Orange Grove Sun Farm

Glint & Glare Risk Assessment

For: Orange Grove Sun Farm Pty Ltd

November 2018

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1. INTRODUCTION

1.1. Introduction

SMEC has been commissioned by Orange Grove Sun Farm Pty Ltd (OGSF) to undertake a glare and glint assessment of a proposed solar farm near the township of Gunnedah, NSW. The project includes the development, construction and operation of a large-scale solar photovoltaic (PV) generation facility and associated building and electrical infrastructure including grid connection works.

The specific purpose of this assessment is to provide additional information for the Environmental Impact Statement (May 2018), on potential environmental impacts for submission to the Department of Planning and Environment (DPE).

This assessment investigates the potential glare and glint impacts upon receptors in near vicinity of the proposed solar farm. The receptors have been identified as:

- Residential receptors - houses within close proximity to the proposed solar farm;
- Recreational Gun club near to the proposed solar farm; and
- Motorists travelling along Orange Grove Road in vicinity of the solar farm.

1.2. Glare and Glint from Solar Panels

Glare occurs when sunlight is continually reflected off a surface causing excessive brightness. Glint is a momentary flash of light, typically from a moving object that reflects the sun.

The impact of glare in the field of view ranges from:

- Veiling glare: where the light source causes a loss of contrast;
- Discomfort glare: interferes with the perception of visual information and can cause some discomfort; and
- Disability glare: caused by intense light sources that reduce the ability to be able discern visual information.

Glare and glint is produce by reflective surfaces that are typically shiny and flat, such as glass, steel and water. The surface material and the angle of incidence of the sunlight is relevant in the amount of reflection that occurs.

While solar panels can produce glare, they are designed for light absorption rather than reflection and PV cells typically have an anti-reflective coating applied.

1.3. Site context

1.3.1. Notable Features

The proposed solar farm is located approximately 12 kilometres east of the township of Gunnedah in NSW. The solar farm will encompass an area of approximately 226 ha, spanning across 192 ha to the north of, and 34.1 ha to the south of Orange Grove Road.

Orange Grove Road transects the site, with the Namoi River to the south tracking east to west. The properties are currently used for rural grazing and cropping. There is a small hill range to the north of the site which contrasts to the relatively flat surrounds. The desktop analysis shows that the range is covered in native vegetation, with a few unsealed private access tracks and there appears to be no significant viewing point.
Notable features and land uses in proximity to the site include:

- Orange Grove Road – transects the site;
- Gunnedah Town Centre - 12 kilometres west (population 9,726 - 2016 census);
- Village of Carroll – 5km to the east (across the Namoi River, population 176 - 2016 census);
- Namoi River – flowing south of the site tracking from the east to west;
- Lake Keepit – 12.3km north-east of the site;
- Various Agricultural – situated around the project boundary and scattered throughout the surrounding area; and
- Namoi Pistol Club's pistol range (east of the site) and 900m rifle range to the north-east of the site.

Refer to Figure 1-1 for further information.

1.3.2. Existing Vegetation and Screening

A desktop study including studying aerial images of the site, shows that within the subject site there is minimal scattered native trees. The density of the scattered native trees increases to the south east through to south west towards the Namoi River.

A vegetative screening plan which will include upper and lower canopy visual screening is proposed by OGSF along the immediate western boundary with receptor 'R1' (refer to Figure 2-1 on page 7).

