Environment Management Plan

for Golden Sun Moth habitat on

Reservoir Hill, Lawson South

Prepared by
Alison Rowell
Biologist and Environmental Consultant
PO Box 777
DICKSON ACT 2602
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1. The project

The Land Development Agency has received approval from the Department of Sustainability, Environment, Water, Population and Communities to develop a new residential estate Lawson South, Belconnen (EPBC Act referral 2010/5549). This approval is subject to a number of conditions designed to protect a listed threatened species and threatened community (Golden Sun Moth and Natural Temperate Grassland). This is to be achieved by managing the species and community on part of the South Lawson site, and by developing and implementing an Offset Strategy and Offset Management Plan at a site in West Macgregor.

This Environment Management Plan (EMP) has been prepared to address Condition 5 of the approval (main points follow):

> 5) The person taking the action must engage a suitably qualified expert to prepare an Environment Management Plan (EMP) to maintain or improve the Golden Sun Moth habitat within Reservoir Hill. The EMP must be submitted to the Minister for approval within six months of the date of this approval. The approved EMP must be implemented within 12 months of the date of this approval. The EMP must address, but not necessarily be limited to:
>
> > a) measures to maintain or improve the quality and condition of the Golden Sun Moth habitat within Reservoir Hill through appropriate management actions, including, and not limited to, weed control and biomass management as informed by a suitably qualified expert;
> >
> > b) measures to prevent the access of unauthorised vehicles into the Golden Sun Moth habitat on Reservoir Hill, prior to, during and post construction.
> >
> > c) details of a baseline survey of the quality and condition of the Golden Sun Moth habitat within Reservoir Hill to be conducted by a suitably qualified expert during an optimal ecological time prior to the commencement of construction within Golden Sun Moth habitat within Reservoir Hill.
> >
> > d) details of an annual monitoring survey to determine the quality and condition of the Golden Sun Moth habitat within Reservoir Hill to be conducted by a suitably qualified expert during an optimal ecological time.
> >
> > e) details of corrective actions to be undertaken should the monitoring required in Condition 5) d) indicate a decline, as determined by a suitably qualified expert, in the quality or condition of the Golden Sun Moth habitat within Reservoir Hill; and
> >
> > f) details of the administration arrangements for the measures referred to in Conditions 5) a) to 5) e).

2. Site description and values

The area to be protected as Golden Sun Moth habitat within Reservoir Hill is 7.4 ha of sloping land around the top of Reservoir Hill (Figure 1), with aspects ranging from south-east through south and west to north-west. The vegetation is native-dominated grassland (not threatened Natural Temperate Grassland community), with a few Broad-leaved Peppermint *Eucalyptus dives* on the south-facing slope. The grassland on the eastern and southern slopes is dominated by Tall Speargrass *Austrostipa bigeniculata* and Weeping Rice Grass *Microlaena stipoides.* Wallaby Grasses *Rytidosperma* species are dominant on shallow soils at the western end of the area, and Speargrasses and Wallaby Grasses are co-dominant on deeper soils on the west to north-west facing slope of the main hill. These grassland types merge into one another. The area at the top of the hill

that is not included in the Golden Sun Moth habitat has been disturbed by the removal of previous structures, and dominated by weeds associated with grazing.

Previous surveys have identified the Reservoir Hill area as Speargrass-Wallaby Grass native pasture/secondary grassland containing a low to moderate density population of Golden Sun Moths (Eco Logical 2008, Hogg & McIntosh 2010, Rowell 2010).

The baseline monitoring of the GSM habitat found introduced pasture species and other exotic species, relatively high biomass and litter and few intertussock spaces in some areas (see initial monitoring report for summer 2012-13, Attachment A).

The former Belconnen Naval Transmission Station, directly to the north of South Lawson, contains over 100 ha of Natural Temperate Grassland with a dense population of Golden Sun Moths ('key habitat' ACT Government 2005, Clarke & Dunford 1999).

3. Golden Sun Moth

3.1 Status of GSM

The Golden Sun Moth *Synemon plana* is listed as a critically endangered species under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and as endangered under the ACT *Nature Conservation Act 1980* (NC Act). A critically endangered species is considered to be facing an extremely high risk of extinction in the wild in the immediate future.

3.2 GSM habitat and biology

The information in this section is summarised from *Significant Impact Guidelines for the Critically Endangered Golden Sun Moth* (*Synemon plana*)(DEWHA 2009), unless otherwise attributed.

The current understanding of habitat is that Golden Sun Moth (GSM) occurs in primary or secondary native grassland, or clearings in open woodland, especially habitats containing a moderate component of Wallaby Grasses. Wallaby Grasses were until recently known as *Austrodanthonia*, but have been renamed *Rytidosperma*. GSM has also been found in association with other native grasses, and the exotic Chilean Needlegrass *Nassella neesiana*. The larvae feed on the roots of the grasses, and recent dietary studies have confirmed that the larvae feed on plants that use the C3 carbon-fixing metabolic pathway, and that the C3 plants found on GSM sites are predominantly Speargrasses *Austrostipa* species, Wallaby Grasses and Chilean Needlegrass (Richter et al 2010).

Sites are usually flat or gently sloping, with northerly aspects favoured. Sites are generally low in phosphorus (unimproved) and have bare ground between the tussocks. High biomass appears to make the habitat less suitable, as females use bare ground to bask and display, and males tend to search for females in areas of relatively low open grassland.

The short-lived adult moths emerge between mid October and early January, and are active in the middle of warm, sunny, and relatively still days. Adult males fly constantly over the grassland in search of the relatively immobile females, which sit on the ground and display their golden hindwings. The mated females lay their eggs around the bases of grass tussocks.

3.3 Threats to GSM

DEWHA (2009) identifies key threats to GSM. Those relevant to the South Lawson site include:

- loss and degradation of habitat, through processes including clearing of vegetation, introduction of pasture species, fertiliser application, soil disturbance, weed invasion, shading, pesticide use and altered fire, grazing and hydrological regimes

- population isolation/fragmentation. Small habitat remnants are more vulnerable to damage by fire or degradation, and sites from which the species has gone extinct are unlikely to be recolonised. Due to the poor flying abilities of the females and the reluctance of the males to fly long distances over unsuitable habitat, populations separated by distances greater than 200 m are considered effectively isolated. Isolated populations may suffer from the effects of inbreeding.
- predation by birds, which is likely to be increased by the planting of trees in or near the grassland habitat.

4. Objectives of the Environment Management Plan

The site should be managed as one unit, with different recommendations for the construction and post-construction phases of the project.

