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MONITORING OF GOLDEN SUN MOTH SYNEMON PLANA AND ITS HABITAT AT RESERVOIR HILL

(LAWSON SOUTH OPEN SPACE)

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Reservoir Hill, 2013

Reservoir Hill, 2020

GSM Monitoring at Lawson South, 2019. A. Rowell.

Contents

Summary

The density (based on highest daily count) of Golden Sun Moths on the retained habitat at Reservoir Hill has remained low but relatively stable since 2012.

The combined cover of native food grasses remains below the desirable range identified in the approved Environmental Management Plan. It is suggested that this range is not achievable at Reservoir Hill due to the physical characteristics of the site and that the target should be revised.

The combined cover of native food grasses has also declined since 2012 and this is mostly due to a reduction in cover of Wallaby Grasses (thought to be preferred larval food plants). It is likely that the grassland has not been maintained at a low enough height and that the smaller Wallaby Grasses are being shaded out by taller (mainly native) grasses. Adjustments to the mowing regime are suggested to correct this problem.

Revised management recommendations are aimed at reducing average grass height and litter/thatch cover, maintaining bare ground/cryptogams in the current range and reducing weed cover to create conditions favouring an increase in the density of the GSM population.

Interpretive signage is currently adequate but recommendations are made for minor changes and additions for any future signage.

MONITORING OF GOLDEN SUN MOTH SYNEMON PLANA AND ITS HABITAT AT RESERVOIR HILL (LAWSON SOUTH OPEN SPACE)

1. The Project

Lawson South in Belconnen ACT contains areas of habitat for the Golden Sun Moth *Synemon plana*, which is listed as critically endangered under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999.* The Land Development Agency received approval from the Department of Sustainability, Environment, Water, Population and Communities to develop the new Lawson South residential estate subject to a number of conditions protecting listed threatened communities and species (EPBC Act referral 2010/5549).

An Environment Management Plan (EMP) was prepared to address Condition 5 of the approval (Rowell 2013), and a Construction Environment Management Plan (CEMP) was prepared based on the EMP (Indesco 2013). These documents outlined measures required to maintain or improve the Golden Sun Moth (GSM) habitat on Reservoir Hill, with habitat condition benchmarks to be monitored for compliance with the Referral conditions. Annual reporting was carried out for the pre- and post-construction period (Rowell 2015, 2016, 2017, 2018) then by ACT government (ESDD 2019).

The EMP noted that in 2012 there were no universally accepted quantitative guidelines for desirable ranges for habitat parameters of importance to GSM, and that these habitat features can vary rapidly in response to drought or rain. It was therefore accepted that the recommended frequency ranges for habitat features such as cover of food plants, bare ground, exotic plants and litter were provisional and could be modified in light of future research or from monitoring results at this site.

2. Scope of this report

The site conditions and management of the GSM habitat within Reservoir Hill are assessed according to the project approval, which includes a requirement for an annual monitoring survey of the moth and its habitat, plus a description of corrective actions to be undertaken if the monitoring indicates a decline in habitat condition (EPBC Act referral 2010/5549, conditions 5(d) and 5(e)).

The current project has the following specific requirements:

1. Qualified ecologist to monitor the GSM population at Reservoir Hill, Lawson South during spring/summer 2019, ideally during November and December when the moths are flying.
2. Develop a yearly disturbance/management plan for the site (grazing, fire and slashing).
3. Undertake follow-up vegetation monitoring at the three transects to identify if the habitat has improved following previous management actions.
4. Provide wording on the threats to GSM to ensure signage is compliant with EPBC approvals.

3. Methods

3.1 Monitoring of Golden Sun Moth and its habitat

3.1.1 Golden Sun Moth

The site was surveyed on four days of suitable weather (as far as possible) during the local flight period of the moth, as determined by GSM activity at reference sites. Good weather conditions for GSM emergence are generally between 1000 and 1400 hours in warm sunny weather with little wind, and more than two days since significant rainfall or an unusually cold night.

Transect counts were carried out as prescribed in the EMP, which involved walking (approximately) north-south transects 50 metres apart across the whole site and recording the number of flying male moths seen in each 50-metre segment of the transects. Concurrent searches were made for female moths and pupal cases. Results were compared with the results of previous monitoring.

The GSM monitoring transects are shown in Figure 1. The direction of travel was alternated between surveys to reduce the effect of time of day on survey results.

3.1.2 Habitat monitoring

The vegetation was monitored as prescribed in the EMP. This involved measurement of vegetation and other habitat parameters on the three fixed 100 metre step-point transects at the end of the moth flying season. The ground was searched for pupal cases during the vegetation transect survey. Transect results were compared with previous monitoring and the desirable range of habitat parameters in the EMP. The locations of the vegetation monitoring transects are shown in Figure 1 and Table 3.1.

The predominant habitat feature present at each metre mark on a transect was recorded ('single hit' method). Plant species or other features which are uncommon on a site are not likely to be recorded using this method, but it adequately defines the structure of GSM habitat.

The features measured were placed in the following categories derived from ACT government guidelines in 2012:

- Cryptogams
- bare ground
- rock
- litter (detached dead vegetation)
- potential larval food plants (native or exotic)
- other perennial native grasses
- other native species
- perennial exotic grass
- exotic annual grass
- exotic broadleaf

Monitoring by ACT government (ESDD 2019) added measures of grass height and thatch depth, and separated Wallaby Grasses *Rytidosperma* from Speargrasses *Austrostipa* as native food plants on the grounds that Wallaby Grasses are likely to be the primary food plant. These useful additions to the monitoring (described below) were incorporated in the January 2020 surveys and should be included in future monitoring.

A photographic record of the transects was made as described in the Draft *ACT Golden Sun Moth Monitoring Plan* (Rowell & Evans 2014). This requires a close-up plan view at the zero point and a landscape view of the transect from the zero point with a measuring stick at the three-metre mark.

Detailed method for measuring average grass height and thatch depth (ESDD 2019):

A 1m quadrat is placed every at each 10 metre point along a 100 metre transect. The average grass height is measured in each quarter of the 1 metre quadrat and those measures are averaged.

To measure average grass height, measure the average leaf height of the grass in centimetres, the same amount of grass mass should be above and below the average height (illustrated below). This accounts for both tall and short leaves and areas of bare ground, providing a more accurate picture of herbage mass, habitat structure and grazing impacts.

Thatch depth in the same one square metre quadrats is measured by placing a ruler against the soil and recording the average depth of thatch (dead detached grass material) in 0.5 cm increments. Thatch is the detached, dead component of the grassy layer which is usually dead grass leaves and stems but can also include forbs. Thatch is often a smaller component in native swards (< 5% of total herbage mass) but can make up a substantial component of exotic and annual grass communities (ca 30%) due to rapid growth (e.g. Phalaris) or short life cycle (e.g. Wild Oats) in these communities.

