Vipac Engineers and Scientists Limited
3 Sir Thomas Mitchell Road, Chester Hill, NSW 2162, Australia

t. +61 2 9422 4222 | **f.** +61 2 9420 5911 | **e.** sydney@vipac.com.au
w. www.vipac.com.au | A.B.N. 33 005 453 627 | A.C.N. 005 453 627

Vipac Engineers & Scientists

Southern Sustainable Electric Pty Ltd

Benalla Solar Farm
Lot 331 Sydney Road Benalla Vic
Glint & Glare Assessment Report

20E-20-0019-TRP-6772920-0

2020-02-10

Glint & Glare Assessment Report Job Title:		
DOCUMENT NO: 20E-20-0019-TRP-6772920-0 **PREPARED FOR:** **Error! Reference source not found.** Level 1 135 Fryers Street Shepparton, Victoria, 3630, Australia **CONTACT:** Gary Steigenberger **Tel:** +61 3 5820 770 **Fax:**	**REPORT CODE:** TRP **PREPARED BY:** Vipac Engineers and Scientists Limited Office Address 3 Sir Thomas Mitchell Road, Chester Hill, NSW 2162, **Tel:** +61 2 9422 4222 **Fax**: +61 2 9420 5911	
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1 EXECUTIVE SUMMARY

Vipac Engineers & Scientists Ltd (Vipac) has been commissioned to carry out a Glint & Glare Assessment report for Benalla Solar Farm at Lot 331 Sydney Road Benalla Vic.

The proposed design is for a low rise (less than 1.2 m high) fixed array of solar panels across a flat terrain site with perimeter fence/hedge, and associated power transmission equipment. The solar farm consists of approximately 10,240 solar panels.

This report is considered a preliminary Stage 1 assessment, suitable for design evaluation of potential reflection hazards as defined and evaluated in the scope of this report only.

Summary of the findings

The design as presented represents an acceptable level of reflectivity and the authors suggest that the design will perform without an adverse disposition to its environs in consideration of solar reflection and glare as described in this report.

A summary of the key findings is shown in the following Table.

SUMMARY OF KEY FINDINGS			
Areas of Interest	**FINDINGS PER TIME PERIOD** (AEST – not daylight savings time)		
	MID WINTER	EQUINOX	SUMMER
ALL AREAS A – residence B – Sydney Road C – Benalla Airport (on Ground)	**NONE**	**NONE**	**NONE**
Within Site Boundary	1600 Minor local incidence within confines of site **No Hazard**	1700 Minor local incidence within confines of site **No Hazard**	0600 Minor local incidence within confines of site **No Hazard**

Conclusion:

Given the design documentation and assumption of Flat Terrain, the solar farm does not present any reflectance and thus no incidence of glare hazard for surrounding environment, specific to road users and residential lots.

It is advised the recommendations pertaining in this report form part of the design procurement process.

For full analysis please refer to Appendices A and B of this report.

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1 METHODOLOGY

This report examines the reflectivity of sunlight from the proposed design under normal sunlight conditions with consideration of the physical geometry and material selection inherent in the design.

The glare analysis typically can form a number of interrelated protocols (or Stages of Analysis) for reviewing and defining the reflectivity that may be experiences.

Stage 1 Heat Map Analysis looks at the distribution of where reflections will occur and reviews a number of critical factors - duration, saturation or density and the position. In situations in which it may be considered that these factors may not present significant potential adverse impacts a conclusion may be reached at this stage.

Stage 2 Glare Analysis looks at specific locations as determined in stage 1 and evaluates the reflection in respect to veiling luminance and glare hazard. Often the most important factor will be pedestrian and vehicle hazard analysis, to which a number of analysis techniques such as Photomontage, Car Windscreen Protractor and Luminance Calculation will be used to further determine if the reflection presents as a hazard.

3D Computer modelling is used to investigate the proposed design under a sunlight system based on real life data, to which sun position, size and intensity are controlled by an IES (Illuminating Engineering Society) certified daylight system.

The findings of the report are based extensively on the data analysis contained within this report.
The review and analysis protocols of this report are based on the work of Mr David Hassall, University of NSW, and the de- facto industry standard book "Dealing with Rogue Solar Reflections", Hassall 1991.