4.1 Pre-construction and construction period

The aims during this period are to protect GSM and enhance their habitat by:

1. assessing the extent and density of the GSM population and the condition of the habitat by baseline monitoring
2. designing a potential corridor for movement of GSM between Reservoir Hill and the population at the former Belconnen Naval Transmission Station, and applying the same protections to the corridor as below
3. protecting the native grassland by fencing to exclude vehicles and prevent dumping
4. maintaining the grassland structure by biomass removal (grazing and/or mowing) at the appropriate time of year, and ensuring compatibility with fire management
5. treating existing weed infestations and controlling the introduction of weeds
6. minimising damage to the soil by compaction, erosion, disturbance, contamination, asbestos removal and changes in drainage
7. designing path edges and access points to minimise trampling of the finished site by pedestrians, cyclists etc
8. installing educational/interpretive signs describing the significance of GSM and their habitat

4.2 Post-construction period

After construction, the aims of the EMP are to protect and increase the GSM population and enhance their habitat by:

1. revegetating areas on Reservoir Hill and the corridor disturbed by track construction, asbestos removal or other activities with appropriate native grasses
2. maintaining appropriate grassland structure in both areas by mowing
3. controlling weeds in both areas
4. monitoring GSM numbers and habitat quality in both areas annually
5. reviewing management in response to results of monitoring

5. Management recommendations

5.1 Pre-construction and construction period

These recommendations are summarised in Table 5.1.

5.1.1 Site induction

Site inductions for contractors should identify the protected GSM habitat area and corridor, and the instruct contractors to follow the relevant prescriptions below.

5.1.2 Fencing and signage

Before construction begins, the GSM habitat on Reservoir Hill should be surrounded by temporary fencing erected 10 metres outside the boundary of the habitat. This buffer zone can be reduced later in the construction phase as required. The fencing should be adequate to prevent unauthorised vehicles entering or crossing the habitat for the duration of the construction period, and carry signs identifying the area as a protected environmental zone.

5.1.3 Site hygiene and protocols

Vehicles, tools and machinery (including mowers) used in the habitat area should be free of soil and vegetation. Authorised vehicles should not traverse the habitat when soil moisture is high, and unnecessary pedestrian access should be avoided. No soil should be brought onto the site except as specified in these recommendations.

5.1.4 Timing

Construction and prescribed management activities within the GSM habitat on Reservoir Hill should take place outside the breeding period of GSM as far as possible, i.e. avoiding late October to early January.

5.1.5 Asbestos removal

When the asbestos pipes are removed, the area disturbed should be as small as possible. The topsoil should be retained and the width of the trenching should be minimised. If additional soil is needed to level the trenchline, this should be put at the bottom of the trench and covered with the original topsoil. The trenchline should either be left to regenerate naturally, or planted with native grass seed. Follow-up weed control should be undertaken as necessary, up to four times in the next year.

When the larger area at the top of Reservoir Hill is excavated and capped, temporary fencing should be installed to restrict machinery movement and parking to the exotic-dominated area between the hill-top and the southern end of the pine plantation. Access to the hill-top should be via the existing track or along the eastern side of the pine plantation. The area of disturbance should be restricted to the decontamination zone as far as possible. Clean fill (not high nutrient standard topsoil) should be used for capping, which should be level with the surrounding hill to minimise run-off. The decontaminated area can be planted with local native grasses with follow-up weed control as additional GSM habitat, or covered in an inert surface if this better suits the projected use of the site.

5.1.6 Path and facility construction and revegetation

Machinery for path construction and for installation of other facilities (signs, railings) should be restricted to the path footprint as far as possible. Path surface should be permeable (e.g. compacted

gravel) to minimise run-off or ponding. Revegetation of path edges etc should be with native grass seed planted into existing soil, fertiliser should not be used and soil should not be brought onto the site. The species mix should include local Wallaby Grasses and Speargrasses, with Redleg Grass *Bothriochloa macra* as a secondary species on western and northern aspects, and Weeping Rice Grass *Microlaena stipoides* as a secondary species on eastern and southern aspects. Native forbs should not be introduced until after the construction phase, to allow more robust weed control.

No facilities should be installed that cause significant shading of the GSM habitat.

5.1.7 Biomass and fuel management

The baseline monitoring found that biomass and litter was too high in most areas, particularly on the east-facing slope. The current low level of stocking with cattle should continue until works begin. As soon as the stock are removed and before the habitat is fenced, 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 initial mowing should occur between February and September, i.e. outside the GSM flying period, and not when soil moisture is very high. It is not known how fire affects GSM in the ACT, but on a site as small as Reservoir Hill, fire should be avoided.

Mowing with a flail mower should take place about twice per year after this, 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. If high spring rainfall and fuel build-up necessitates summer mowing, this should be done after the end of December, with raking and baling if biomass is high.

5.1.8 Weed control

To facilitate weed control during the first part of this project, any revegetation/restoration should use local native grasses only (i.e. no forbs). This will allow the use of targeted herbicides to control broad-leaved weeds.

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 Johns Wort and Saffron Thistle.

5.1.9 Landscaping

Nothing other than local native grasses should be planted in the Golden Sun Moth habitat zone during the construction period. Natural regeneration of the existing Broad-leaved Peppermints should be confined within the area of the original trees.

5.1.10 GSM corridor

A corridor should be retained to facilitate movement of GSM between the Reservoir Hill habitat and the GSM population at the former Belconnen Naval Transmisson Station to the north. This should be on the western side of the tree plantation, 10 metres wide where possible, and planted with local native grasses.

When the existing pine plantation is removed, access should be from the east and movement and turning of machinery on the future corridor should be avoided as far as possible, to minimise soil disturbance and compaction. Once the corridor has been marked out and levelled, it should be planted with local native grasses as above, with regular follow-up weed control and mowing as for the Reservoir Hill grassland. To avoid the corridor being used as a track, a compacted gravel track

could be constructed closer to the edge of the new tree plantation. Bollards, posts or a step-through gate should be installed to discourage access by bicycles etc.

5.1.11 Administration

The Land Development Agency or their delegate should have an officer whose duties include initiating the above actions, monitoring compliance and reporting deficiencies. This officer should inspect the site weekly during the construction period, and have the authority to instigate corrective actions. For short-term activities that have a high potential impact (e.g. asbestos removal), inspections should take place daily.

