.6	6090849	2	Male	TRAVERSE
26/11/2018	3	688496.3	6090822	2	Male	TRAVERSE
26/11/2018	3	688502.1	6090778	1	Male	TRAVERSE
26/11/2018	3	688504.9	6090748	1	Male	TRAVERSE
26/11/2018	3	688507.5	6090732	2	Male	TRAVERSE
26/11/2018	3	688527.1	6090722	1	Male	TRAVERSE
26/11/2018	3	688532.1	6090720	3	Male	TRAVERSE
26/11/2018	3	688535.7	6090721	1	Male	TRAVERSE
26/11/2018	3	688587.7	6090663	1	Male	TRAVERSE
26/11/2018	3	688606.5	6090640	10	Male	TRAVERSE
26/11/2018	3	688701.7	6090648	2	Male	TRAVERSE
26/11/2018	3	688658.5	6090735	1	Male	TRAVERSE
26/11/2018	3	688656.4	6090757	11	Male	TRAVERSE
26/11/2018	3	688651.4	6090779	3	Male	TRAVERSE
26/11/2018	3	688648.1	6090791	8	Male	TRAVERSE
26/11/2018	3	688643	6090804	6	Male	TRAVERSE
26/11/2018	3	688636.5	6090814	4	Male	TRAVERSE
26/11/2018	3	688626.4	6090837	6	Male	TRAVERSE
26/11/2018	3	688621.6	6090851	1	Male	TRAVERSE
26/11/2018	3	688611.9	6090867	4	Male	TRAVERSE
26/11/2018	3	688595.3	6090891	4	Male	TRAVERSE
26/11/2018	3	688575.9	6090922	16	Male	TRAVERSE
26/11/2018	3	688564.4	6090950	17	Male	TRAVERSE
26/11/2018	3	688557.9	6090962	3	Male	TRAVERSE

Date	Survey	X	Y	Number of GSM	Sex/Pupae Case	Survey Type
26/11/2018	3	688564.7	6090978	4	Male	TRAVERSE
26/11/2018	3	688590.7	6090958	2	Male	TRAVERSE
26/11/2018	3	688602.7	6090943	1	Male	TRAVERSE
26/11/2018	3	688616	6090921	2	Male	TRAVERSE
26/11/2018	3	688620.6	6090905	1	Male	TRAVERSE
26/11/2018	3	688626.1	6090883	1	Male	TRAVERSE
26/11/2018	3	688627.9	6090877	1	Male	TRAVERSE
26/11/2018	3	688634.8	6090849	4	Male	TRAVERSE
26/11/2018	3	688640	6090819	2	Male	TRAVERSE
26/11/2018	3	688645.1	6090808	5	Male	TRAVERSE
26/11/2018	3	688659.6	6090792	27	Male	TRAVERSE
26/11/2018	3	688686.9	6090779	12	Male	TRAVERSE
26/11/2018	3	688704.3	6090761	9	Male	TRAVERSE
26/11/2018	3	688703.7	6090741	2	Male	TRAVERSE
26/11/2018	3	688704.9	6090730	1	Male	TRAVERSE
26/11/2018	3	688711.9	6090694	1	Male	TRAVERSE
26/11/2018	3	688723.9	6090676	2	Male	TRAVERSE
26/11/2018	3	688759.8	6090647	1	Male	TRAVERSE
26/11/2018	3	688772.7	6090667	2	Male	TRAVERSE
26/11/2018	3	688731.1	6090755	4	Male	TRAVERSE
26/11/2018	3	688713.2	6090775	5	Male	TRAVERSE
26/11/2018	3	688715.4	6090575	2	Male	TRAVERSE
26/11/2018	3	688710.4	6090566	1	Male	TRAVERSE
26/11/2018	3	688424	6090681	1.6	M	POINT COUNT (AVERAGE)
26/11/2018	3	688333	6090691	3.5	M	POINT COUNT (AVERAGE)
26/11/2018	3	688387	6090809	0.9	M	POINT COUNT (AVERAGE)
26/11/2018	3	688421	6090864	0.1	M	POINT COUNT (AVERAGE)
26/11/2018	3	688431	6091040	0.5	M	POINT COUNT (AVERAGE)
26/11/2018	3	688534	6090760	1.3	M	POINT COUNT (AVERAGE)
26/11/2018	3	688888	6090612	0	M	POINT COUNT (AVERAGE)
26/11/2018	3	688735	6090654	0.6	M	POINT COUNT (AVERAGE)