For full analysis please refer to Appendices A and B of this report.

2 ASSESSMENT

2.1 LOCATION

The project is located on a clear open site that presents as open grass paddock from aerial images. From discussions with the client it has been assumed that the terrain and surrounds should be considered as “Flat Terrain” and no slope or contour profiles have been modelled in the design. From preliminary setup it has been determined that this assumption is suitable up to approximately a 1:8 slope profile .

Traffic axis around the site is from one local road to the South.

A residence is located to the West approximately 370m away from the nearest solar panels.

Benalla Airport is located 2.3km away in a South West direction. Some discussion will include the likely approach axis directions to this airport.

Trees and other structures have not been modelled in this analysis as these will have a reducing influence over any sources of reflectance. This report is therefore presenting a worst case scenario.

2.2 PROPOSED DEVELOPMENT

The proposed design is for fixed angle solar panel array on clear field site.

The solar panel array consists of pairs of solar panels tilted at 8° towards East and West to form a ridge. This pair is then arrayed in regular spacing to form a module, which then is arrayed to form the entire site design as per the Concept drawings. From the drawings a working height of 1.2 m high has been established for the solar panels above Natural Ground.

Ancillary structures have been considered to be of neutral reflectance and modelled according to site plan.

Figure 1: 3D rendered image of the proposed solar panel array

The main components of reflectance from the design comprises the solar panel Photovoltaic cell tilted at an angle of 8° in an East or West direction. The Solar Panel cell is modelled as a solid high gloss black reflectance, which is then artificially interpreted as a RED colour for visual clarity.

The high gloss surface has been attributed values similar to solid glass type with standard optical glass values (reflection, refraction and transmission). The specific material values of the solar panel surface qualities have not been investigated in this preliminary Stage 1 assessment as the “generic” high gloss glass like surface is considered to produce very similar or worst case scenario reflectance. It carries the recommendation if areas of concern for reflectance are found then additional investigation and modelling of the glass surface or panel surface will be required to determine the actual energy (glare and veiling intensity) of the reflectance in question.

The design calls for a perimeter fence (2.1m high), to which the concept drawings indicate a 2m high hedge planting. From consultation with the clients it is determined that the nature and detail of this fence and hedge design is suitable for revision if reflectance or other controls deem suitable. For this instance the fence is modelled as a solid structure (ie taking into consideration the potential for hedge planting) however is only modelled at a height of 1.4m.

2.3 INPUT DATA

Data	Classification	Source / Details
Design files	Proposed Design and surrounding context	SSE, Layout and Concept Drawings, Revision V5.1 Dated Jan 2020
Environs	Limited survey (Site Plan) , Aerial Image	As provided by PDF from client
Scientific Methodology	Analysis protocols and methodology	Hassall 1991

2.4 AREAS OF INTEREST

Areas of interest include the road, airport (flight paths) and local residences. Whilst pedestrian traffic may be considered unlikely, all forms of use of these transport corridors have been included up to a height plane of 2.5m above the road surface. The Benalla airport will be discussed in an overall capacity, noting that a specific FAA Airport analysis (SGHAT) can be carried out if required.

Refer to the Figure below and a higher resolution version is available in the Appendix B of this report.

Figure 2: Areas of Interest Map.

2.4.1 AREA A – RESIDENCE

Local neighbouring residence.

2.4.2 AREA B – SYDNEY ROAD

East – West direction of travel. The solar array is below the height of the perimeter fence, with the panels' setback from the road, as such reflectance from the panels cannot intersect the roadway. This includes a calculated height tolerance of at least 2m above the surface of the road – and thus self-shielding of all road users.

Figure 3 - Sydney Road – Adjacent to Site (Google Maps)

2.4.3 AREA C – BENALLA AIRPORT

A specific FAA Approved airport reflectivity report, using a SGHAT style analysis, is beyond the commissioned scope of this report, however the general discussion with respect to relative location and geometry will enable an understanding of any potential considerations to pilots line of vision on approach and departure to Benalla Airport.

Based on the anticipated traffic into this airport and the distance from the Solar Array, it is the opinion of this report that the FAA – SGHAT style report may not be necessary and that this preliminary stage 1 assessment should be sufficient.