Table 1. Vegetation transect co-ordinates (GDA 94)

	Transect 1	**Transect 2**	**Transect 3**
Start	690243 E 6099246 N	689978 E 6099308 N (break from 28 to 42 metres)	690100 E 6099310 N
Finish	690286 E 6099331 N	689874 E 6099315 N	690130 E 6099404 N

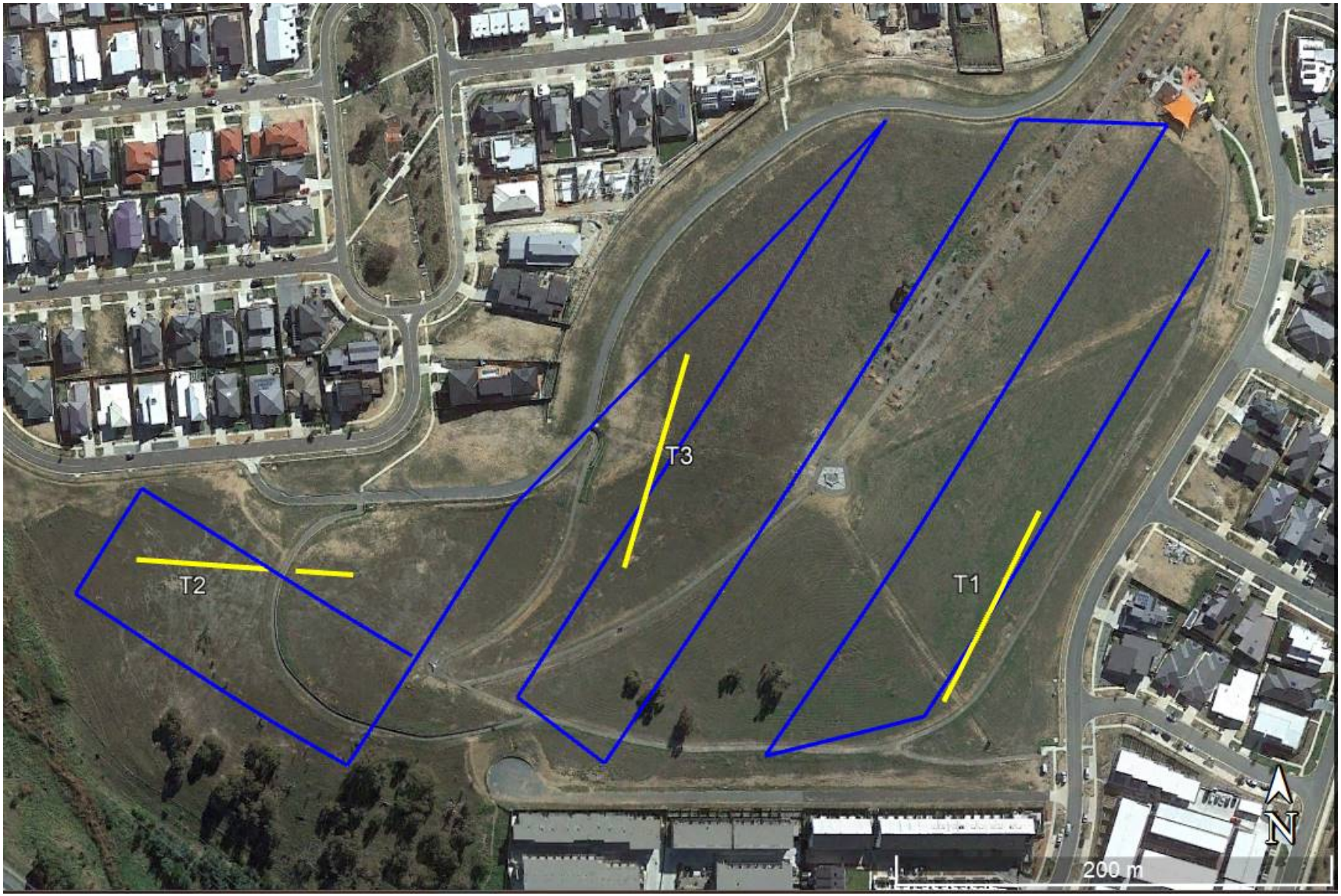

Figure 1. Location of vegetation and GSM monitoring transects, Lawson South 2019

4. Results

4.1 Golden Sun Moth monitoring

4.1.1 Survey conditions

Winter 2019 was very dry, with very warm and dry conditions in spring and early summer. The mean maximum temperatures for the October to December period were up to 4°C above the long-term average for those months (Bureau of Meteorology website).

The first flying male GSM were reported earlier than usual on 24 October, and by the end of the month they had been seen on nine different sites in the district. The season continued hot and dry, with high winds on many days. There was also heavy dust haze and smoke from bushfires on most days from the last week of November to the end of the flying season.

By the end of the first week of November moderate to high numbers of flying males were reported from many sites and this continued until near the end of the month. After a week of fluctuating conditions when a minimum of 1.6°C and a maximum of 15.1°C were recorded, GSM numbers declined in early December and the last reported sighting in the district was on 17 December. The flying season was near the normal length but started and finished earlier than usual; this pattern was probably associated with the seasonal and weather conditions.

Surveys were conducted on 29 October, 14 and 23 November and 8 December 2019, with the starting point alternating between the eastern and western end. All surveys were within the 2019 GSM flying season and the second and third surveys were during the peak flying period (as determined retrospectively by shared reports from other sites). Weather conditions during the surveys are summarised in Table 4.1.

The time period between surveys was nine to fifteen days. Due to the short life span of adult GSM, this ensured that different cohorts of moths were counted in each survey. No GSM were seen in the first or last surveys, despite GSM activity at another site on those days. Numbers of GSM sighted were fairly low so locations were mapped for every 1-2 moths rather than recording counts for 50 m transect segments (a method better suited to large sites with high density populations).

4.1.2 GSM survey results

The distance surveyed was about 2.3 km, which is 2.0 km over grassland in the transects shown in Figure 1, plus 0.3 km additional walking across the site to and from the survey start and points. GSM can be counted up to 25 metres each side of the observer in mown grassland, so the area surveyed in each survey 2019 was about 11.5 ha (with some overlapping of paths).

Distribution of flying males (Figure 2) showed the same general pattern as the previous four surveys, with most sightings on the warmer west-facing slope being earlier in the season (14 November), and more activity on the east-facing slope later in the season (23 November). This is a common feature of GSM behaviour, with emergence occurring earlier on warmer parts of a site.

As in 2017, no GSM were recorded in the central northern part of the site west of the landscaped track to the top of the hill where the grass was relatively tall, dense, thatchy and weedy.

Table 2. Golden Sun Moth monitoring at Lawson South, 2019

Date	Time (AEDT)	Daily Temp. range °C	Temp. range during survey T °C	Conditions during survey
29 Oct 19	1105-1245	6 - 27	21 - 24	No cloud, wind light to medium on eastern slope and medium on western slope
14 Nov 19	1115-1250	7 - 25	19 - 22	No cloud, wind light to medium on eastern slope and medium to high on western slope
23 Nov 19	1115-1245	13 - 33	27 - 30	No cloud, raised dust in air. Wind medium on eastern slope and high on western slope
8 Dec 19	1100-1240	11 - 30	22 - 26	Dense smoke haze, dull. Wind none to light.

As in previous years, no female GSM or pupal cases were found during the 2019 survey. This is not unusual for sparse GSM populations as the transect survey method is not designed to detect females or pupal cases.