Date	Survey	X	Y	Number of GSM	Sex/Pupae Case	Survey Type
26/11/2018	3	688789	6090726	2.4	M	POINT COUNT (AVERAGE)
26/11/2018	3	688685	6090779	40.9	M	POINT COUNT (AVERAGE)
26/11/2018	3	688631	6090838	9.4	M	POINT COUNT (AVERAGE)
26/11/2018	3	688612	6090954	1.5	M	POINT COUNT (AVERAGE)

APPENDIX D

Summarised meteorological data

Year	Month	Monthly Precipitation (mm)	Average Maximum Daily Air Temperature (ºC)	Average Minimum Daily Air Temperature (ºC)	Average Maximum Daily Soil Temperature (ºC at 10 cm depth)	Average Minimum Daily Soil Temperature (ºC at 10 cm depth)
2013	January	72.6	32.3	13.9	33.2	23.8
2013	February	30	27.4	12.8	30	21.4
2013	March	197.2	25.7	9.6	Data unavailable	Data unavailable
2013	April	9.8	22.1	5.5	Data unavailable	Data unavailable
2013	May	19.8	17.4	1.3	Data unavailable	Data unavailable
2013	June	85.2	13.9	1.6	Data unavailable	Data unavailable
2013	July	42.8	13.4	1.7	10.5	6.2
2013	August	27	14.8	2.4	12.1	6.6
2013	September	91	19.9	4	17.8	10.8
2013	October	13.4	21.9	3.8	21.7	13.3
2013	November	105.6	23.8	6.7	25.3	16.3
2013	December	23.2	28.5	11.5	33.7	23.6
2014	January	4.8	31.6	12.1	35.7	24.8
2014	February	83.6	29.4	13.5	33.2	23.8
2014	March	88	24.2	12.2	25	18.7
2014	April	16.9	19.7	7.4	19.3	13.9
2014	May	14.4	17.6	2.7	14.7	9.5
2014	June	57.2	13.2	2.8	10.7	7.3
2014	July	34.9	12.2	0	9.1	4.9
2014	August	26.8	14.3	-0.8	11.8	5.7
2014	September	36.2	17.9	2.7	16.9	9.5
2014	October	53.4	22.5	5.4	22.5	13.9
2014	November	29	27.9	10.2	29.5	19.9
2014	December	102	27.7	12.7	29.5	20.4
2015	January	34.8	27.2	13.9	29.6	21.4
2015	February	30.2	28.3	13	30	21.4
2015	March	12.4	26.1	9	27.1	18.6

Year	Month	Monthly Precipitation (mm)	Average Maximum Daily Air Temperature (ºC)	Average Minimum Daily Air Temperature (ºC)	Average Maximum Daily Soil Temperature (ºC at 10 cm depth)	Average Minimum Daily Soil Temperature (ºC at 10 cm depth)
2015	April	91.8	19.1	7.1	17.7	12.6
2015	May	12.2	16	2.8	14	8.8
2015	June	55.2	13.7	-0.8	10.6	5.7
2015	July	37.2	11.6	-0.7	8.6	3.9
2015	August	66.8	13.7	1	10.7	5.3
2015	September	13.6	17.7	1.5	17.3	8.7
2015	October	26.6	24.8	8.3	24.6	16.2
2015	November	67.6	25.6	10.9	26.1	17.9
2015	December	34.8	29.3	11.4	32.3	21.9
2016	January	106.4	28.5	14	29	21.5
2016	February	23.4	29.3	13.3	31.5	22.6
2016	March	28.4	27.7	12.6	28.1	20.2
2016	April	6.8	23.8	8.3	22.8	16.3
2016	May	47.6	17.4	4.8	15	9.9
2016	June	144.2	13	3	10.4	6.6
2016	July	71	12.7	2.2	10.2	5.8
2016	August	46.2	14.3	1.1	11.9	5.8
2016	September	149.2	15.8	4.8	14.7	8.7
2016	October	43.6	18.5	5.2	19.5	11
2016	November	56.8	24.8	8.6	28	17.6
2016	December	64.6	28.7	13.5	29.8	21.4
2017	January	8.4	32.8	14.9		
2017	February	20.6	30.1	12.9		
2017	March	85.2	25.9	12.8		
2017	April	31.6	19.9	5.5		
2017	May	34.2	16.4	1.6		
2017	June	2.4	13.6	-1.4		