The Benalla Airport has only been reviewed based from aerial images, with an indicative direction of flightpaths drawn based on runways visible. Generally the concern for pilots with regard to reflectivity from ground based sources is during final approach. With the location of 2.3km away to the NNE, the solar array will only be of consideration on final approach when using the North South (approx.) runway.
In take-off the pilot's line of sight is towards the sky, and the nose up orientation shields very quickly any ground based reflections.

Likewise the East West flight paths aligning to this runway orientation, will see any potential reflection from the solar array entering the side of the cockpit, and thus not directly interfering with the line of sight of the pilot. Consideration of veiling glare (as discussed in greater detail in this report) should not be of significance – primarily as pilots and cockpits are more attuned to potential reflectance from the Sun itself, and thus secondary lower intensity potential reflectance from the solar array will be negligible.

As such the only consideration is likely to be from an aircraft on final approach from the North as it passes by the solar array to the East. Final approach path trajectory (as defined as 2 miles from 50 feet above landing threshold using a standard 3° degree glide path) has not been calculated.

2.5 OUTCOMES

The solar farm generally has very low incidence of reflectance that intersect with the surrounding environs, and has no recorded incidence of reflectance when considering the key areas of interest.

A summary of the key findings is shown in the following Table.

SUMMARY OF KEY FINDINGS			
Areas of Interest	**FINDINGS PER TIME PERIOD** (AEST – not daylight savings time)		
	MID WINTER	EQUINOX	SUMMER
ALL AREAS **A – residence** **B – Sydney Road** **C – Benalla Airport (on Ground)**	**NONE**	**NONE**	**NONE**
Within Site Boundary	1600 Minor local incidence within confines of site **No Hazard**	1700 Minor local incidence within confines of site **No Hazard**	0600 Minor local incidence within confines of site **No Hazard**

Areas of interest that show any potential interaction with reflections are limited to those shown in the above table.

2.5.1 ALL AREAS (A, B, C & WITHIN SITE BOUNDARIES)

GENERAL COMMENTS ACROSS ALL TIME PERIODS

At no times has the area of the road (or verge) been subjected to potential reflectance illumination from the solar panels.

Low Risk Hazard

GENERAL RECOMMENDATIONS

A 1.6m high fence of solid opaque transmittance has been shown in the modelling. There may present certain site irregularities or construction methods that may result in solar panels orientated at a greater angle of 8°. To safe guard against any possible reflectance from these irregularities an optional recommendation of maintaining the proposed screen /fence design of 2.1m tall is considered appropriate.

2.5.2 STAGE 1 – BENALLA AIRPORT

The Stage 1 assessment has not shown any reflectance carried across the Benalla Airport. This shows that ground users are not going to experience any reflectance from the solar array. For Pilots in the air, this stage 1 assessment is limited.

Using angle of reflections from the solar panels, and direction of flight paths, only one area of the flight path is of any consideration.
The Northern Final Approach is the only area in which reflectance may intersect from mid-morning sun angles reflecting from the solar array. The geometry of the final flight path has not been analysed. (Final Approach Path as defined as 2 miles from 50 feet above landing threshold using a standard 3° degree glide path.)

It is likely that if reflectance was carried from the solar panels, then it would be of a very short duration, from the side of the cockpit, and thus would only present in the worst case situation as a brief veiling glare. Further this situation would be limited to approximately less than 1 hour a day.

This is considered to be a low risk, based on the likely lower intensity of the reflected light, the brief area of exposure and the direction away from the Pilot's direct line of sight and finally the very brief duration (a few seconds as the plane passes through the distance equivalent to the width of the solar panel at approach landing speed).

Further, pilots landing in regional airports are likely to be experienced in dealing with similar potential glare hazards such as lakes and dams which can present greater reflectance areas and intensity than the solar panel arrays in this proposal.

2.5.3 RECOMMENDATIONS

2.5.3.1 PERIMETER FENCE

To enable a greater tolerance in angle and solar panel placement (to safe guard against installation and or maintenance alignment) the maintaining of the proposed screen /fence design of 1.8m tall is considered appropriate , with a full height mature canopy of trees providing a suitably opaque shield. For clarity this report has modelled such fence at only 1.6m high only, with no adverse implications, but it stands as this reports recommendation to maintain the 1.8m tall fence/hedge as per the design documentation.