Table 5.1. Summary of pre-construction management recommendations

Task	Action	Timing
5.1.1 Site induction	Induction of contractors	Before start of any works
5.1.2 Fencing and signage	Erect site fencing with signs	Before start of works
5.1.3 Site hygiene, protocols	Clean vehicles, no access when wet	Throughout construction period
5.1.4 Timing of actions	Avoid works in habitat area late October to early January	Throughout construction period
5.1.5 Asbestos removal	Removal of loose asbestos and buried pipes	Before other works, but avoiding late October to early January
5.1.6 Path/facility construction/revegetation	Minimise disturbance, runoff. Replant with native grasses	Avoid late October to early January
5.1.7 Biomass/fuel management	• Mow habitat area to 8 to 10 cm, rake, bale, remove • Use flail mower to maintain grass at 5-15 cm	• After stock removed, but not late Oct to early Jan • Late January to late September
5.1.8 Weed control	Spot spraying	February to April, September
5.1.9 Landscaping	Native grasses only, contain eucalypt regeneration	Avoid late October to early January
5.1.10 GSM corridor	10 m wide grassed corridor	After removal of pine break, time planting to maximise seedling establishment
5.1.11 Administration	Compliance monitoring of all other actions, instigating corrective actions	Weekly throughout construction period, daily for sensitive works (asbestos)

5.2 Post-construction period

These recommendations are summarised in Table 5.4

5.2.1 Fencing, paths and signage

The boundary of the site should be protected by log barriers. Fencing, bollards and paths should direct pedestrians to desirable areas such as lookouts, and discourage short-cuts or making of informal tracks. Permanent interpretive signs should be installed, describing the life cycle and endangered status of GSM, and the need to protect its habitat from disturbance.

5.2.2 Site induction

Site inductions for contractors involved in mowing, weed control and other maintenance should identify the protected GSM habitat area and corridor, and instruct contractors to follow the relevant prescriptions below.

5.2.3 Site hygiene and protocols

Vehicles, tools and machinery (including mowers) used in the habitat area should be free of soil and vegetation. Authorised vehicles should not traverse the habitat when soil moisture is high, and no soil should be brought onto the site except as specified in these recommendations.

5.2.4 Timing

Prescribed management activities within the GSM habitat on Reservoir Hill should take place outside the breeding period of GSM as far as possible, i.e. avoiding late October to early January.

5.2.5 Biomass and fuel management

Unless removal of slashed material is again required following habitat condition monitoring, mowing should continue to be done with a flail mower. This 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. If high spring rainfall and fuel build-up necessitates summer mowing, this should be done after the end of December, with removal of slashed material if biomass is high. Mowing may be suspended in periods of extended drought.

The GSM corridor can be mown more often if considered necessary for fuel control on the western side of the tree plantation. Short grass (5 cm) will encourage movement of GSM, and the corridor is not likely to become breeding habitat, at least in the short term.

5.2.6 Weed control

Weed control should be by regular spot-spraying (at least three times annually) by a suitably qualified person, outside the GSM flying period. The most suitable periods are February to April, and September. Priority species are Serrated Tussock, African Lovegrass, Chilean Needlegrass, Phalaris, St John's Wort and Saffron Thistle. If the latter two species can also be mown before seed set this may improve control. Particular attention should be paid to recently disturbed and revegetated areas, such as asbestos removal sites, the GSM corridor, and verges of tracks and fire trails. If dense patches of weeds are killed, the site should be reseeded with local native grasses. Native forbs such as Yellow Buttons *Chrysocephalum apiculatum* should not be introduced to the revegetation mix until adequate weed control has been achieved.

5.2.7 Inspections and corrective actions after inspection or incident

The site should be inspected quarterly by the compliance officer, with one inspection in September to ensure that vegetation height is optimal for the breeding season (tussock height at 10 cm or less).

After inspections, any disturbance of the habitat should be rectified, and temporary signage installed if necessary to explain removal of informal play sites, blocking of unauthorised access points, revegetation of damaged areas etc. Any dumped materials should be removed, and additional weed control prescribed if required.

5.2.8 Annual monitoring of GSM and habitat

Monitoring of GSM should be undertaken by a suitably qualified person (Attachment A). It should begin after GSM are confirmed to have started flying on Reservoir Hill, and should be undertaken four times during the main part of the flying season (usually November to mid-December), with surveys spread over at least two weeks. Surveys should take place on warm to hot, sunny and relatively calm days, between 1100 and 1300 hours. The observer should walk transects no more than 50 metres apart, counting flying males and recording their location with a GPS unit. One transect should include the new GSM corridor. If numbers are high, the number of flying males can be recorded for each 50 metre section of transect. Numbers per minute or hour of survey should also be recorded. Locations of females or pupal cases should be recorded and mapped.

If numbers of GSM decline more than the district seasonal average for two years in a row, this should trigger a review of the management plan.

GSM habitat should be monitored in December using the same step-point transects used in the initial monitoring in 2012 (method differs slightly from Attachment A). Observations are made at each metre along a 100 metre tape, recording the single predominant feature touching a vertical thin wire at that point. Categories are:

- cryptogams
- bare ground
- rock
- litter/dead vegetation
- perennial native grass (potential larval food plants, **specify genus**)
- other native species
- perennial exotic grass
- exotic broadleaf

The start and end points of the transects (WGS 84) are:

	Transect 1	**Transect 2**	**Transect 3**
Start	690250 E 6099240 N	689978 E 6099308 N	690100 E 6099310 N
Finish	690297E 6099325 N	689882 E 6099314 N	690130 E 6099404 N

A single grass leaf touching the wire over bare ground would be recorded as bare ground, but if the wire was in the middle of a tussock, that would be recorded as a perennial grass (native with genus specified, or exotic). There are 100 observations for each transect, so a percentage frequency can be

expressed for each feature. There are no accepted guidelines for GSM habitat, and habitat parameters can vary considerably due to drought and rain, independent of site management. Initial settings of the desirable frequency ranges for habitat features thought to be the most important for GSM are in Table 5.2, but these will be changed in the future if further research or results on this site indicate that the settings are too narrow, broad, high or low.

Plant species which are uncommon on a site are not likely to be recorded using the step point method. All plant species noted during the GSM and vegetation surveys are therefore recorded, to provide a general indicator of the diversity of native and exotic plant species on the site.

The ground should be scanned for pupal cases during GSM surveys and along the vegetation transects, as these indicate sites of past egg-laying and larval development.

Table 5.2 Desired frequency range for GSM habitat features at South Lawson

Habitat feature	**Optimal % frequency range**
Native C3 perennial grasses	55-65
Bare ground	5-15
Litter	5-15
Exotic species	<5

5.2.9 Corrective actions following monitoring

Any changes in GSM numbers due to altered survival or breeding success associated with changes in the habitat may not be detected until two to three years after the habitat change, as this is thought to be the length of the larval period. GSM numbers also vary from year to year for unknown reasons, some probably related to general seasonal conditions rather than specific site conditions. Examples of corrective actions to be taken if habitat parameters in the step-point transects fall outside the set range are in Table 5.3. Note that parameters may be outside the range in one area and not another. If the average for a parameter across the transects is within the range, action may not be warranted. If a parameter is far outside the range at just one transect, the corrective action can be applied in that area (i.e. eastern slope, western slope or north-western slope).