Year	Month	Monthly Precipitation (mm)	Average Maximum Daily Air Temperature (ºC)	Average Minimum Daily Air Temperature (ºC)	Average Maximum Daily Soil Temperature (ºC at 10 cm depth)	Average Minimum Daily Soil Temperature (ºC at 10 cm depth)
2017	July	17	12.9	-2.3		
2017	August	49.2	13.9	0.5		
2017	September	13.4	18.1	2.7		
2017	October	58.4	23.2	7.1		
2017	November	70.4	24.3	9.6		
2017	December	95.2	27.8	13.9		
2018	January	38	31.6	14.4	33.4	23.4
2018	February	86.4	29	12.8	31.5	22.0
2018	March	7.2	26.3	10.4	27.7	19.0
2018	April	19.6	25	8.7	23.9	16.6
2018	May	15	17.5	2.2	15.1	8.8
2018	June	27.8	13.2	1.8	10.7	6.1
2018	July	7.8	13.3	-1.7	10.6	4.2
2018	August	29	13.9	0.8	12.2	5.7
2018	September	38.2	18	1.8	17.8	9.1
2018	October	14.2	22.8	7.3	23.5	14.9
2018	November	82.4	24.5	10.5	25.6	16.8
2018	December	106.4	29.3	13.7	31.1	21.1