A summary of GSM monitoring results is shown in Table 4.2. As is usual for this site, the number of flying males recorded was relatively low, but with a shorter active period in 2019 (i.e. no records in first or last survey). The highest daily count in a survey in 2019 represented an average of 2.5 flying males per hectare surveyed, which is at the higher end of the range of maximum density for this site (2.0 in 2017, 2.4 in 2016, 2.6 in 2015, 2.1 in 2012).

The concentration of GSM activity at Reservoir Hill in the middle part of the local flying season may indicate that fewer GSM emerged there during the 2019 season, but this could only be determined by carrying out more surveys in each season. Having co-ordinated mass emergences may also increase the chance of successful breeding in a sparse population.

Table 3. Golden Sun Moth survey results, Lawson South, 2019

Date	Total GSM/ survey	GSM/hour	Average GSM/100m of transect	GSM/hectare of transect	GSM activity at other sites on same date
29/10/19	0	0	0	0	Ainslie
14/11/19	29	16.6	1.26	2.52	Majura, Fyshwick, Yarralumla, Throsby and 3 sites in NSW
23/11/19	28	18.7	1.22	2.44	O'Connor, Curtin
8/12/19	0	0	0	0	Ainslie

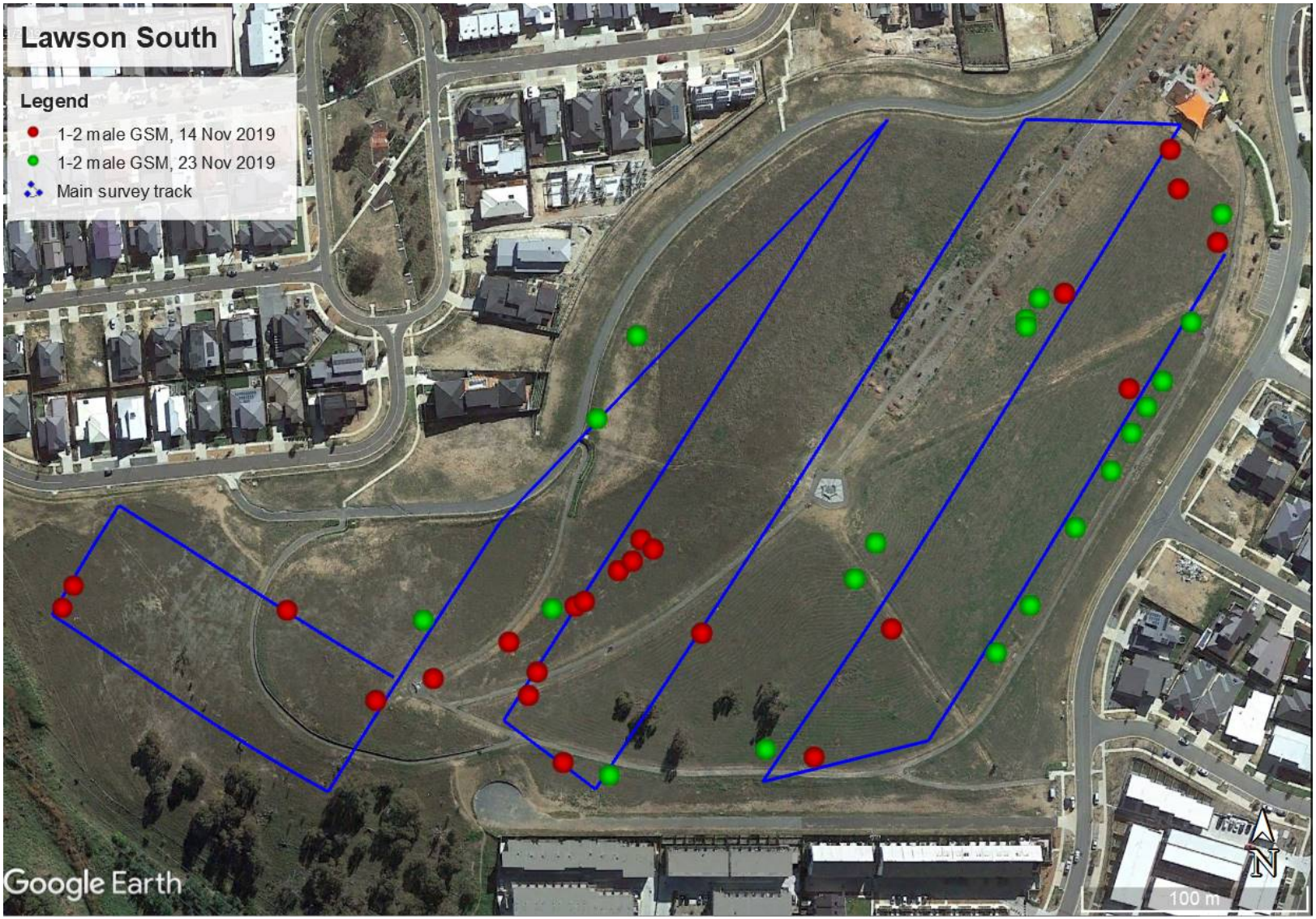

Figure 2. Golden Sun Moth records at Lawson South, November 2019

4.2 Golden Sun Moth habitat monitoring

4.2.1 GSM habitat condition

Prior to 2012 Reservoir Hill was grazed by cattle, and subsequently by small numbers of kangaroos. As the suburb of Lawson was built, fewer kangaroos have used the site and they are now uncommon there.

All parts of the site had been mown in the preceding year, and variations in vegetation height, density and thatch cover appeared to be mainly due to aspect and soil depth or the presence of exotic plants (Photograph 1).

The vegetation on the mid and lower west-facing slope (measured by Transect 2) was low to medium height, dominated by native wallaby and speargrass tussocks with some bare ground. This is seen as the desirable condition for GSM habitat. The grassland on the east (Transect 1) and south-facing slopes was taller and denser, with higher cover of litter and weeds and less bare ground, and the vegetation in the north-central sector was the densest (as measured by the northern half of Transect 3).

There were patches of Phalaris, African Lovegrass, St John's Wort and other perennial exotic species near the top of Reservoir Hill, on the south-eastern slope and in other disturbed areas, which consequently also had higher biomass and thatch cover. There was evidence that some weed control had been undertaken, with dead Serrated Tussock seen and many woody weeds having been removed since 2018. Where larger areas of weeds had been sprayed these had generally been replaced by other weeds. Wild Oats (tall annual exotic grass) occurred on some sparsely vegetated path verges and other areas that had been disturbed.

In 2016, Greening Australia undertook the revegetation of the path verges and the pipeline scars on the eastern slope with Wallaby and Speargrasses, with some Hoary Sunray *Leucochrysum albicans* established on the pipeline scars (GA 2017). In 2017 the path verges and hilltop area were resown with Perennial Ryegrass, Tall Fescue and White Clover, which may have been an error by another landscaping contractor. The exotic grasses have persisted but have not spread and the White Clover has declined. Continued closer mowing and dry summers should favour the native species which have established in most areas.

The EMP prescribes use of a flail mower between late January and late September to maintain the grass at 5-15 cm, including raking and baling if required as a corrective action for high biomass or for fuel management. The grass height on the measured transects fell within this range in January 2020 (Table 4.3) and was shorter than the previous year, but Transect 3 exceeded the 4-8 cm recommended for GSM habitat by ACT Government (2019). The thatch depth in 2020 on two transects also exceeded the maximum of 1.0 cm recommended by ACT Government (ESDD 2019). Thatch may have been more persistent this season due to the ongoing drought which meant that fallen or cut material did not break down as quickly as usual.