Table 5.3 Triggers and corrective actions

Habitat feature	Trigger	Corrective action
Native C3 perennial grasses	<55% frequency	Increase weed control
	>65% frequency	Mow, removing cut material if biomass high
Bare ground	<5% frequency	Mow, removing cut material if biomass high
	>15% frequency	Reduce mowing frequency
Litter	<5% frequency	Reduce mowing frequency if biomass low
	>15% frequency	Mow, removing cut material if biomass high
Exotic species	>5% frequency	Increase weed control

5.2.10 Review of Environmental Management Plan and monitoring methods

It is usual for an EMP to contain a Works Program, specifying actions to be taken each month over a given period. It is difficult to prepare this until the starting date of construction is known, as the recommended timing of some actions will vary according to where the starting date for construction falls within the life cycle of GSM. When the start date is known, a specific Works Program can be prepared.

It would be usual to review the EMP for a relatively stable site after three to five years. This site will undergo large changes during and immediately after construction, and the effect on GSM and their habitat is difficult to predict. There will be changes in the surrounding land use, and loss of a large contiguous area of GSM habitat. The remaining habitat will be disturbed by construction of paths, and biomass management will change from light grazing by cattle and kangaroos to mowing. Weed control will probably improve, but pedestrian traffic is likely to increase. The extent of habitat restoration that will be required is not yet known, and more rigorous intervention may be needed. There is also ongoing research on GSM and their habitat in the ACT region, which may refine the definition of optimal GSM habitat and management methods.

In view of the unknown extent of the changes likely to occur at the site, it is recommended that the EMP and monitoring methods be reviewed at the end of the construction stage, to confirm that they are up-to-date and relevant for the post-construction stage, and to refine the Works Program.

Table 5.4. Summary of post-construction management recommendations

Task	Action	Timing
5.2.1 Fencing, paths, signage	Protect site from vehicle access and informal tracks, install interpretive signs re GSM	After construction of tracks, facilities in habitat area
5.2.2 Site induction	Site induction for maintenance contractors	Before contractors begin work
5.2.3 Site hygiene, protocols	Clean vehicles, no access when wet	At all times
5.2.4 Timing	Avoid maintenance or works in habitat area late October to early January	At all times
5.2.5 Biomass, fuel management	• Use flail mower to maintain grass at 5-15 cm • Mow habitat area to 8 to 10 cm, rake, bale, remove	• Late January to late September • If required as corrective action or for fuel management, and only early January to late September
5.2.6 Weed control	Spot spraying	February to April, September
5.2.7 Inspections and corrective actions after inspection or incident	• Compliance inspections • Ensure habitat <10 cm before GSM flying season • Rectify damage, install temporary signs as appropriate	• Quarterly incl. September • September • As required
5.2.8 Monitoring of GSM and habitat	• GSM transect surveys • Habitat transect surveys	• ~November – December • December
5.2.9 Corrective actions following monitoring	Increase weed control, increase or decrease mowing frequency	As required, but avoiding late October to early January
5.2.10 Review of EMP and monitoring methods	Review both in light of site condition and new information	After construction phase

6. References

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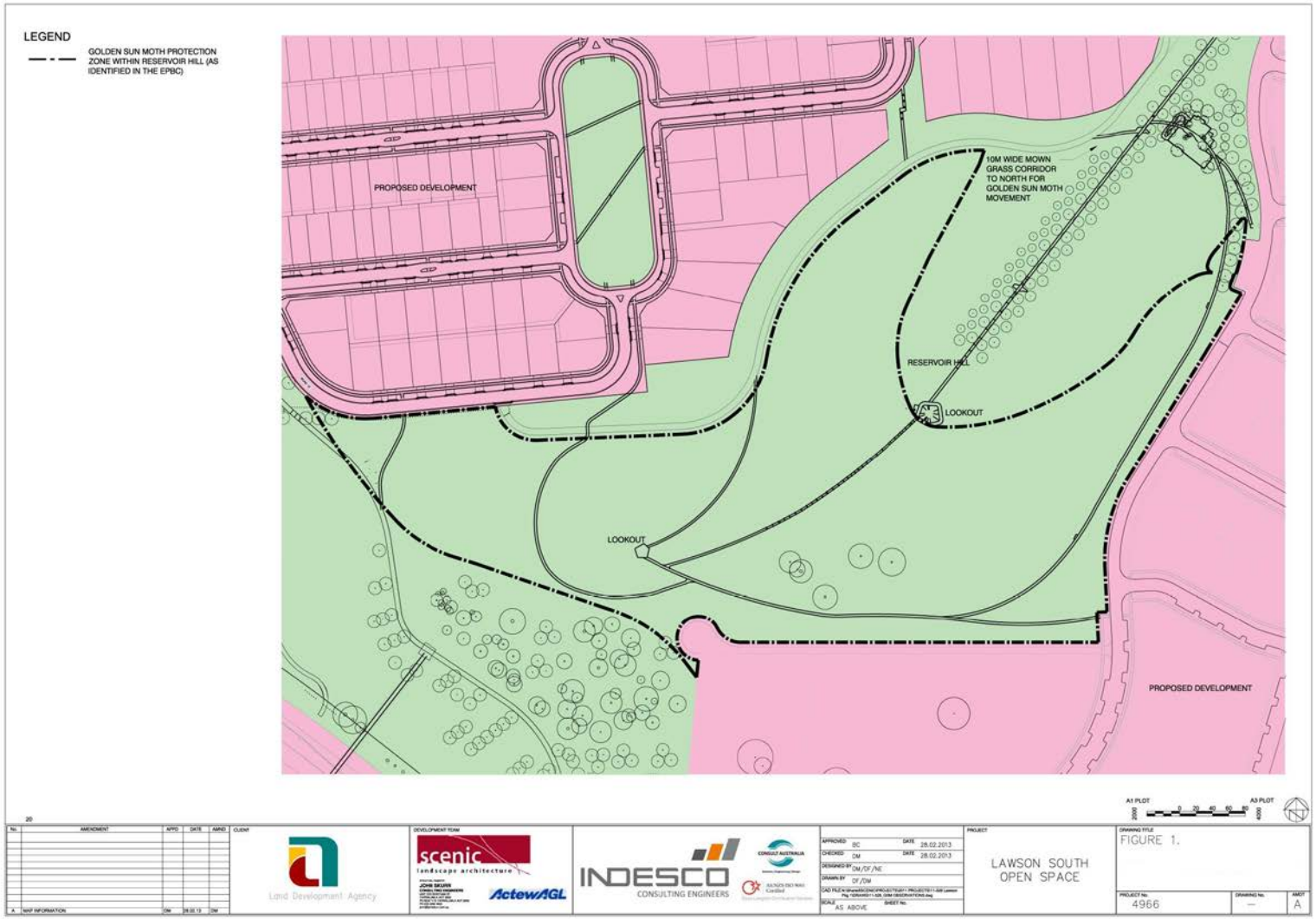