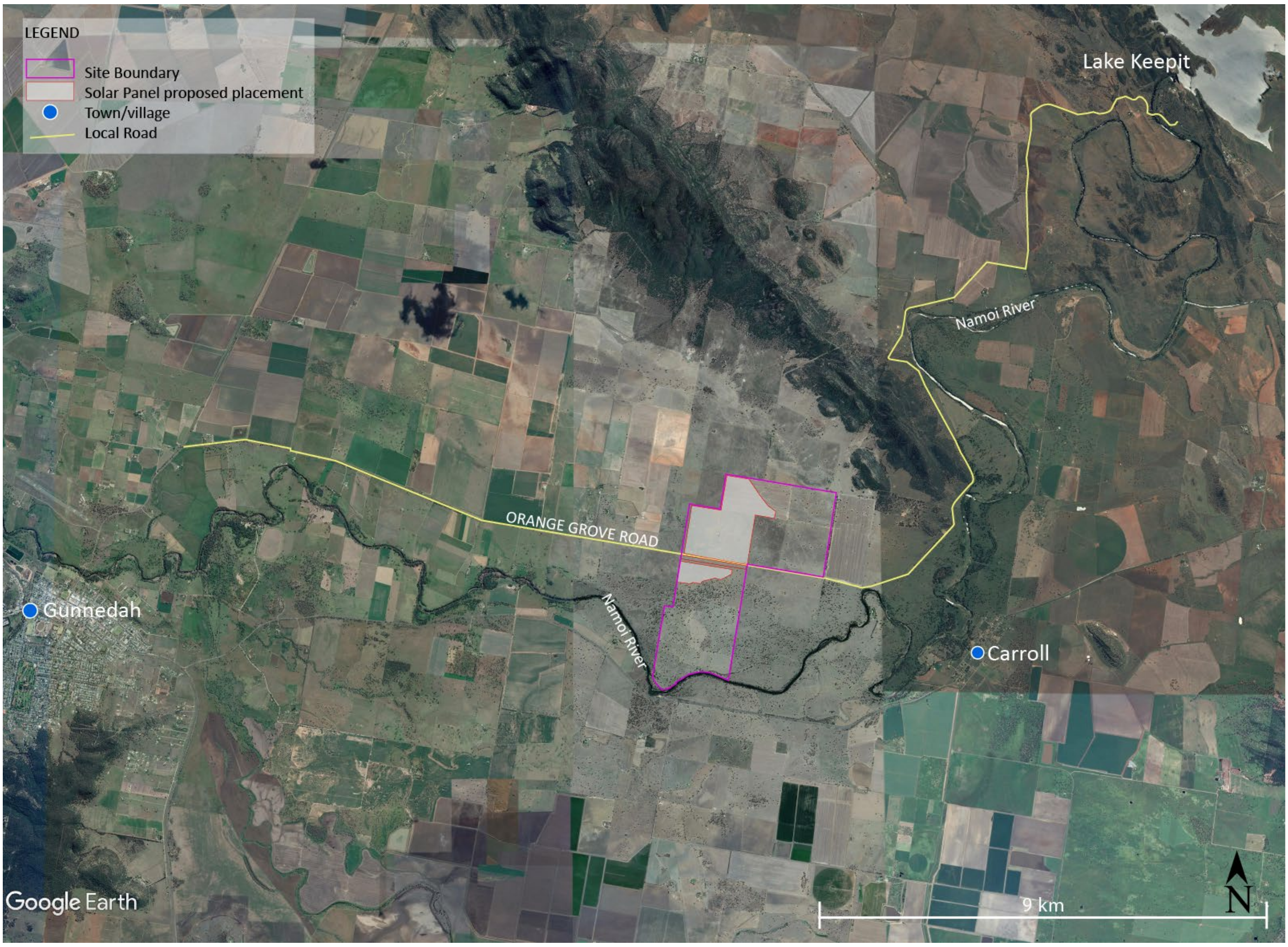


Figure 1-1 Site Context Plan

2. VISUAL RECEPTORS AND SENSITIVITY TO GLARE

2.1. Visual Receptors

Although the proposed site is in a rural setting, there are a number of receptors in the vicinity of the proposed solar farm. A number of these receptors have been included in this assessment to provide an indication of potential for glare and glint impacts to be experienced by nearby receptors. Receptors indicated by OGSF include local residents and the local pistol club and rifle range (refer to Figure 2-1). Other potential receptors included motorists travelling along Orange Grove Road.

The effects of glare can impact the type of receptor differently, dependant on the activity which they are performing or their level of comfort. Risks to the type of receptor include the below.

- Traffic: severe functional performance disturbance caused by reduced the ability to be able discern visual information that can result in:
  - Object or obstacle recognition and the ability to slow in time
  - Ability to view the road clearly
  - Safety risk
- Residential / Farming: perceived discomfort in their homes or in outdoor spaces.

Farming functions including the operation of machinery or vehicles could have the same risks as traffic.

Views towards the solar farm will be in the peripheral view of motorists travelling both east and west along Orange Grove Road. The below table lists likely visual receptors and rates their likely sensitivity based on their activity or occupation of the area.

Table 2-1: Receptor sensitivity

Land Use	Typical Receptor	Sensitivity to glare or glint
Residential / Farming	Local Residents	Medium. Residential receptors will experience views towards the project site for an extended duration given this is their principal place of residence they will have a high familiarity with the existing conditions. Vegetation screening is proposed along the immediate west property boundary with R1 (refer to Figure 2-1). Vegetation at maturity will be 3-5m in height.
Namoi Pistol Club	Club Members	High. Patrons require focus and visual clarity when shooting, there is high sensitivity for reasons of safety. The firing line is to the north. Only if range views are directly towards the solar farm, will there be potential as a safety risk.
Orange Grove Road	Motorists	High. Given drivers require focus and visual clarity when driving, there is high sensitivity for reasons of safety.