2.5.3.2 INTERNAL AREAS

A secondary recommendation relates to the possible incidence of glare hazard within the confines of the site boundary – and particularly with pedestrian egress near and above the horizontal plane of the solar panel array. In such circumstances it should be considered a requirement for suitable work place operations to warn and prepare OH&S operations to protect against likely and significant glare hazard. The nature, extent and presence of this glare hazard is beyond the scope of this report, however it should be considered in context with the design applicants site procedures.

2.5.3.3 FLIGHT PATH – SGHAT ASSESSMENT

This scope of this report has not included advanced Solar Glare Hazard Analysis Tool (SGHAT) assessment as required by the FAA when considering solar arrays in close proximity to significant airports in the USA and as adopted as a defacto standard when reviewing reflectivity in airports in other countries, including Australia.

The only perceived possible interaction of reflected light from the solar array intersecting the Northern Final Approach Flight Path is during mid-morning sun angles. As discussed these will likely have a very limited duration and will be very unlikely to present as a glare hazard.

Nevertheless, this report must draw attention to the advanced review capabilities available in the SGHAT analysis when providing more definitive glare review to this flight path.

Given the information and scope of this report, there is no findings that recommend the conducting of further analysis using the SGHAT. The SGHAT advanced assessment is not recommended at this stage.

3 CONCLUSION

In consideration of all items of key findings, this report has not found reason for further Stage 2 analysis to be conducted. The possibility of glare hazard is very low, and no evidence of possible reflectivity issues have been found when considering the use of the road networks and residential lots in proximity to the site.

Given the design documentation and assumption of Flat Terrain, the solar farm does not present any reflectance and thus no incidence of glare hazard for surrounding environment, specific to road users and residential lots.

It is advised the recommendations pertaining to the interior glare mitigation and the perimeter fence in this report form part of the design procurement process.

For full analysis please refer to Appendices A and B of this report.

4 DISCLAIMER

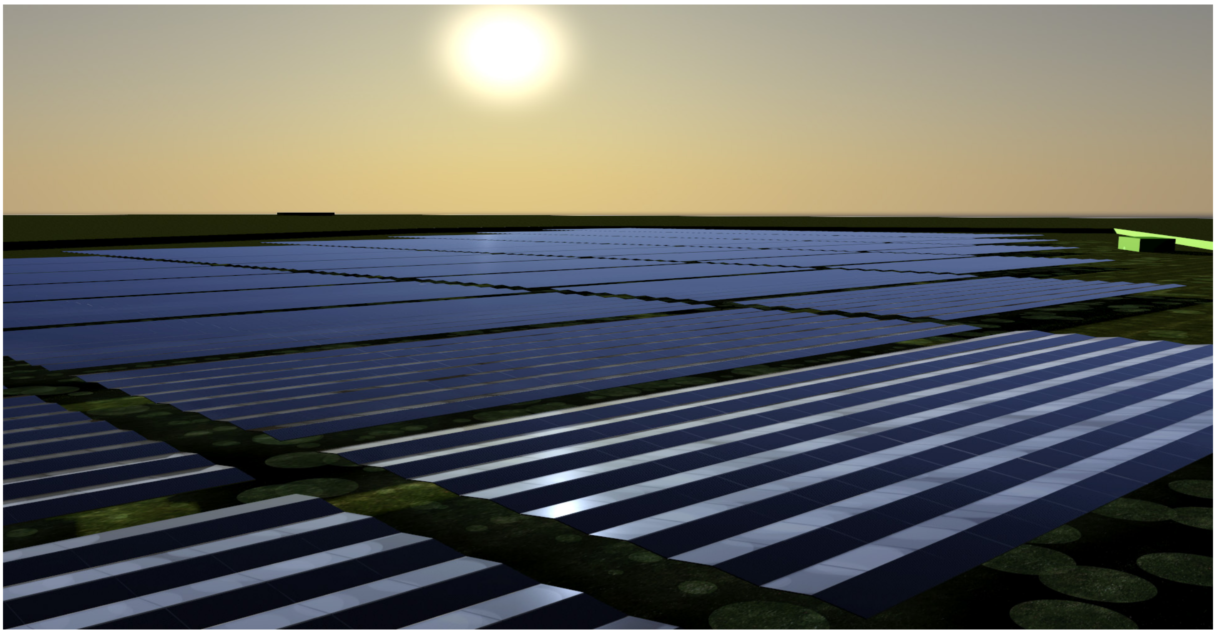
This report is prepared using the information described above and inputs from other consultants. Whilst Vipac has endeavoured to ensure the information used is accurate, no responsibility or liability to any third party is accepted for any loss or damage arising out of the use of this report by any third party. Any third party wishing to act upon any material contained in this report should first contact Vipac for detailed advice which will take into account that party's particular requirements. This revision of the report includes a review of the nominated design updates and not a full re-assessment.