Figure 1. Golden Sun moth protection zone within Reservoir Hill

ATTACHMENT A

Initial Monitoring of Golden Sun Moths and their habitat at Reservoir Hill, November 2012 to January 2013

Prepared for INDESCO and LDA
by Alison Rowell
Biologist and Environmental Consultant
PO Box 777
DICKSON ACT 2602
February 2013

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Initial Monitoring of Golden Sun Moths and their habitat at Reservoir Hill, November 2012 to January 2013

1. Methods

1.1 Golden Sun Moth activity

Known Golden Sun Moth (GSM) sites in central Canberra were visited in late October and early November, until the start of the flying season was recorded on 5 November 2012 in Barton. Some cooler weather and rain followed, and flying was not reliably established in the ACT until mid-November. The breeding season continued through December, with numbers of flying males declining in the last week. The last record for the season was at West Macgregor on 3 January 2013.

The GSM habitat within Reservoir Hill was visited for GSM surveys five times during the GSM flying season, in warm sunny weather during the daily activity period of the moth. The surveys were five or more days apart, and therefore measured different cohorts of GSM. Table 1 shows the date, time and weather conditions of the surveys.

Table 1. Golden Sun Moth monitoring at Reservoir Hill, Nov-Dec 2012

Date	Time	Overnight min. T ºC	Daily max. T ºC	Conditions during survey
21 Nov	1230-1340hrs	5.3	28.9	Warm, no cloud, light wind
26 Nov	1120-1230	9.4	31.3	Warm, high haze, light wind
2 Dec	1135-1235	16.7	29.8	Warm, mostly sunny, wind light to mod.
9 Dec	1215-1320	12.6	27.8	Warm, mostly sunny, wind light to mod.
23 Dec	1140-1245	15.9	33.9	Hot, mostly sunny, wind light to moderate

For the initial visit, the survey was a timed meander through the GSM habitat area on Reservoir Hill to confirm GSM activity. On subsequent visits the surveys were undertaken on linear transects about 50 metres apart, and the total length of transects surveyed was about 1.85 km (Figure 1). Results for transect surveys are usually recorded as the number of GSM seen in 50 or 100 metre segments of the transect. However, numbers were very low in these surveys so the locations of individual GSM were recorded on a handheld GPS.

1.2 Golden Sun Moth habitat

Three 100 metre step point vegetation transects were surveyed in early January 2013 to characterise the GSM habitat at Reservoir Hill. The transects were placed to sample different slopes, aspects and vegetation types on the site (Figure 1).

The current understanding (various authors in DEWHA 2009) is that GSM occurs in primary or secondary native grassland, or clearings in open woodland, especially habitats containing a moderate component of Wallaby Grasses (various species of *Austrodanthonia*, recently renamed *Rytidosperma*). GSM has also been found in association with other native grasses, and the exotic Chilean Needlegrass *Nassella neesiana*. The larvae feed on the roots of the grasses, and recent dietary studies have confirmed that the larvae feed on plants that use the C3 carbon-fixing metabolic pathway, and that the C3 plants found on GSM sites are predominantly Speargrasses *Austrostipa* species, Wallaby Grasses and Chilean Needlegrass (Richter *et al* 2010). Sites are usually flat or gently sloping, with northerly aspects favoured. Sites are generally low in phosphorus (unimproved) and have bare ground between the tussocks. High biomass appears to make the habitat less suitable, as females use bare ground to bask and display, and males tend to search for females in areas of relatively low open grassland.

The transects were surveyed in two different ways. Both are standard methods, and each gives slightly different but equally useful results. Observations were made at each metre along a 100 metre tape, recording the plants touching a vertical thin wire at that point, as well as cryptogams, bare ground, rock and dead plants/litter. The proportion of the various features indicates the quality of the GSM habitat.

One set of observations ('multiple hits') consisted of every plant (or other feature as above) that was touching the wire at that point, apart from the flowering heads of grasses or lilies. Plants were identified to species if possible, but all Wallaby Grasses were classed together, as the florets had fallen from the heads making identification difficult.

The second set of observations allowed only one record at each point ('single hit'), with only the predominant feature at that point being recorded. For example, a single grass leaf touching the wire over bare ground would be recorded as bare ground, but if the wire was in the middle of a tussock, that would be recorded as a perennial grass (native or exotic). For the 'single hit' method, the records were placed into broad categories.

Plant species which are uncommon on a site are not likely to be recorded using the step point method. All plant species noted during the GSM and vegetation surveys were therefore recorded. The list is incomplete as the data was collected incidentally to the other surveys, but it provides a general indicator of the diversity of native and exotic plant species on the site.

The ground was scanned for pupal cases during GSM surveys and along the vegetation transects, as these indicate sites of past egg-laying and larval development.

2. Results

2.1 Golden Sun Moth activity

No female moths or pupal cases were seen during the surveys. Flying males were recorded on most parts of Reservoir Hill, but numbers were very low on all visits. The activity/density of GSM is usually expressed as number of flying males per 100 metres of transect or per minute of survey (Table 2), with less than four GSM per 100 metres or less than two per minute suggested as indicating low density in the ACT (Hogg 2010). At South Lawson in 2012 numbers of about this magnitude were recorded per hour and per kilometre (Table 3 and Figure 2).

Table 2. Relative measures of Golden Sun Moth activity/density for transects surveyed at moderate walking pace (Hogg 2010)

GSM activity/density	Flying male GSM per 100 m of transect	Flying male GSM per minute of walking
High	40 or more	20 or more
Moderate	10 to 20	5 to 10
Low	4 or less	2 or less

Table 3. Golden Sun Moth survey results, Reservoir Hill, Nov-Dec 2012

Date	GSM/km	GSM/100m	GSM/hour	GSM/min	Notes
21 Nov	-	**-**	2.6	0.04	In medium density grassland with Spear and Wallaby grasses
26 Nov	3.2	**0.32**	6.0	0.10	
2 Dec	2.2	**0.22**	4.0	0.07	In low to medium density grassland with Spear and Wallaby grasses
9 Dec	5.0	**0.50**	9.2	0.15	
23 Dec	10.5	**1.05**	19.4	0.32	Most GSM activity on eastern side of hill, possibly due to NW wind during survey
Average	5.2	**0.52**	8.2	**0.14**	**GSM activity/density very low for all surveys**

Higher numbers of GSM were recorded in surveys at South Lawson in 2007 and 2009, i.e. 2 to 2.5 GSM per 100m (Eco Logical 2008, Rowell 2010). These numbers still fall into the low density category. These surveys used somewhat different methods, were undertaken on a single day late in the season, and covered the whole site rather than just Reservoir Hill, so are not strictly comparable with the current survey. However, the very low numbers of GSM recorded on five different days suggest that the adult GSM population at Lawson South was relatively small in 2012.