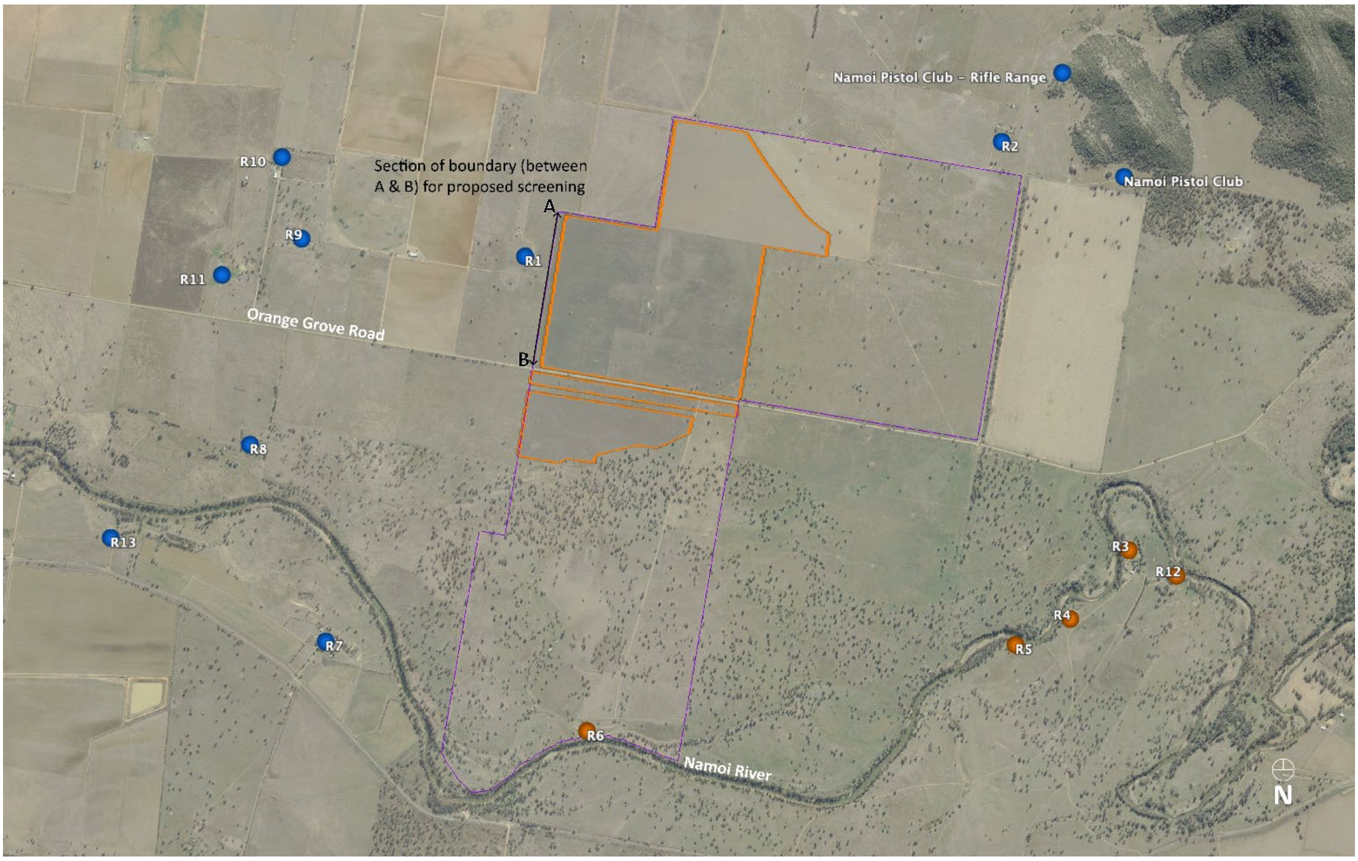


Figure 2-1 Identified Receptors (provided by OGSF)

3. PHYSICAL DIMENSIONS AND ARRANGEMENT OF SOLAR PANELS

The PV module proposed and used as the basis of the glint and glare analysis is the 'NX Horizon' (NEX Tracker, 370W PERC module). Dimensions for individual photovoltaic cells are provided in Figure 3-1.

In order to maximise electricity production, it is also understood that the photovoltaic cells will be installed on a single axis tracking system that rotates about a north-south aligned axis to follow the sun +/-60° from the horizontal, with the aim being to have the panels oriented as close to perpendicular to the sun as is possible.

These tracking systems will be arranged in rows running in a north-south direction. Further details on the PV module and associated tracking system dimensions are provided within Figure 3-1.

Note: Figure 3-1 is a typical tracking system and PV cell arrangement. OGSF proposes a maximum height of 2.4m.

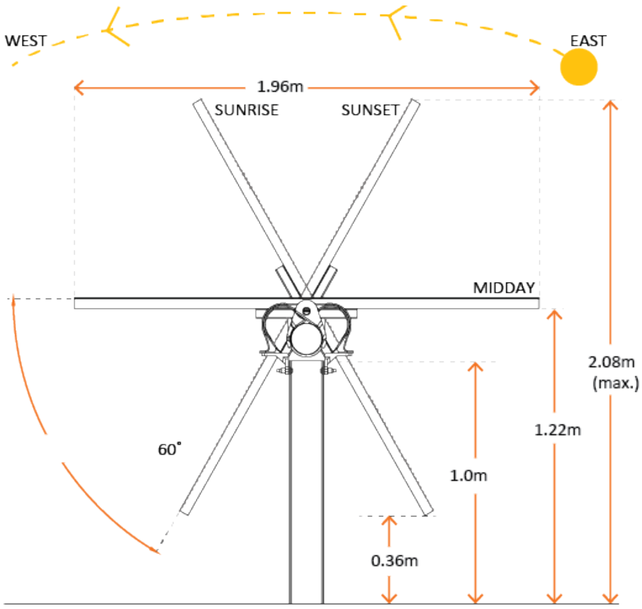


Figure 3-1 Photovoltaic cell design on tracking system

3.1. Angle of reflection

The angle of reflection of sunlight hitting the photovoltaic cells is directly related to the angle of incidence (shown as *r* in Figure 3-2) of a sun's rays hitting the cell surface. The position of the sun relative to the solar panels, and by extension the angle of reflection, will vary by the time of day and season of the year.

The amount of light reflected by a surface typically increases with a greater angle of incidence (i.e. increased *r* angle shown in Figure 3-2).