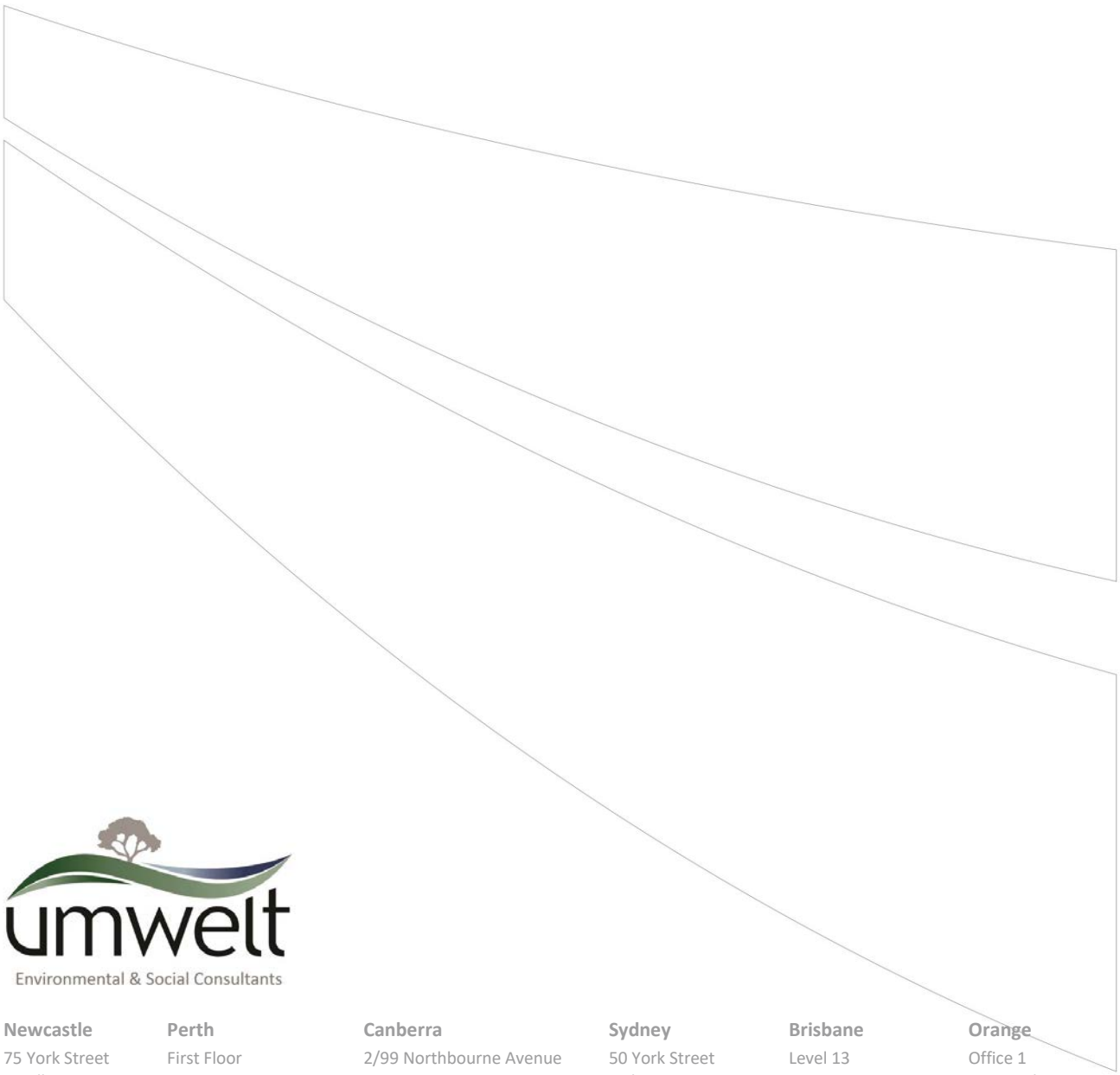
APPENDIX E

Daily meteorological data (October-December 2013-2018)

Year	Month	Day	Precipitation 24 hours before 9am (mm)	Max temp. 24 hours after 9am (ºC)	Min. temp. 24 hours before 9am (ºC)	Max soil temp. 10 cm depth (ºC)	Min soil temp. 10 cm depth (ºC)
2018	October	1	0	22.6	0.4	23	11.4
2018	October	2	0	24.7	0	23.1	11.9
2018	October	3	0	17.6	6.5	17.3	14.8
2018	October	4	1	14	9.1	14.2	12.9
2018	October	5	1	16.4	8.2	17.2	10.9
2018	October	6	0	18.6	3.7	22.5	10.9
2018	October	7	0	21.2	2.3	21.6	11.2
2018	October	8	0	23.5	8.5	24	14
2018	October	9	0	24.2	5	23.1	14.6
2018	October	10	1.8	13.2	10.9	17.9	14
2018	October	11	0	14.7	6.2	17	11.7
2018	October	12	0	16.8	6	18.1	12.3
2018	October	13	0.2	21.3	5.7	20.8	12.7
2018	October	14	0	18	10.8	18.5	14.4
2018	October	15	0	23.7	11.8	24.2	15
2018	October	16	0	26.1	14.8	25.2	17.5
2018	October	17	0	22.9	11.6	22.1	17.8
2018	October	18	0.8	24.9	11.4	24.5	16.5
2018	October	19	0	27.8	5.5	26.9	15.6
2018	October	20	0	27.2	10.3	21.7	17.7
2018	October	21	9.4	21.9	4.7	23.9	13.1
2018	October	22	0	25.5	8.8	26.6	15.5
2018	October	23	0	28.9	4.6	26.5	14.8
2018	October	24	0	21.4	9.9	27.4	17.4
2018	October	25	0	25.2	8.8	27.3	17.4
2018	October	26	0	26.4	7.6	28.2	16.9
2018	October	27	0	27.9	6.4	28	17.6
2018	October	28	0	24.2	5.9	28.3	16.9
2018	October	29	0	24.6	6	28.7	17.4
2018	October	30	0	29.1	8.4	29.2	19.5
2018	October	31	0	31.1	6.4	30.4	17.9
2018	November	1	0	34.2	8.1	30.5	19.3
2018	November	2	0	33.4	17.4	26.7	22.8
2018	November	3	1	27.5	15.9	28.3	19.6
2018	November	4	0	30.3	6.8	28.9	18.1