Aggregated results from a number of surveyors at various sites in the ACT in 2012 suggested that GSM activity was low to moderate compared to some previous drier years.

2.2 Golden Sun Moth habitat

Table 4 shows the transect results using the 'single hit' method. There was considerable variation in the cover of cryptogams, bare ground and litter, but the total of non-vegetation 'hits' was similar for all transects. The lack of bare ground in Transect 1 on the wetter eastern slope of the hill was due to the high cover of litter. Native perennial grasses formed the predominant cover across all transects, and native forbs were rare.

Table 4. Vegetation transect results, 'single hit' or predominant category per point

Category	**Transect 1** **% hits**	**Transect 2** **% hits**	**Transect 3** **% hits**
Cryptogams	0	14	0
Bare ground	1	6	11
Rock	0	3	1
Litter/dead vegetation	25	5	16
non-vegetation hits	***26***	***28***	***28***
Annual exotic grass	4	4	4
Perennial exotic grass	4	0	0
Exotic broadleaf	5	2	3
exotic hits	***13***	***6***	***7***
Perennial native grass	59	65	65
Other native	2	1	0
native hits	***61***	***66***	***65***
TOTAL HITS	**100**	**100**	**100**
End points of transects, WGS 84.			
Start	690250 E 6099240 N	689978 E 6099308 N	690100 E 6099310 N
Finish	690297E 6099325 N	689882 E 6099314 N	690130 E 6099404 N

The results of the 'multiple hit' method are shown in Table 5. The breakdown of the native perennial grass category shows that the proportions of the different grass genera differed considerably among the transects. Transect 1 on the eastern slope was dominated by Tall Speargrass *Austrostipa bigeniculata* and Weeping Rice Grass *Microlaena stipoides*. Wallaby Grasses *Rytidosperma* species were dominant on Transect 2, which was on shallow soil on the west-facing slope. Speargrasses were dominant and Wallaby Grasses were common on Transect 3, which was on deeper soil on the west-facing slope. All the above grasses are C3 plants, and the cover of C3 grasses on all transects was high, and very similar (occurring at 65-67 of the record points).

The cumulative plant list for the site (Table 6) confirms that native plant diversity is fairly low, with grasses being more abundant than forbs. Five species of Wallaby Grasses were collected and identified in November 2012. There were five native forb species that are seen as relatively sensitive (Rehwinkel 2007), but all were fairly rare on the site. Three Weeds of National Significance were present: Chilean Needlegrass, Serrated Tussock *Nassella trichotoma*, and St John's Wort *Hypericum perforatum*. St John's Wort was the most common of these, and Saffron Thistle *Carthamus lanatus* was the other most abundant weed.

Table 5. Vegetation transect results, multiple hits per point.

	Transect 1 Hits/100 m (% freq)	**Transect 1 % veg composition (88 veg hits)**	**Transect 2 Hits/100 m (% freq.)**	**Transect 2 % veg composition (100 veg hits)**	**Transect 3 Hits/100 m (% freq.)**	**Transect 3 % veg composition (81 veg hits)**
Bare ground	1		7		11	
Rock	**0**		**0**		**1**	
Litter	**27**		**10**		**23**	
Cryptogam	**0**		**17**		**0**	
Native grasses						
Aristida ramosa (C4)			5	5		
Rytidosperma spp. (C3)	6	6.8	59	59	23	28.4
Austrostipa bigeniculata (C3)	26	29.5			10	12.3
Austrostipa scabra (C3)			2	2	33	40.7
Bothriochloa macra (C4)	1	1.1	14	14	2	2.5
*Elymus scaber (*C3)	6	6.8			1	1.2
Microlaena stipoides (C3)	26	29.5				
Poa sieberiana (C3)	1	1.1				
Total native grasses	**66**	**74.8**	**80**	**80**	**69**	**85.1**
Austrostipa+ Rytidosperma	**32**	**36.3**	**61**	**61**	**66**	**81.4**
Total C3 native grasses	**65**	**73.8**	**66**	**66**	**67**	**82.7**
Native forbs						
Carex inversa	1	1.1	1	1		
Convolvulus erubescens	2	2.3				
Wahlenbergia sp.	2	2..3				
Total native forbs	**5**	**5.7**	**1**	**1**	**0**	**0**
TOTAL NATIVES	**71**	**80.5**	**81**	**81**	**69**	**85.1**
Exotic grasses						
Aira sp.			8	8	3	3.7
Bromus hordeaceus	2	2.3				
Holcus lanatus	3	3.4				
Lolium perenne	2	2.3				
Nassella trichotoma	1	1.1				
Vulpia sp.	4	4.5	1	1	4	4.9
Total exotic grasses	**12**	**13.6**	**9**	**9**	**7**	**8.6**

	Transect 1 Hits/100 m (% freq)	**Transect 1 % veg composition (88 veg hits)**	**Transect 2 Hits/100 m (% freq.)**	**Transect 2 % veg composition (100 veg hits)**	**Transect 3 Hits/100 m (% freq.)**	**Transect 3 % veg composition (81 veg hits)**
Exotic forbs						
Acetosella vulgaris	1	1.1				
Centaurium erythraea			6	6		
Hypericum perforatum	1	1.1				
Hypochoeris radicata	1	1.1	4	4	5	6.2
Plantago lanceolata	2	2.3				
Total exotic forbs	**5**	**5.6**	**10**	**10**	**5**	**6.2**
TOTAL EXOTICS	**17**	**19.2**	**19**	**19**	**12**	**14.8**

3. Analysis of habitat results

The good cover of native C3 grasses found across the site, especially those most often associated with GSM (*Rytidosperma* and *Austrostipa*), is desirable, but their density may be too high in parts. The high cover of litter and relatively low amount of bare ground on Transects 1 and 3 is not ideal for GSM, and probably indicates reduced habitat quality. Both of the above may be partly the result of relatively light grazing and three years of moderate to high rainfall in the ACT.

The results for South Lawson from both transect methods were similar, but the breakdown of perennial native grasses into genera in the 'multiple hit' method gave more useful data. It is suggested that the methods be combined in future monitoring, with the simpler 'single hit'/predominant cover method being used, but with the native grass data being recorded by genus so that C3 and C4 cover can be assessed separately (see Recommendations and Management Plan).