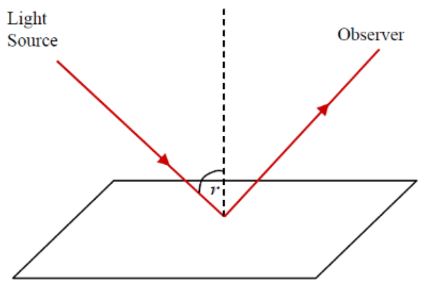


Figure 3-2 Angle of reflection

3.2. Reflectivity

Photovoltaic cells are designed to absorb light in order to maximise energy production, and accordingly reflect only a portion of the sunlight that falls on them. A review of various technical studies by photovoltaic cell manufacturers indicates that whilst the level of reflection is dependent upon the amount of light available (driven by geographic location, time of year, cloud cover and cell orientation), reflectance levels associated with photovoltaic cells are typically much less than those of other common materials including paint and standard glass (such as that found in a car windscreen)[1].

At the extreme of 80° angle of incidence of the light source (when reflectance levels are approaching their maximum), metallic paints reflect back as much as 85% of the incident light, depending on the colour, while an ordinary car windshield reflects 40% on average. Photovoltaic cells have optimum optical characteristics and the average reflectivity level at the same angle of incidence was about 30%, while measurements below a 70° angle had an average of 15%[2].

[1] *C Protogeropoulos and A Zachariou. PHOTOVOLTAIC MODULE LABORATORY REFLECTIVITY MEASUREMENTS AND COMPARISON ANALYSIS WITH OTHER REFLECTING SURFACES. Paper submitted to the 25th European Photovoltaic Solar Energy Conference, 2010.*

[2] *C Protogeropoulos and A Zachariou. PHOTOVOLTAIC MODULE LABORATORY REFLECTIVITY MEASUREMENTS AND COMPARISON ANALYSIS WITH OTHER REFLECTING SURFACES. Paper submitted to the 25th European Photovoltaic Solar Energy Conference, 2010.*

The PV modules that are proposed for this project are constructed of solar glass with a dark-coloured anti-reflective surface which is designed to increase light absorption and minimize light reflection.

3.2.1. Key considerations

The following considerations have been factored into the glare risk assessment for the proposed OGSF:

- In order for glare-related impacts to be experienced, a direct line of sight to the photovoltaic cells is required.
- Reflectivity associated with photovoltaic cells is typically less than commonly found objects within the surrounding area (e.g. motor vehicles, steel roofing, water);
- The likely use of a tracking system means that for the most part, the angle of reflectance from the photovoltaic cells will be relatively close to perpendicular to the surface of the cell itself (refer to Figure 3-3). At times when the tracking system has reached the limit of its range of movement and the angle of incidence shifts away from the perpendicular (i.e. at sunrise and sunset) the reflected light is expected to be reflected up and away from the ground (refer to Figure 3-3). It is therefore assumed that, relative to ground level and airborne receptors, reflected light will typically be reflected up and away from the ground at or near to a minimum of 30° relative to the horizontal.

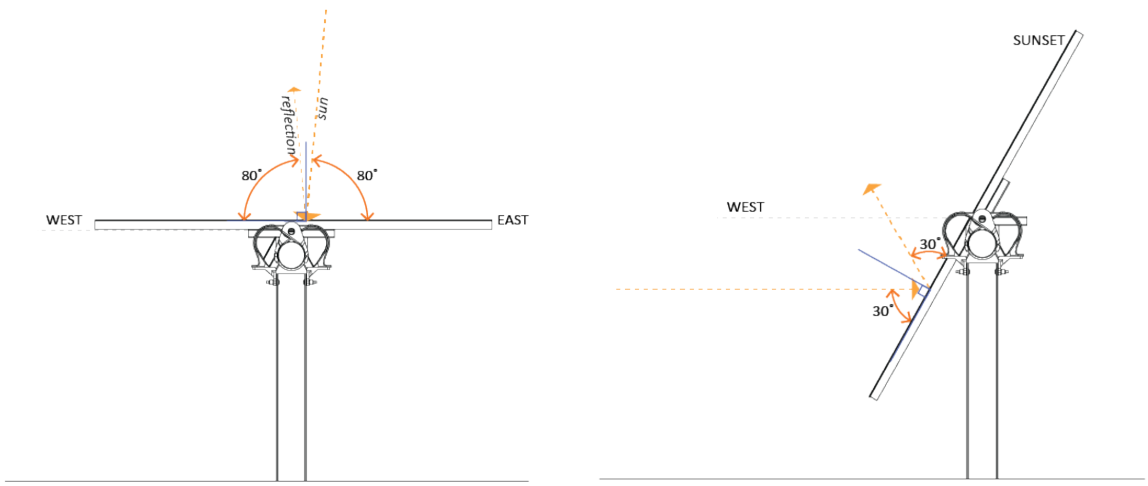


Figure 3-3 Typical daytime (left) and sunset/sunrise (right) reflection scenarios illustrating direction of reflection and associated glare

4. QUANTITATIVE GLARE ANALYSIS

4.1. Methodology

The glare is calculated using a technical modelling program specialising in glare analysis. The tool used is the Solar Glare Hazard Tool (SGHAT) developed by 'Sandia National Laboratories', licensed as 'Forge Solar'. This is an industry standard program required by the United States Federal Aviation Administration (FAA), is recognised by the United Kingdom's Civil Aviation Authority (CAA) and the Australian Government Civil Aviation Authority (CASA).

The SGHAT determines when and where solar glare can occur throughout the year. The results are calculated by site specific data derived by user-input on an interactive Google Maps interface locating the position of the solar panels, the location of sensitive receptor observation points, the time zone, elevation (derived from Google geographical position), and input of the PV cell specifications.
The results highlight the potential ocular impact from the observed glare, where is observed from and the time of day that this is likely to incur, to help determine mitigation measures.