Computer performance assessment provides an estimate of building performance. This estimate is based on a necessarily simplified and idealised version of the building that does not and cannot fully represent all the intricacies of the building once built. As a result, simulation results only represent an interpretation of the potential performance of the building. No guarantee of the performance in practice can be based on simulation results alone. Vipac and its employees and agents shall not be liable for any loss arising because of, any person using or relying on the Report and whether caused by reason or error, negligent act or omission in the report. This report and recommendations are based on the data to hand and form a considered opinion in the context of the entirety of this report as a whole. The authors reserve the right to retract these recommendations if additional information or design changes are fore coming that contravene or supplement the set of information this report is based on.

APPENDIX A – DETAILED REFLECTIVITY ANALYSIS

REPORT : RA169701

REFLECTIVITY ANALYSIS - STAGE 1



PROPOSED SOLAR FARM

BENALLA SOLAR FARM
Lot 331 Sydney Road
Benalla

VERSION 01 Prepared 02/2020
By Deneb Design

PO Box 539 MonaVale NSW 1660 T 02 9997 7480
info@denebdesign.com.au www.denebdesign.com.au
Nominated Architect: Cameron McFadzean # 8750NSW

ABSTRACT

This assessment report is for provision of a Glint and Glare Assessment (Reflectivity Analysis) for the proposed design of the Solar Farm (Fixed Array) at Benalla in country Victoria. .
The proposed design is for a low rise (less than 1.2 m high) fixed array of solar panels across a flat terrain site with perimeter fence/hedge, and associated power transmission equipment. The solar farm consists of approximately 10,240 solar panels.

This report is considered a preliminary STAGE 1 assessment, suitable for design evaluation of potential reflection hazards as defined and evaluated in the scope of this report only.

The design as presented represents an acceptable level of reflectivity and the authors suggest that the design will perform without an adverse disposition to its environs in consideration of solar reflection and glare as described in this report.

ANALYSIS DETAILS FOR REFLECTIVITY ANALYSIS		
Project Details	BENALLA SOLAR FARM. As detailed in PDF Drawing – Rev V5.1 supplementary set provided by VIPAC Engineers & Scientists Lt ,6 Feb 2020 – by ACE ENERGY.	
Applicable for ANNEXURE	RA169701	
Issue	Version 01	
Dated	07.02.2020	
ACCURACY DETAILS	**DATA**	**TOLERANCE**
Topography and Site	Layo ut and Concept Drawings, (Ref G.2 and6-000846) dated 06.11.18	
Proposed Design		+/- 300mm X and Y Flat Terrain assumed
REFLECTIVITY METHOD – STAGE 1	RAY TRACED – (Mental Ray Caustics Engine)	
Ray Tracing (Caustics)	3D Max – Mental Ray	1m field, 40000 photon,
Lighting	IES certified Sun only	Latitude and Longitude daylight system, clear sky , clear horizon AEST (Australian Eastern Standard Time) not Daylight savings time adjusted.
Source	Solar Panel – assumed highest reflectance properties .	Index of Refraction IOR – Fresnel curve – Standard Glass 1.5

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1.0 Introduction

This report will examine the reflectivity of sunlight from the proposed design under normal sunlight conditions with consideration of the physical geometry and material selection of the Solar Panels in array as outlined in the concept drawings. The reflectivity analysis typically can form a number of inter related protocols (or Stages of Analysis) for reviewing and defining the reflectivity that may be experiences.