Table 4. Grass length and thatch depth on habitat transects

Transect	Average grass length (cm)		Average thatch depth (cm)	
	January 2019	January 2020	January 2019	January 2020
1	10.2	6.4	1.4	1.0
2	Not available	5.7	Not available	0.5
3	11.4	9.4	0.8	1.2

The habitat transects were surveyed in the same locations as in 2016, when some minor adjustments to the original transects were made to avoid the new paths. Reference photographs for the vegetation transects are at the end of this report. The results of the habitat transect surveys and comparisons with previous results are shown in Table 4.4. The ACT Government (ESDD 2019) habitat transect results could not be incorporated into Table 4.4 as these appear to have been collected using a different method.

Notable findings are:

- The combined cover of Wallaby and Speargrasses was below the desirable range identified in the EMP and has declined by 9 to 15 percentage points at all transects since 2012. This has not yet been followed by a decline in density of GSM, and the achievability of this desired range at Reservoir Hill and adjustments to it are discussed in Section 5 below.
- Importantly, Table 4.5 shows that the decline in total native food plant cover has been almost entirely due to a reduction in Wallaby Grass cover (by more than 50% on all transects), with Speargrass cover unchanged or slightly reduced on two transects and increased six-fold on Transect 2. This change may be associated with the move from grazing to mowing for biomass control, and suggests that the smaller Wallaby Grasses are being shaded out by the Speargrasses.
- Percentage cover of all native grasses combined has only declined slightly on Transects 2 and 3, suggesting that other (non-food) native grasses have also increased at the expense of the Wallaby Grasses. In 2020 these were Redleg Grass *Bothriochloa macra*, Weeping Grass *Microlaena stipoides*, Hairy Panic *Panicum effusum* and Purple Wiregrass *Aristida ramosa*.
- Bare ground was within the recommended range of 5-15% on all transects, possibly boosted by ongoing drought conditions in 2020.
- At Transect 2 (western slope) bare ground has been consistently higher and exotic cover and litter have been consistently lower than in other areas. This reflects the exposed westerly aspect, steep slope and shallow soil which discourages high biomass developing under most conditions, and although within recommended habitat parameters this has not been associated with higher numbers of GSM on this site. This is probably because not all conditions which favour Wallaby Grasses are also favourable to GSM larval development.

- Increased exotic cover at Transect 1 is mainly due to annual grasses, especially Wild Oats *Avena fatua* which have developed in disturbed areas near the track and pipeline scar, and does not necessarily represent the condition of all the habitat on the eastern slope. Alternative transect locations to better monitor habitat condition in this area are suggested in Section 5.

Minor vehicle damage was seen to the grassland which suggests that some people still view the western slope of Reservoir Hill as a hill-climb challenge. Access appears to be from the far western end of the site at Solong Street. Excluding vehicles will also reduce dumping of rubbish.

Some rabbit digging and a collection of droppings (buck heap) were seen on the western slope (Photograph 2).

Some eucalypts have been planted on the southern and western slopes of Reservoir Hill to augment the remnant woodland. Most are not in GSM habitat, but a few on the lower western slope near a patch of naturally occurring Silver Wattles appear to be within in the area shown in the referral as the 7.4 hectares to be conserved as GSM habitat (Figure 3).

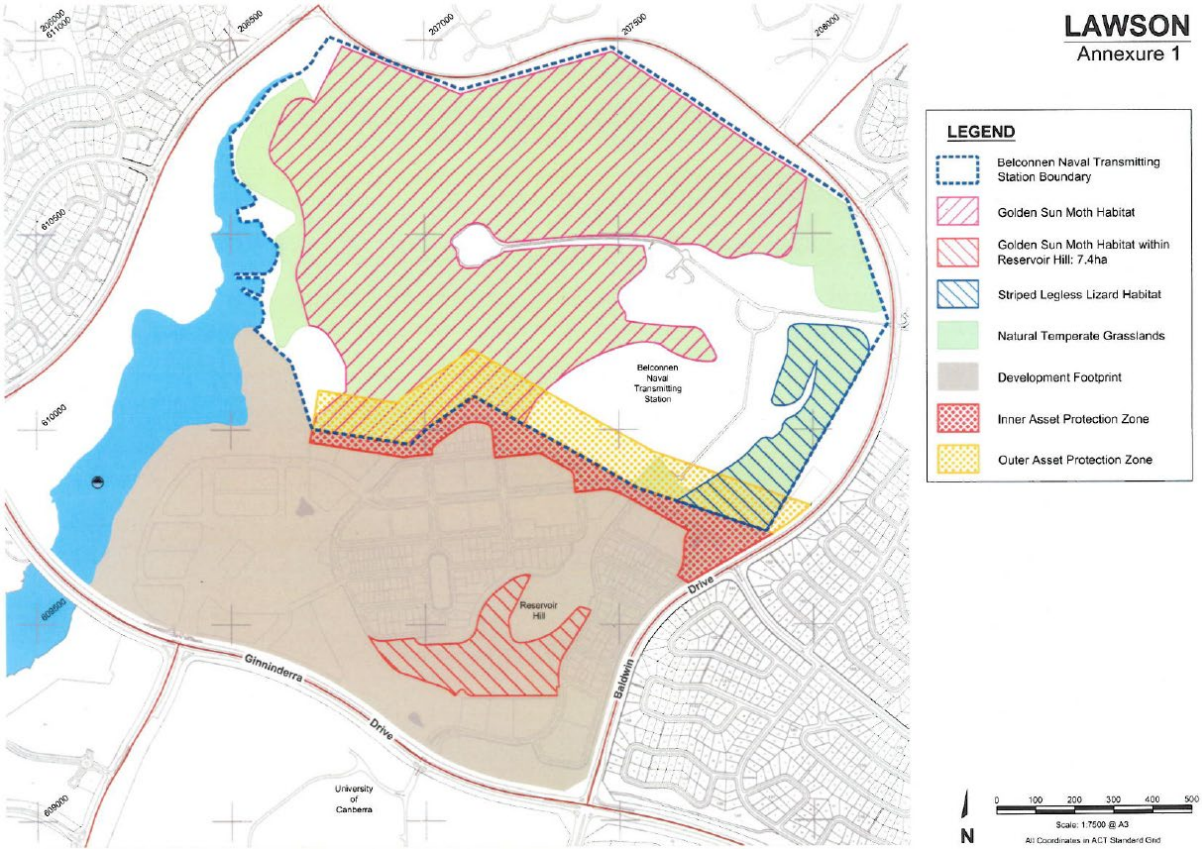

Figure 3. GSM habitat at Reservoir Hill (from EPBC referral)