The analysis software calculates the potential minutes of glare on observation receptors at different times of the day, with results indicating the type of glare, if any, and the amount of potential to cause flash blindness. The software classifies glare into three types in the results tables, being:

Low Potential Hazard / Green Glare: indicates the presence of glare with a low potential for temporary after-image.

Moderate Potential Hazard / Yellow Glare: indicates the presence of glare with a moderate potential for temporary after-image.

High Potential Hazard / Red Glare: indicates the presence of glare with a high potential for permanent eye damage.

The glare analysis does not account for physical obstructions between the receptor and the PV cells, including buildings, tree cover and geographical obstructions. Therefore, the worst-case scenario is calculated. Refer to Appendix B for ForgeSolar Glare Analysis results.

4.1.1. Model inputs

The following parameters were input into the model for the proposed solar farm.

- Photovoltaic modules with a tracking axis located 1.2 meters above ground level, consisting of solar glass with anti-reflection surface treatment;
- Single-axis tracking rotation aligned on a north-south axis with a range of +/- 60 degrees from vertical; and
- The geographical extent of the proposed solar arrays as shown in Appendix A: preliminary site layout.

An assumption has been made that once the panels reach their maximum tracking angle, they remain in this position until the sun has set.

Impacts were assessed against the following observational points (refer to Figure 4-1):

- Residential receptors within close proximity of the project site and as indicated by OGSF;
- Points located in position of the nearby pistol club and rifle range; and
- Points located along Orange Grove Road in proximity of the subject site, at approximate 500m intervals.

A viewing height was assigned to each visual receptor to approximate the viewing height of a person either at home or in a passenger vehicle.

- 1.2 meter height for residential and gun-club (at the firing line) receptors; and
- 1.5 meter height for motorists.