'Multiple hit' step-point transects have been measured in two drought years and one wetter year at the York Park GSM site in Barton (Rowell 2012), providing useful comparative data. The York Park site is very small and flat, managed by mowing, contains relatively diverse native grassland, and is known to have had a relatively dense and stable GSM population for many years. This suggests that habitat quality is high at York Park. The York Park transects had much more bare ground in the dry years than South Lawson did in January 2013. The amount of bare ground at York Park in a wetter year was very similar to the South Lawson results (average of 5 points in the 'multiple hit' measure for York Park, 6 at South Lawson). The average amount of bare ground in dry years at York Park was 21 points using the same method. The ideal amount of bare ground for GSM habitat is not known, but the average of wet and dry years for the York Park site can be used as a guide, i.e. about 13 points using the 'multiple hit' method.

The amount of litter at York Park was similar in wet and dry years, and mostly higher than seen at South Lawson. This may be due to the management of York Park by mowing without the removal of cut material. More litter is left by mowing in wet years due to the heavier growth of grasses, but some decays under wet conditions. Less litter results from mowing in dry years, but there is little decay of the litter that is present. Grazing should result in less litter, as some of the grass is eaten before it can die and add to the litter layer. A change of management of South Lawson from grazing to mowing may increase the amount of litter present, which could be detrimental to the GSM habitat.

The slope and some aspects of Reservoir Hill are not typical of good GSM habitat, and it may not be possible to increase GSM density above a certain level by site management. Loss of surrounding GSM habitat to development, changes caused by disturbance and increased use of the site may also have an impact on the GSM population. However, there are several features of the GSM habitat which can be improved by better management, and this may increase the GSM population density on Reservoir Hill.

4. Recommendations

The following recommendations for the desirable ranges for GSM density and habitat parameters are made after comparing the GSM and habitat data from South Lawson with quantitative data from York Park, and with qualitative and quantitative observations from other ACT sites.

Management at South Lawson should aim for:

- an increase in the number of flying male GSM recorded in transect surveys
- a reduction in the biomass of native C3 grasses while maintaining moderate cover
- an increase in the amount of bare ground
- reduction in the amount of litter in most areas
- reduction in weed cover
- maintenance where possible of corridors to the larger GSM population at the Belconnen Naval Transmission Station.

Given that GSM density at South Lawson is currently very low, the aim should be to increase the density over five years to the low to moderate category, i.e. more than five GSM per 100 metres of transect.

For the 'single hit' transect method the desirable range for the selected habitat parameters corresponds to about 55-65% frequency for native C3 grasses, 5-15% for bare ground, 5-15% for litter and <5% for exotic species.

5. References

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Table 6. Plant species list, Reservoir Hill, 2012-13.

* Weeds of National Significance
# Indicator Species 2 (Rehwinkel 2007)
C = common
O = occasional
R = rare

Native grasses

Species	Common name	Abundance
Aristida ramosa	Wiregrass	R
Rytidosperma auriculatum	Lobed Wallaby Grass	O
Rytidosperma caespitosum		C
Rytidosperma carphoides	Short Wallaby Grass	C
Rytidosperma erianthum		C
Rytidosperma laeve	Smooth Wallaby Grass	O
Rytidosperma sp.	Wallaby Grass	O
Austrostipa bigeniculata	Tall Speargrass	C
Austrostipa scabra	Rough Speargrass	C
Bothriochloa macra	Redleg Grass	O
Elymus scaber	Wheatgrass	O
Microlaena stipoides	Weeping Rice Grass	C
Panicum effusum	Hairy Panic Grass	O
Poa sieberiana	Snow Grass	R
Themeda triandra	Kangaroo Grass	O
Number of native grasses		**14**

Native forbs

Species	Common name	Abundance
Asperula conferta *	Common Woodruff	O
Carex inversa	Knob Sedge	O
Convolvulus angustissimus	Australian Bindweed	O
*Desmodium varians**	Slender Tick Trefoil	R
*Dichopogon fimbriatus**	Chocolate Lily	R
Gonocarpus tetragynus	Common Raspwort	R
Juncus sp.	A Rush	R
Rumex brownii	Swamp Dock	O
Rumex dumosus		R
Tricoryne elatior	Yellow Rush Lily	R
Triptilodiscus pygmaeus	Austral Sunray	O
Wahlenbergia luteola	A Bluebell	O
Wahlenbergia sp.	A Bluebell	O
Number of native forbs		**13**

Exotic grasses

Species	Common name	Abundance
Exotic Grasses		
Aira sp.	A Hairgrass	C
Avena sp.	Wild Oats	O
Briza minor	Shivery Grass	O
Bromus hordeaceus	A Brome Grass	O
Eragrostis curvula	African Lovegrass	R
Holcus lanatus	Yorkshire Fog	O
Lolium perenne	Perennial Ryegrass	O
Lolium perenne	Ryegrass	O
Nassella neesiana #	Chilean Needlegrass	R
Nassella trichotoma #	Serrated Tussock	R
Phalaris aquatica	Phalaris	O
Vulpia sp.	Rat's-tail Fescue	C
Number exotic grasses		

Exotic forbs

Species	Common name	Abundance
Acetosella vulgaris	Sorrel	C
Carthamus lanatus	Saffron Thistle	C
Centaurium erythraea	Pink Stars	C
Chondrilla juncea	Skeleton Weed	R
Gamochaeta purpurea	A Cudweed	O
Hypericum perforatum #	St John's Wort	O
Hypochaeris radicata	Catsear	C
Petrorhagia nanteulii	Proliferous Pink	O
Plantago lanceolata	Ribwort Plantain	O
Trifolium angustifolium	Narrow-leaved Clover	R
Trifolium subterraneum	Subterranean Clover	O
Number of exotic forbs		**11**