Table 5. Vegetation transect results at Lawson South

Category	Desirable range EMP/ESDD 2019	Transect 1 (% cover)					Transect 2					Transect 3				
		Jan-13	Dec-15	Jan-17	Feb-18	Jan-20	Jan-13	Dec-15	Jan-17	Feb-18	Jan-20	Jan-13	Dec-15	Jan-17	Feb-18	Jan-20
Cryptogams		0	0	0	1	0	14	18	14	12	15	0	6	3	4	3
Bare ground	5-15/5-25%	1	1	7	4	7	6	10	7	12	9	11	13	11	10	10
Rock		0	0	0	0	0	3	6	2	0	5	1	3	1	0	0
Litter/dead vegetation	5-15/<30%	25	17	20	11	31	5	12	6	7	9	16	24	16	36	35
Non-vegetation hits		**26**	**18**	**27**	**16**	**38**	**28**	**46**	**29**	**31**	**38**	**28**	**46**	**31**	**50**	**48**
Annual exotic grass		4	30	8	23	20	4	1	3	0	0	4	7	7	4	3
Perennial exotic grass		4	7	7	2	0	0	0	0	0	0	0	0	0	0	2
Exotic broadleaf		5	15	10	22	6	2	3	1	1	2	3	4	3	1	1
Total exotic hits	<5%	**13**	**52**	**25**	**47**	**26**	**6**	**4**	**4**	**1**	**2**	**7**	**11**	**10**	**5**	**6**
All perennial native grasses		59	29	47	37	36	65	50	64	66	59	65	43	59	45	55
Other native species		2	1	1	0	0	1	0	3	2	1	0	0	0	0	0
Total native hits		**61**	**30**	**48**	**37**	**36**	**66**	**50**	**67**	**68**	**60**	**65**	**43**	**59**	**45**	**55**
TOTAL HITS		**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Table 6. Density of native larval food plants on habitat transects

Native larval food plants	Desirable % range (EMP)	Transect 1					Transect 2					Transect 3				
		Jan-13	Dec-15	Jan-17	Feb-18	Jan-20	Jan-13	Dec-15	Jan-17	Feb-18	Jan-20	Jan-13	Dec-15	Jan-17	Feb-18	Jan-20
Austrostipa+ Rytidosperma	55-65	**32**	**14**	**17**	**12**	**26**	**61**	**32**	**41**	**44**	**34**	**66**	**32**	**56**	**45**	**47**
Rytidosperma		**6**				**2**	**59**				**22**	**23**				**11**
Austrostipa		**26**				**24**	**2**				**12**	**43**				**36**

4.3. Interpretive signs

The interpretive signs relating the life cycle of GSM on the site are in good condition and are a fair representation of the current state of knowledge about the species (Figure 4). Comments from passers by indicated that some people read them, become interested and look for GSM.

When the signs need replacing, some information relating to the site could be added along these lines: *'Reservoir Hill is managed to conserve a population of the critically endangered Golden Sun Moth, a species which prefers low, open, unshaded native grasslands containing few weeds'*. This should help explain to the public why the site is not suitable for tree-planting or more intensive recreational use.

Some other minor word changes could be made:

- 'Native grasses such as Small Wallaby Grass are thought to be the main food plant**s for Golden Sun Moth larvae which feed on their roots**' (text in bold to be added)
- 'depend**e**nt' not 'depend**a**nt'.
- Replace 'Females do not fly' with 'Females fly less than males', as many observers report significant flights by females especially late in the day, perhaps after most of their eggs have been laid, reducing their wing-loading.

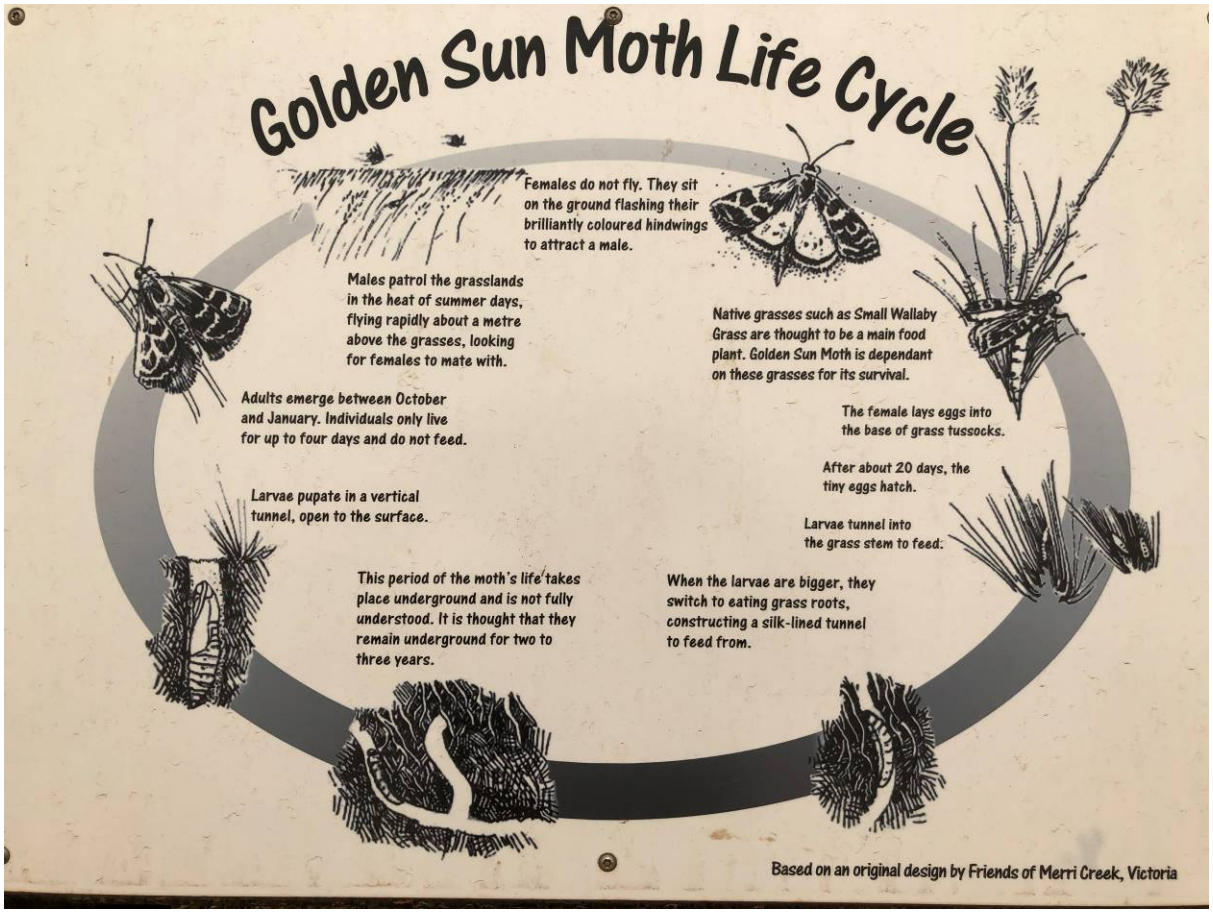

Figure 4. Existing interpretive sign

5. Discussion

5.1 GSM population and habitat condition

The GSM population is still present at Reservoir Hill and maximum density recorded in surveys has remained relatively stable. However, the cover of their preferred food plants (Wallaby Grasses) has declined and this is likely to be due to the average sward length being greater than desirable for GSM habitat, with the smaller Wallaby Grasses being shaded out by taller plants. This decline should be arrested and reversed by increasing the frequency of mowing to reduce the average height of the grasses throughout the year.