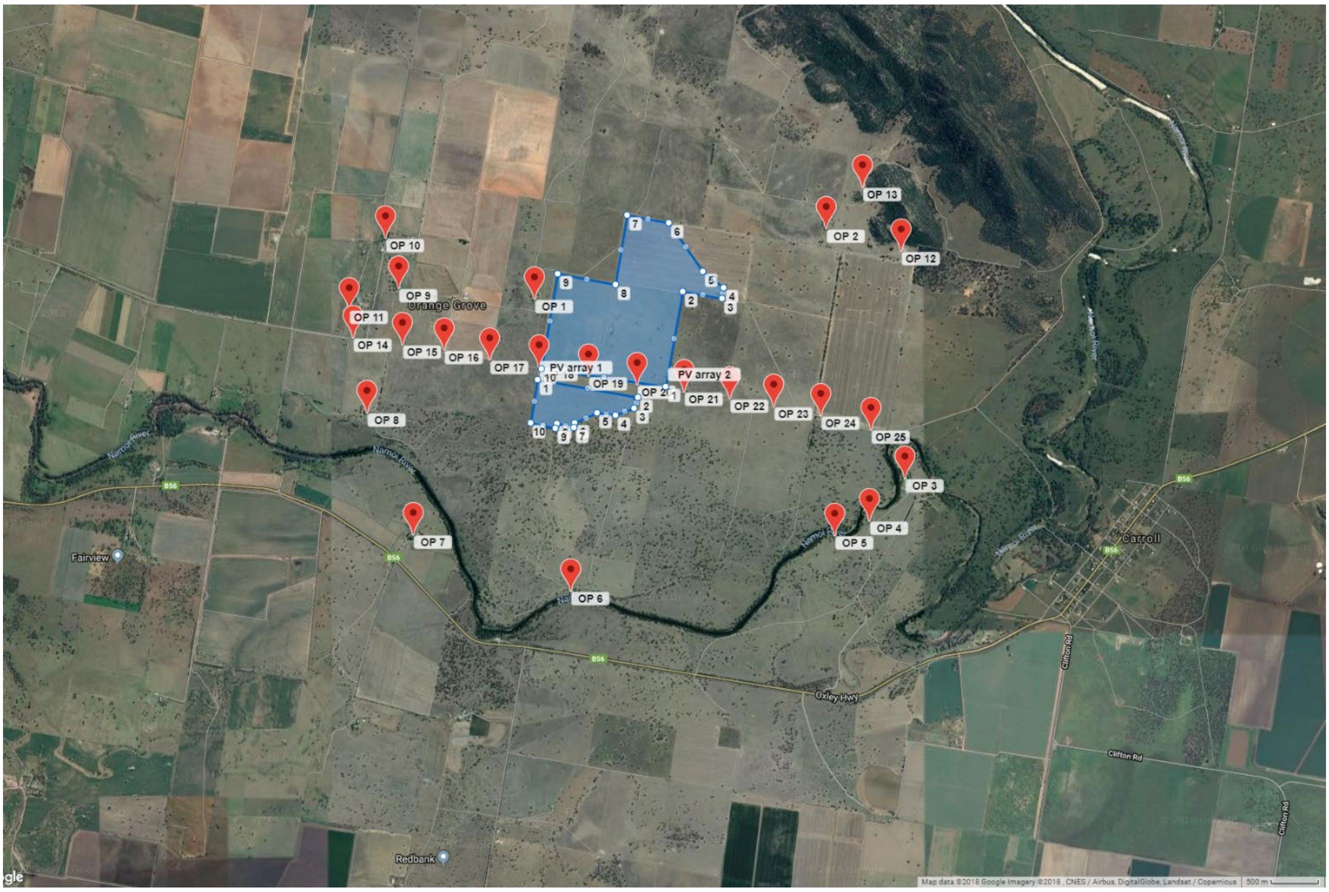


Figure 4-1 Site location and assessed observation points

LEGEND
Visual Receptors
Location of Solar Panels

Table 4-1 Details of Observation points indicated in Figure 4-1

Observation Points	Type of Visual Receptor	Comments
OP 1-11	Residential receptors	Receptors as indicated by OGSF
OP12	Namoi Pistol Club – pistol range	Receptors as indicated by OGSF
OP13	Namoi Pistol Club – rifle range	Receptors as indicated by OGSF
OP14-25	Orange Grove Road	Observation points at 500m spacings

4.2. Results

The assessment calculated zero minutes or **'no glare'** predicted upon the any of the observation points, based on the proposed position of the solar farm and the type of PV cells to be used.

Table 4-2 Predicted Glare and Glint experienced by assessed receptors

PV name	"Green" glare (low potential to cause flash blindness) (minutes across the year)	"Yellow" glare (potential to cause flash blindness) (minutes across the year)
PV1	0	0
PV2	0	0

5. SUMMARY

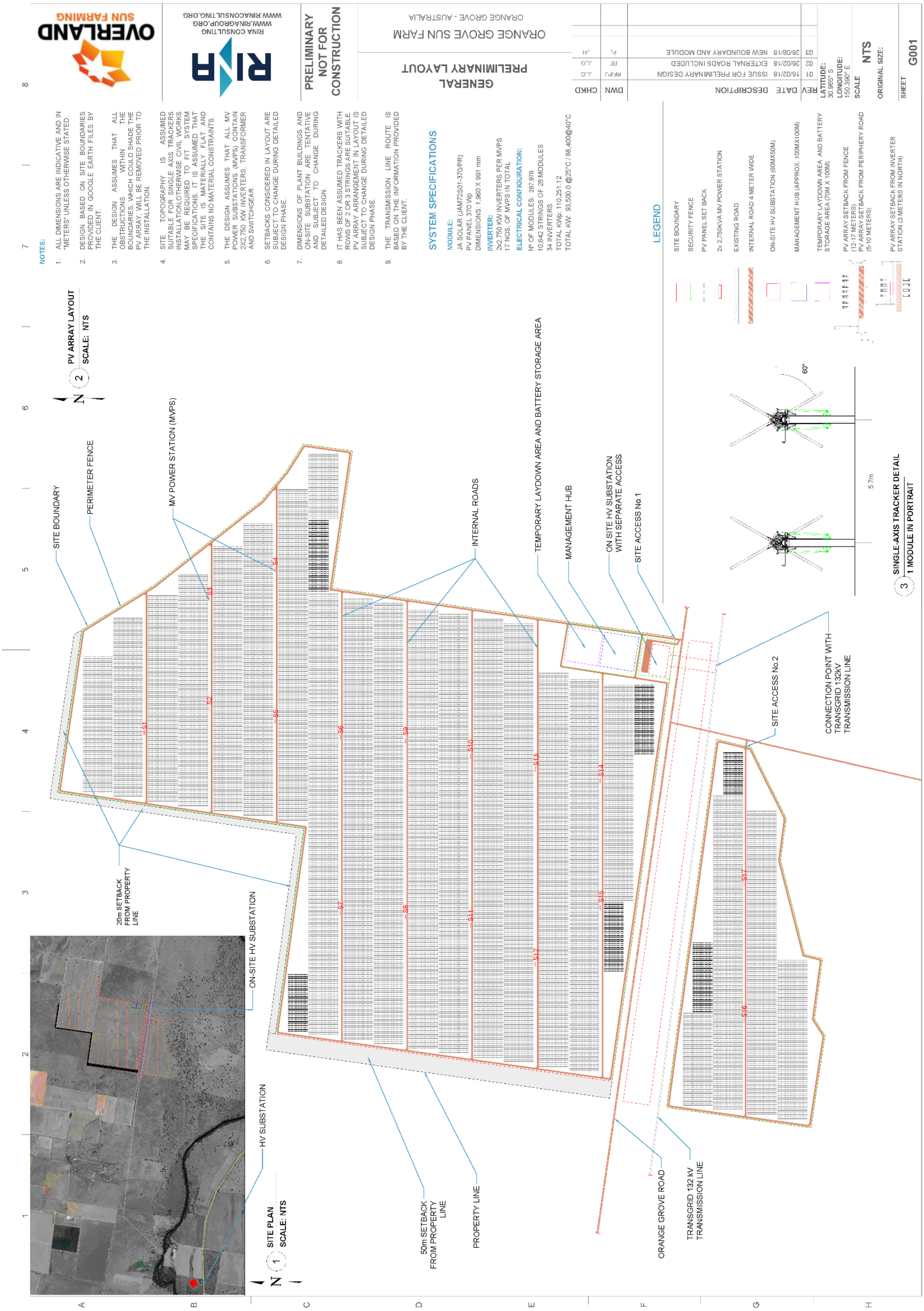
Based upon the glare analysis, preliminary risk assessment, and with consideration of the assumptions outlined herein, the risk of glint and glare related impacts being experienced by either residential receptors, gun club patrons or motorists travelling along Orange Grove Road in close proximity to the project is considered nil due to the following factors and findings:

- Reflectivity associated with photovoltaic cells is typically less than commonly found objects within the surrounding area (e.g. motor vehicles, steel roofing, water);
- The above qualitative findings are reinforced by the quantitative assessment undertaken using ForgeSolar assessment tool which indicates that, for all the assessed observation points there is nil glare or glint experienced at any time throughout the year.
- The comparative quantitative finding indicates that using PV cells on a tracking device, as well as applying an anti-reflective coating, eliminates the potential of glare on the observational points.