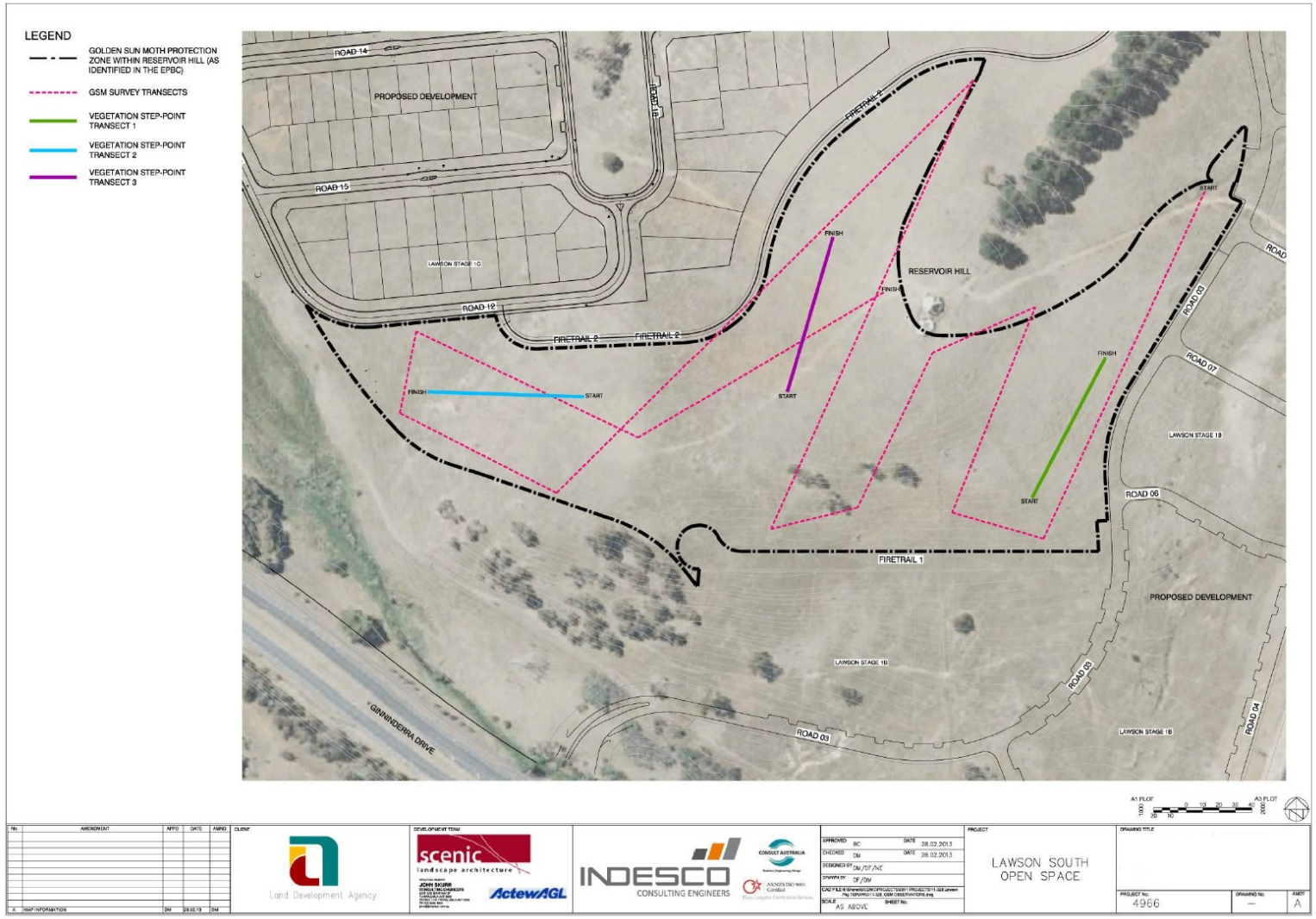

Figure 1. Golden Sun moth Transects and Vegetation Step-point Transects 2012-13

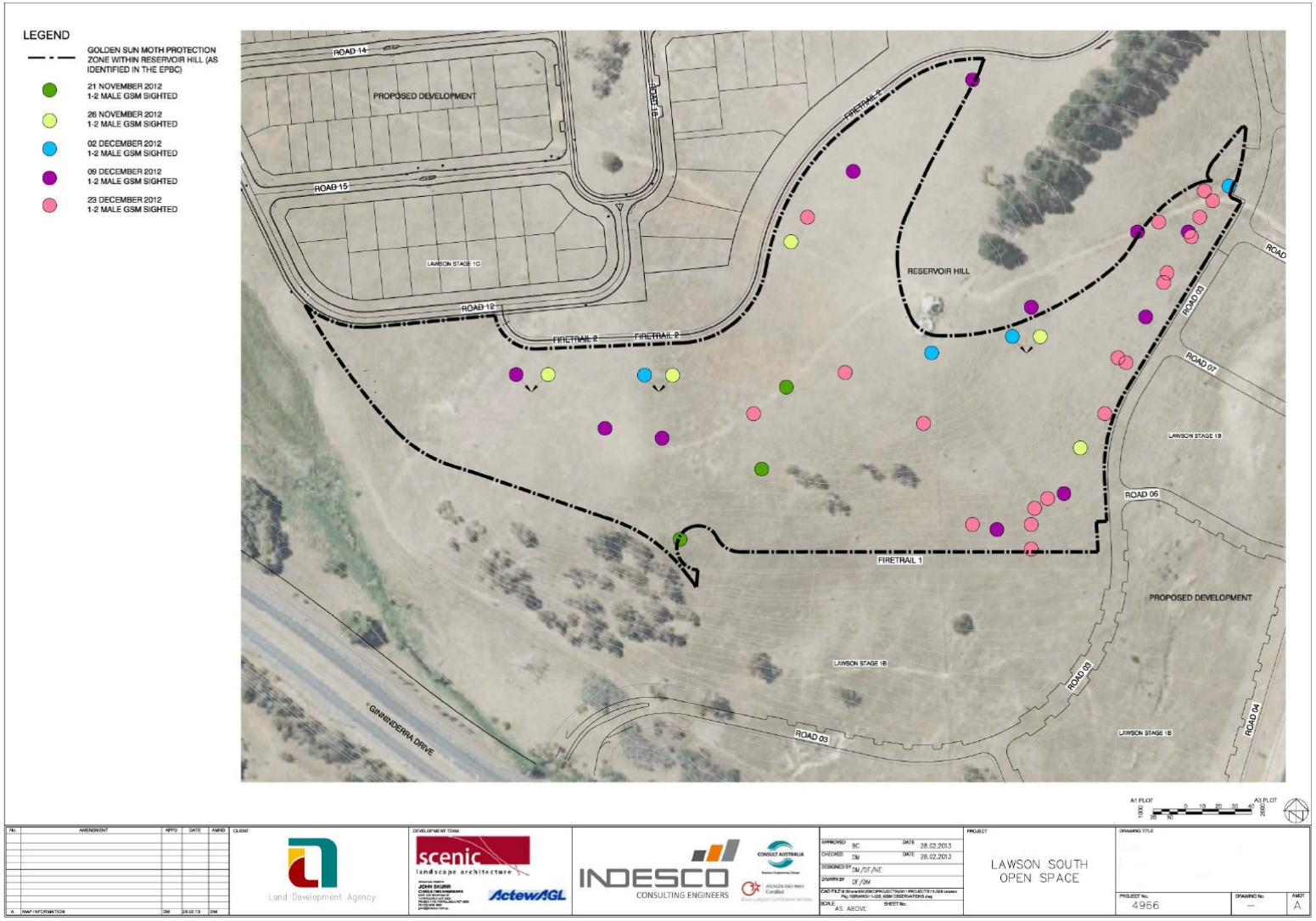

Figure 2. Golden Sun Moth observations November – December 2012