The desirable range for combined native food plant cover (55-65%) in the EMP was selected based on measured cover at some of the best GSM sites in the ACT, and it now appears likely to be unachievable at this site due to its slope, variations in aspect and relatively low native species diversity. GSM numbers may be naturally lower at Lawson South than at other sites containing more typical GSM habitat, but it is still likely that GSM density can be increased with appropriate habitat management.

Another set of parameters was used to define high quality GSM habitat in SMEC (2019):

- Primary NTG or native pasture dominated by native larval food plants (i.e. *Rytidosperma* spp. and/or *Austrostipa* spp.), with low weed cover and some bare ground. Most (but not necessarily all) of the following minimum values should be meet:
- 10% cover *Rytidosperma* spp.
  or
- 15% cover *Rytidosperma* spp. and *Austrostipa* spp. combined
- >5% bare ground
- < 5% exotic broadleaf
- Low to moderate biomass
- Litter sparse to moderate (<25% cover of litter)
- Moderate to high native plant diversity (>30 native species per 20mx20m area)

The above target parameters (apart from native species diversity) appear to be mostly appropriate for Reservoir Hill and if achieved should allow the site to support a larger population of GSM. Cryptogams/soil crust are part of a healthy grassland and they should also be considered. It is suggested that the desirable ranges for habitat parameters for this site be revised to incorporate the best fit from the EMP, ACT Government (2019) general guidelines for managing GSM habitat and SMEC (2019). The original EMP suggested that such adjustments would be necessary and that these could be incorporated into a revised EMP, but an updated plan may need to be recognised by a variation to the project referral conditions. Some suggested provisional targets are in the management guidelines (Section 6).

As noted in Section 4.2.1, the vegetation in part of Transect 1 has been disturbed by path construction and rehabilitation of the pipeline scar, so that it does not now provide a representative measure of habitat quality on the eastern slope of Reservoir Hill. It is suggested that this transect is retained to monitor conditions in these disturbed areas and that another transect is added to the monitoring program that better measures the condition of the whole eastern slope. Possible locations for the additional transect are shown in Figure 5, and the best position should be determined during the next monitoring period.

Figure 5. Suggested additional habitat transect location (T4 or T5)

5.2 Weed management

Weed management is prescribed in the CEMP: 'Weed control should be by regular spot-spraying, outside the GSM flying period. The most suitable months will be February to April and September. Priority species are Serrated Tussock, African Lovegrass, Chilean Needlegrass, Phalaris, St John's Wort and Saffron Thistle.' These exotic species are still scattered across the site, and spot-spraying of them is an ongoing requirement. Vigour and seeding of many these plants will also be reduced by following the prescribed mowing regime.

5.3 Biomass management

Grazing and fire are less suitable for biomass management at this site due to its design as urban open space. Appropriate mowing can control fuel loads, favour Wallaby Grasses, reduce the vigour and seeding of many weeds, is compatible with urban open space uses and helps to maintain the grassland in a suitable condition for GSM at all parts of its life cycle.

The varying slopes, aspects and soil depths on the Lawson South site leads to differences in grass growth and therefore in mowing requirements for each sector. The dry western slope may need mowing only once or twice a year, with no need for the removal of cut material. This is described in the EMP: 'Mowing with a flail mower should take place about twice per year …. depending on seasonal conditions, and should aim to maintain the height of tussocks (excluding seed heads) between 5 and 15 cm. Mowing should take place between late January and late September, to avoid the GSM flying season and to allow spring and summer flowering native plants to set seed.' A revised target of cutting to 4-8 cm (and up to mid-October) to maintain an average grass height of less than 10 cm throughout the year is suggested in the management guidelines (Section 6).

The south and east-facing areas and the north-western sector may require flail mowing up to four times per year. Where this has not happened and the vegetation has been allowed to become tall and dense it will be necessary to bale or rake and remove the cut material as prescribed in the EMP: 'the grassland should be cut to a height of about 8-10 cm, and the slashed material should be immediately raked, baled and removed from the site. Rake height should be set above ground to avoid soil disturbance. This …. should occur between February and September, i.e. outside the GSM flying period, and not when soil moisture is very high.' Again, a revised cut height of 4-8 cm is advised, if the machinery and ground conditions permit.

Allowing extreme fluctuations in biomass reduces GSM habitat quality, while regular and appropriate mowing should reduce the need for expensive removal of cut material. Where slopes permit, the path verges could be mown more closely to suppress weeds and dry out the soil, which should favour the expansion of native species. It is noted that some of the path edges are already mown more often, possibly with a ride-on mower during maintenance of landscaping.

A suggested mowing regime is provided in Section 6, and the frequency of mowing required in different areas will depend on seasonal conditions. The need for mowing and for removal of slashed material should be determined on the basis of at least quarterly site inspections.

6. Management guidelines for GSM habitat at Reservoir Hill.

Task	Actions	Timing
Habitat protection	A map accurately defining the GSM habitat protection area should be provided to site managers.	As soon as possible.
	No further tree planting should occur inside GSM habitat area.	
	Prevent vehicle incursions and development of informal tracks by use of appropriate barriers.	Identify need during quarterly biomass inspections, install barriers as soon as possible.
	Control rabbits by warren destruction.	As soon as possible after detection during site inspection.
Biomass control	Maintain average grass length of <10cm throughout year using flail mower set at 4-8 cm.	Late January to mid-October, frequency as indicated by quarterly inspections. May be 2-4 times/year depending on sector and rainfall. Do not mow when ground is wet.
	Maintain combined cryptogam/bare ground cover at 5-25%, average litter/thatch cover below 25% and average thatch density below 1.0cm by removing slashed material (rake/bale) after mowing denser grassland.	Late January to mid-October, as frequently as indicated by quarterly inspections. Most likely to be necessary on southern and eastern slopes and for first post-breeding cut in late January.
Weed management	Spot spray herbaceous weeds, especially African Lovegrass, Chilean Needlegrass, Serrated Tussock, St John's Wort, Phalaris, Paterson's Curse and Saffron Thistle.	February to May and September to mid-October.
	Remove and poison stumps of all woody weeds in the GSM habitat area, including seedlings from native trees on site. Exceptions are the planted eucalypts and the existing Silver Wattles on the western slope (but spread of both should be prevented).	Annually, during other maintenance if possible.
Habitat restoration	Replant native grasses into bare areas following poisoning of larger weed patches, by seed or tube stock as appropriate.	February to April and September-October, observing recommended period since poisoning.

7. References

ESDD 2019. *GSM habitat monitoring and management recommendations for Reservoir Hill.* Unpublished report, ACT Government.

Greening Australia (GA). 2017. *Lawson Grass Seeding: Final Report*. Greening Australia Capital Region, December 2017.

Indesco, 2013. *Construction Environment Management Plan for Golden Sun Moth habitat on Reservoir Hill, Lawson South.* Prepared by Indesco using information and recommendations from Rowell (2013).

Rowell, A. 2013. *Environment Management Plan for Golden Sun Moth habitat on Reservoir Hill, Lawson South.* Prepared for INDESCO and LDA, February 2013.

Rowell, A. 2015. *Monitoring of Golden Sun Moth* Synemon plana *and its habitat at Reservoir Hill (Lawson South Open Space).* Report prepared for RAM Constructions and LDA.