Although 'nil' glare was calculated from any of the observational points, it cannot be ruled out that infrastructure associated with the solar farm has the potential to create glint or glare.

Mitigation in the form of screening vegetation has already been committed to along the western boundary of the northern area as shown in Figure 2-1 on page 7. As 'no glare' is expected as summarised above, the vegetative screen is likely to limit the views of the proposed solar farm from the closest receptors.

APPENDIX A: PRELIMINARY SITE LAYOUT



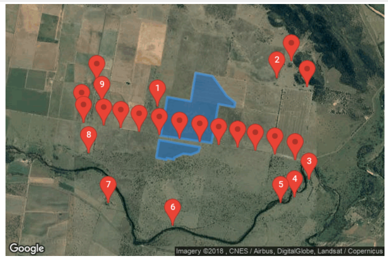
APPENDIX B: GLARE ANALYSIS RESULTS – PROPOSED COMPONENTS

![ForgeSolar PV planning & glare analysis]

GlareGauge Glare Analysis Results

Site Configuration: Orange Grove - 1

Project site configuration details and results.



Created **Oct. 31, 2018 8:50 p.m.**
Updated **Nov. 13, 2018 7:26 p.m.**
DNI **varies** and peaks at **1,000.0 W/m^2**
Analyze every **1** minute(s)
0.5 ocular transmission coefficient
0.002 m pupil diameter
0.017 m eye focal length
9.3 mrad sun subtended angle
Timezone **UTC10**
Site Configuration ID: 22343.3871

Summary of Results No glare predicted!

PV name	Tilt deg	Orientation deg	"Green" Glare min	"Yellow" Glare min	Energy Produced kWh
PV array 1	SA tracking	SA tracking	0	0	-
PV array 2	SA tracking	SA tracking	0	0	1,121.0

Component Data

PV Array(s)

Warning: This PV array encompasses a large surface area. This may reduce the accuracy of certain calculations if receptors are near the array. These calculations utilize the PV footprint centroid, rather than the glare-spot location, due to analysis method limitations. Additional analyses of array sub-sections may provide more information on expected glare. (Note that the subtended source angle is limited by the footprint surface area.)

Name: PV array 1
Description: southern field
Axis tracking: Single-axis rotation
Tracking axis orientation: 0.0 deg
Tracking axis tilt: 0.0 deg
Tracking axis panel offset: 0.0 deg
Maximum tracking angle: 60.0 deg
Resting angle: 60.0 deg
Rated power: -
Panel material: Smooth glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 8.43 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	-30.969125	150.382347	274.04	1.20	275.24
2	-30.970817	150.393462	275.00	1.20	276.20
3	-30.971848	150.393075	274.03	1.20	275.23
4	-30.972547	150.391015	276.14	1.20	277.34
5	-30.972326	150.388955	275.58	1.20	276.78
6	-30.973283	150.386466	275.65	1.20	276.85
7	-30.973724	150.386338	277.22	1.20	278.42
8	-30.973356	150.384449	273.57	1.20	274.77
9	-30.973761	150.384278	274.60	1.20	275.80
10	-30.973246	150.381574	273.94	1.20	275.14

Warning: This PV array encompasses a large surface area. This may reduce the accuracy of certain calculations if receptors are near the array. These calculations utilize the PV footprint centroid, rather than the glare-spot location, due to analysis method limitations. Additional analyses of array sub-sections may provide more information on expected glare. (Note that the subtended source angle is limited by the footprint surface area.)

Name: PV array 2
Description: northern site area
Axis tracking: Single-axis rotation
Tracking axis orientation: 0.0 deg
Tracking axis tilt: 0.0 deg
Tracking axis panel offset: 0.0 deg
Maximum tracking angle: 60.0 deg
Resting angle: 60.0 deg
Rated power: 0.35 kW
Panel material: Smooth glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 8.43 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	-30.969824	150.396594	276.97	1.20	278.17
2	-30.960734	150.398483	277.49	1.20	278.69
3	-30.961434	150.402817	279.98	1.20	281.18
4	-30.960403	150.403032	278.24	1.20	279.44
5	-30.958821	150.400714	276.96	1.20	278.16
6	-30.954220	150.396895	276.00	1.20	277.20
7	-30.953447	150.392260	275.39	1.20	276.59
8	-30.960072	150.390973	275.37	1.20	276.57
9	-30.959078	150.384578	273.01	1.20	274.21
10	-30.968094	150.382776	274.35	1.20	275.55