Year	Month	Day	Precipitation 24 hours before 9am (mm)	Max temp. 24 hours after 9am (ºC)	Min. temp. 24 hours before 9am (ºC)	Max soil temp. 10 cm depth (ºC)	Min soil temp. 10 cm depth (ºC)
2018	November	5	0	27.5	11.8	24.8	20.2
2018	November	6	1.2	26.8	16	24.8	19.9
2018	November	7	7.6	18.1	14.8	21	15.2
2018	November	8	9.8	19	4.1	20.3	11.5
2018	November	9	0	20.8	3.6	23.8	12
2018	November	10	0	24.2	3.2	24.7	13.2
2018	November	11	0	26.5	5.6	29.3	14.9
2018	November	12	0	29.5	8.6	30.6	17.9
2018	November	13	0	31.2	12.1	30.3	20.6
2018	November	14	0	22	16.5	24.2	20.3
2018	November	15	8.8	27.1	12.7	25.2	17.4
2018	November	16	0.2	23.7	11.4	27.6	17.1
2018	November	17	0	21.9	11	25.5	18.3
2018	November	18	0	22.2	10.7	27.5	17.8
2018	November	19	0	26.1	10	31.1	18.4
2018	November	20	0	30.2	9.7	31	19.9
2018	November	21	12	23.7	16.3	24.1	20.4
2018	November	22	22.4	15.2	9.6	18.8	14.4
2018	November	23	6.2	15.2	6.9	14.5	11.6
2018	November	24	0.4	20.8	8.7	20.5	11.6
2018	November	25	0	23.1	5.5	25.7	13.1
2018	November	26	1	23.8	8	27.5	14.3
2018	November	27	0.2	24.2	11.9	26.7	18.2
2018	November	28	7.8	18.2	13.6	19.8	16.8
2018	November	29	3.8	23.4	10.8	25.4	13.1
2018	November	30	0	25.9	13	28.3	17.1
2018	December	1	0	29.3	9	29.9	17.4
2018	December	2	0	26.1	9.7	27.2	18.4
2018	December	3	0	23.9	9.1	27.6	16.7
2018	December	4	0	28.6	13	31.8	18.4
2018	December	5	0	24.7	14.2	29.7	21.3
2018	December	6	0	29.3	12.1	32.9	20.8
2018	December	7	0	32.5	11.5	35.2	21.9
2018	December	8	0	33.5	12.6	34.1	23.4
2018	December	9	0	32.9	14.5	31.8	23.6

Year	Month	Day	Precipitation 24 hours before 9am (mm)	Max temp. 24 hours after 9am (ºC)	Min. temp. 24 hours before 9am (ºC)	Max soil temp. 10 cm depth (ºC)	Min soil temp. 10 cm depth (ºC)
2018	December	10	17	29	16	26.8	22.2
2018	December	11	0	25	16.1	26.9	19.9
2018	December	12	0.6	28.4	14.9	32	19.6
2018	December	13	28.6	24.4	16.8	25.5	21.2
2018	December	14	33.2	23	15.1	24	18.9
2018	December	15	9.2	26.4	16.1	25.5	19
2018	December	16	0	27.8	13.6	27	18.4
2018	December	17	0	28.5	10.7	32.4	18
2018	December	18	0	30.6	14.2	34.1	20.9
2018	December	19	0	29.3	17.8	31.2	23.4
2018	December	20	0	33.3	17.1	35.9	23.4
2018	December	21	0	22.9	15.3	27.8	24.1
2018	December	22	16.2	22.5	11.1	24.4	18.4
2018	December	23	1.6	23.6	7.6	29.7	15.9
2018	December	24	0	28.6	9.5	33	18.6
2018	December	25	0	31.8	11.2	34.9	20.7
2018	December	26	0	34.4	13.2	35.5	22.8
2018	December	27	0	36.5	15	36	24.4
2018	December	28	0	36.8	17.8	35.8	25.5
2018	December	29	0	36.7	16.9	37.3	26.1
2018	December	30	0	34.5	16.7	34.2	26.2
2018	December	31	0	34.1	17.7	33.1	25.5



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