Rowell, A. 2016. *Monitoring of Golden Sun Moth* Synemon plana *and its habitat at Reservoir Hill (Lawson South Open Space).* Report prepared for RAM Constructions and LDA.

Rowell, A. 2017. *Monitoring of Golden Sun Moth* Synemon plana *and its habitat at Reservoir Hill (Lawson South Open Space).* Report prepared for RAM Constructions and LDA.

Rowell, A. 2018. *Monitoring of Golden Sun Moth* Synemon plana *and its habitat at Reservoir Hill (Lawson South Open Space).* Report prepared for RAM Constructions and LDA.

Rowell A. and Evans M. 2014. *Draft ACT Golden Sun Moth Monitoring Plan.* Research Report 2X. Environment and Sustainable Development Directorate, Canberra.

SMEC 2019. *Golden Sun Moth Abundance Monitoring and Habitat Mapping 2018. Bonshaw, Jerrabomberra East and Franklin Grasslands.* Prepared for: ACT Parks and Conservation Service.

Figure 6. Mid-western slope, mowing lines and weed growth below path

Figure 7. Rabbit droppings on western slope

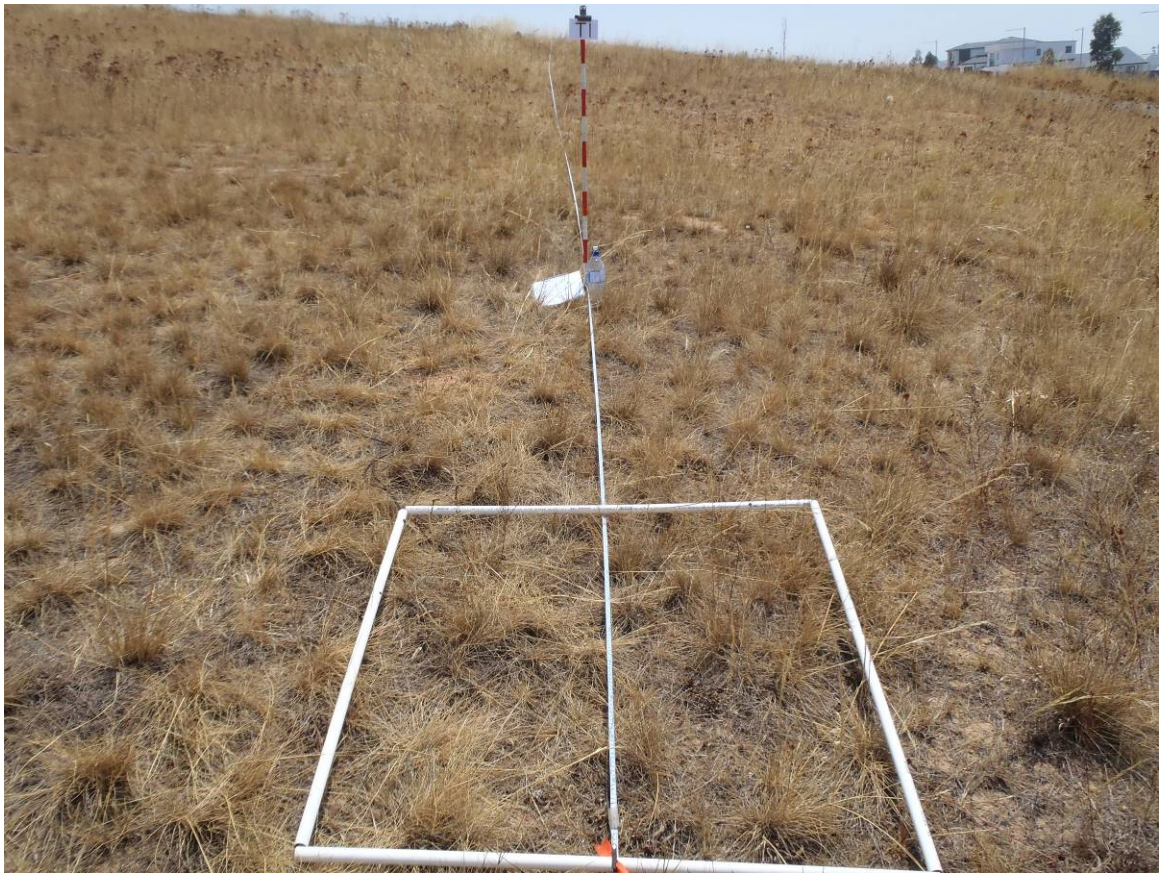

Figure 8. Transect 1 from southern end

Figure 9. Transect 1, start

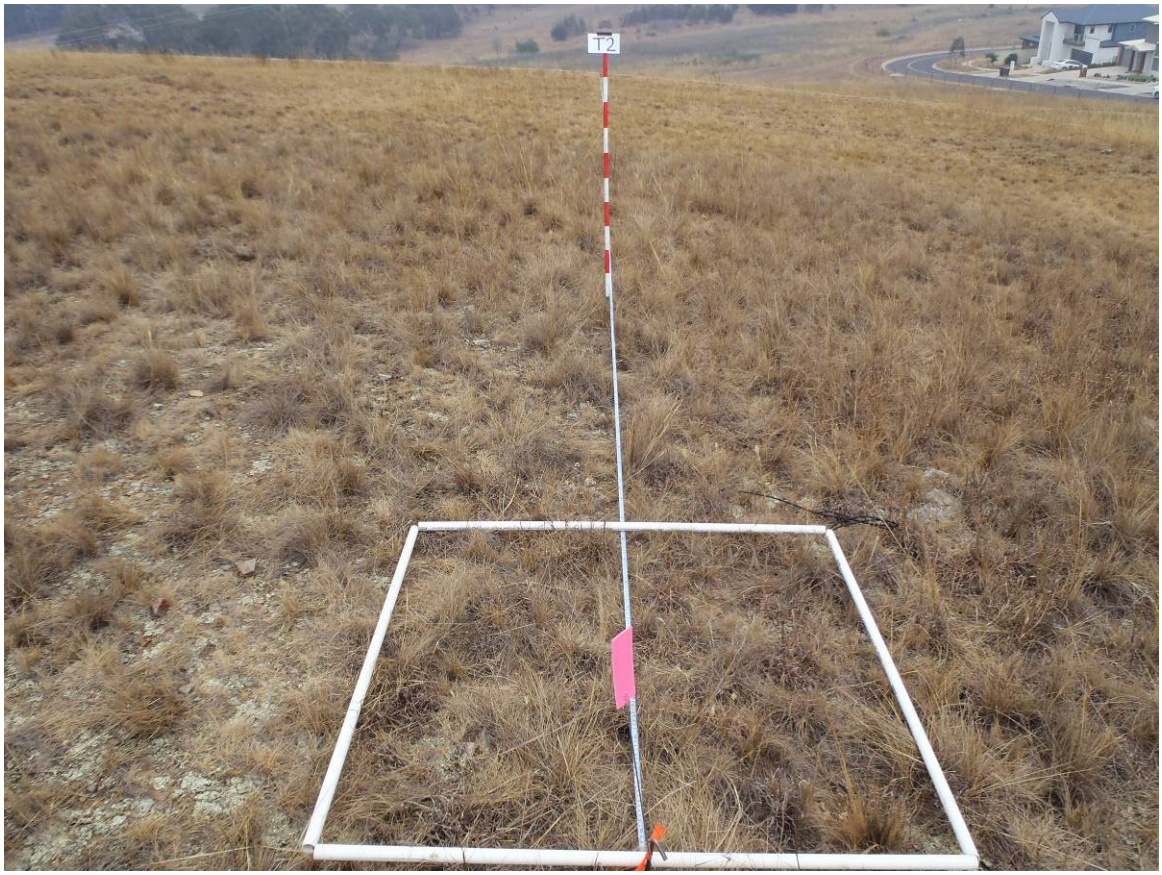

Figure 10. Transect 2 from eastern end

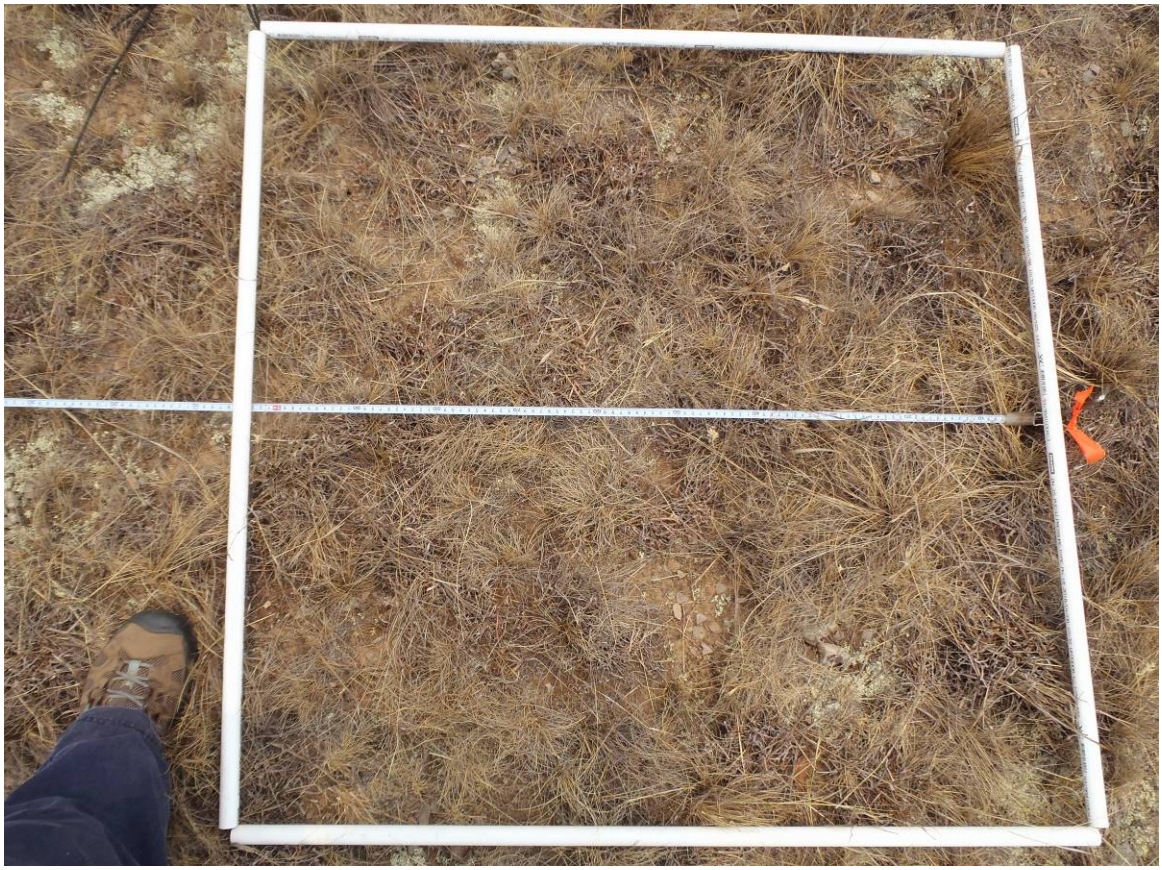

Figure 11. Transect 2, start

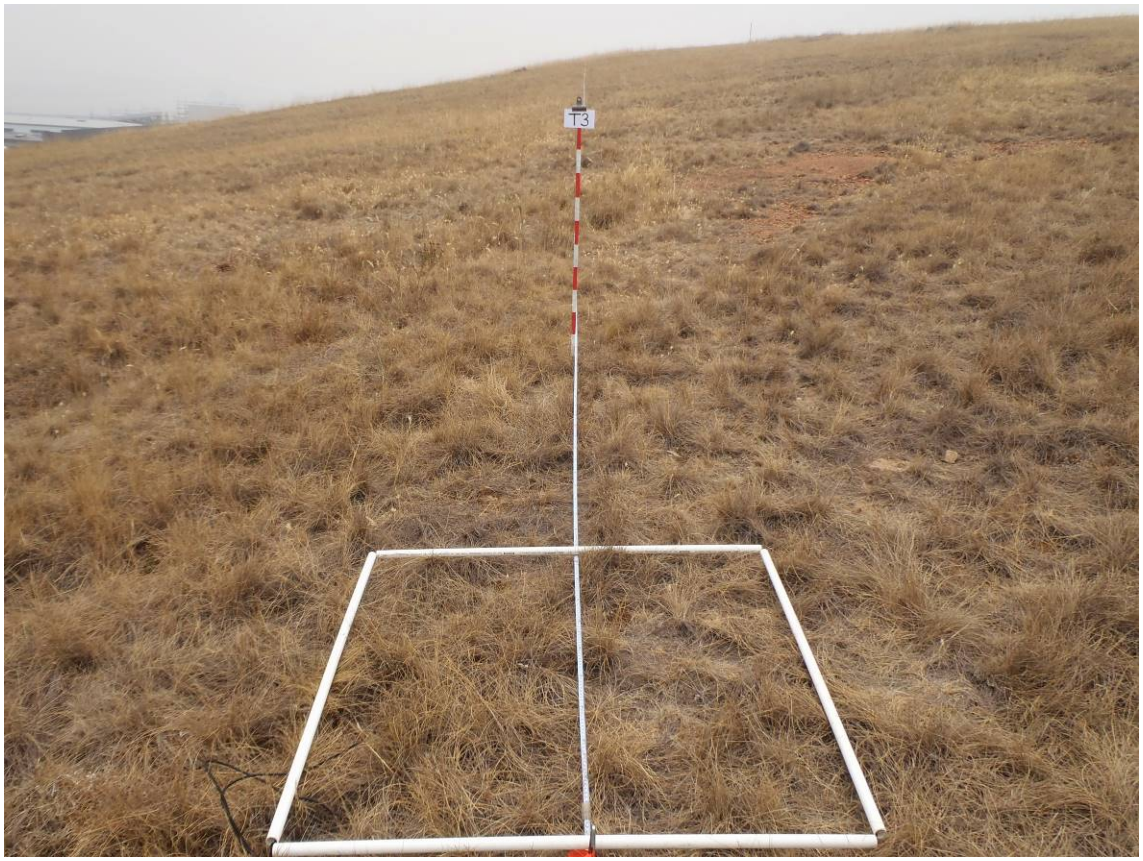

Figure 12. Transect 3 from southern end

Figure 13. Transect 3, start