Discrete Observation Receptors

Number	Latitude	Longitude	Ground elevation	Height above ground	Total Elevation
	deg	deg	m	m	m
OP 1	-30.961484	150.381994	274.95	1.20	276.15
OP 2	-30.954811	150.414391	281.41	1.20	282.61
OP 3	-30.978543	150.423177	281.89	1.20	283.09
OP 4	-30.982591	150.419229	279.29	1.20	280.49
OP 5	-30.984003	150.415404	281.59	1.20	282.79
OP 6	-30.989277	150.386045	276.82	1.20	278.02
OP 7	-30.983927	150.368505	275.98	1.20	277.18
OP 8	-30.972321	150.363321	274.55	1.20	275.75
OP 9	-30.960480	150.366885	274.22	1.20	275.42
OP 10	-30.955652	150.365438	272.89	1.20	274.09
OP 11	-30.962494	150.361358	272.36	1.20	273.56
OP 12	-30.956897	150.422740	287.98	1.20	289.18
OP 13	-30.950790	150.418453	308.00	1.50	309.50
OP 14	-30.965193	150.361840	271.46	1.50	272.96
OP 15	-30.965856	150.367334	273.70	1.50	275.20
OP 16	-30.966371	150.371968	272.11	1.50	273.61
OP 17	-30.967328	150.377032	274.85	1.50	276.35
OP 18	-30.967990	150.382526	273.84	1.50	275.34
OP 19	-30.968873	150.388019	274.87	1.50	276.37
OP 20	-30.969683	150.393426	275.13	1.50	276.63
OP 21	-30.970345	150.398662	277.16	1.50	278.66
OP 22	-30.971008	150.403726	277.80	1.50	279.30
OP 23	-30.971743	150.408618	276.56	1.50	278.06
OP 24	-30.972627	150.413854	277.60	1.50	279.10
OP 25	-30.973963	150.419424	279.92	1.50	281.42

PV Array Results

PV array 1

Warning: This PV array encompasses a large surface area. This may reduce the accuracy of certain calculations if receptors are near the array. These calculations utilize the PV footprint centroid, rather than the glare-spot location, due to analysis method limitations. Additional analyses of array sub-sections may provide more information on expected glare. (Note that the subtended source angle is limited by the footprint surface area.)

×

Component	Green glare (min)	Yellow glare (min)
OP: OP 1	0	0
OP: OP 2	0	0
OP: OP 3	0	0
OP: OP 4	0	0
OP: OP 5	0	0
OP: OP 6	0	0
OP: OP 7	0	0
OP: OP 8	0	0
OP: OP 9	0	0
OP: OP 10	0	0
OP: OP 11	0	0
OP: OP 12	0	0
OP: OP 13	0	0
OP: OP 14	0	0
OP: OP 15	0	0
OP: OP 16	0	0
OP: OP 17	0	0
OP: OP 18	0	0
OP: OP 19	0	0
OP: OP 20	0	0
OP: OP 21	0	0
OP: OP 22	0	0
OP: OP 23	0	0
OP: OP 24	0	0
OP: OP 25	0	0

PV array 2

Warning: This PV array encompasses a large surface area. This may reduce the accuracy of certain calculations if receptors are near the array. These calculations utilize the PV footprint centroid, rather than the glare-spot location, due to analysis method limitations. Additional analyses of array sub-sections may provide more information on expected glare. (Note that the subtended source angle is limited by the footprint surface area.)

×

Predicted energy output: 1,121.0 kWh (assuming sunny, clear skies)

Component	Green glare (min)	Yellow glare (min)
OP: OP 1	0	0
OP: OP 2	0	0
OP: OP 3	0	0
OP: OP 4	0	0
OP: OP 5	0	0
OP: OP 6	0	0
OP: OP 7	0	0
OP: OP 8	0	0
OP: OP 9	0	0
OP: OP 10	0	0
OP: OP 11	0	0
OP: OP 12	0	0
OP: OP 13	0	0
OP: OP 14	0	0
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OP: OP 16	0	0
OP: OP 17	0	0
OP: OP 18	0	0
OP: OP 19	0	0
OP: OP 20	0	0
OP: OP 21	0	0
OP: OP 22	0	0
OP: OP 23	0	0
OP: OP 24	0	0
OP: OP 25	0	0

Assumptions

- Times associated with glare are denoted in Standard time. For Daylight Savings, add one hour.
- Glare analyses do not account for physical obstructions between reflectors and receptors. This includes buildings, tree cover and geographic obstructions.
- Detailed system geometry is not rigorously simulated.
- The glare hazard determination relies on several approximations including observer eye characteristics, angle of view, and typical blink response time. Actual values and results may vary.
- Several calculations utilize the PV array centroid, rather than the actual glare spot location, due to algorithm limitations. This may affect results for large PV footprints. Additional analyses of array sub-sections can provide additional information on expected glare.
- The subtended source angle (glare spot size) is constrained by the PV array footprint size. Partitioning large arrays into smaller sections will reduce the maximum potential subtended angle, potentially impacting results if actual glare spots are larger than the sub-array size. Additional analyses of the combined area of adjacent sub-arrays can provide more information on potential glare hazards. (See previous point on related limitations.)
- Hazard zone boundaries shown in the Glare Hazard plot are an approximation and visual aid. Actual ocular impact outcomes encompass a continuous, not discrete, spectrum.
- Glare locations displayed on receptor plots are approximate. Actual glare-spot locations may differ.
- Glare vector plots are simplified representations of analysis data. Actual glare emanations and results may differ.
- Refer to the **User's Manual** for assumptions and limitations not listed here.