Stage 1 Heat Map Analysis looks at the distribution of where reflections will occur and reviews a number of critical factors - duration, saturation or density and the position. In situations in which it may be considered that these factors may not present significant potential adverse impacts a conclusion may be reached at this stage.

Stage 2 Glare Analysis looks at specific locations as determined in stage 1 and evaluates the reflection in respect to veiling luminance and glare hazard. Often the most important factor will be pedestrian and vehicle hazard analysis, to which a number of analysis techniques such as Photomontage,, Car Windscreen Protractor and Luminance Calculation will be used to further determine if the reflection presents as a hazard.

3D Computer modelling is used to investigate the proposed design under a sunlight system based on real life data, to which sun position, size and intensity are controlled by a IES (Illuminating Engineering Society) certified daylight system.
The findings of the report are based extensively on the data analysis contained within this report.

The review and analysis protocols of this report are based on the work of Mr David Hassall, University of NSW, and the de-facto industry standard book "Dealing with Rogue Solar Reflections", Hassall 1991.

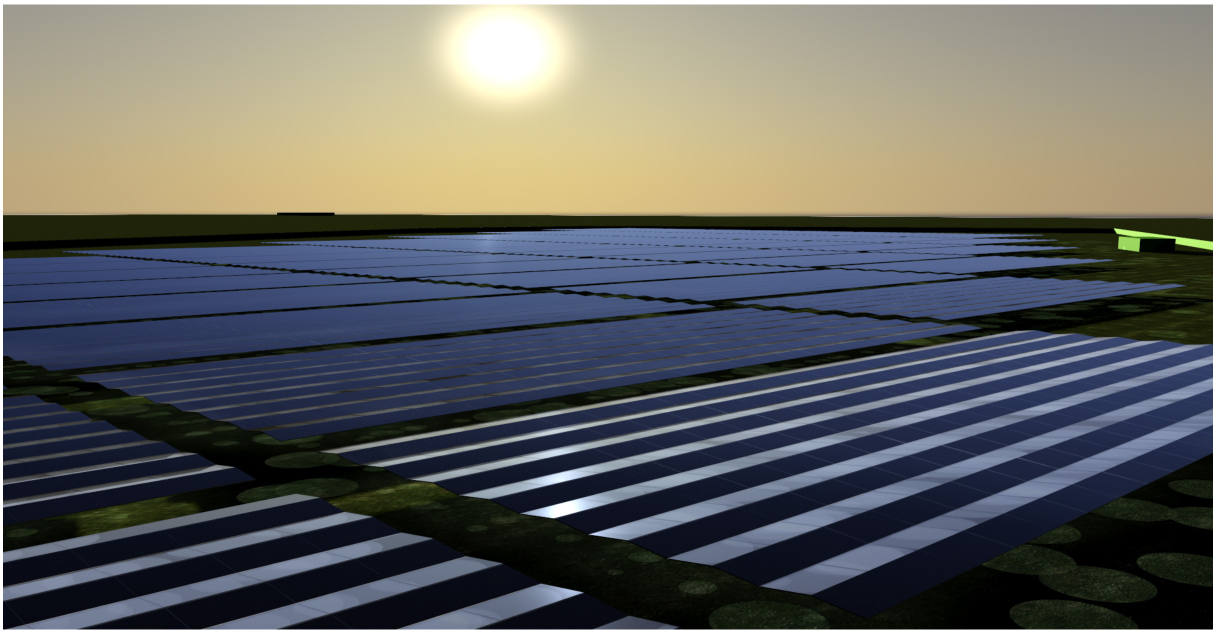
1.1 Project

1.1.1 Overview and Design

The proposed design is for fixed angle solar panel array on clear field site.

The solar panel array consists of pairs of solar panels tilted at 8° towards East and West to form a ridge. This pair is then arrayed in regular spacing to form a module, which then is arrayed to form the entire site design as per the Concept drawings. From the drawings a working height of 1.2 m high has been established for the solar panels above Natural Ground. Ancillary structures have been considered to be of neutral reflectance and modelled according to site plan.

Fig 1.1.2 3D rendered image of the proposed solar panel array



The main components of reflectance from the design comprises the solar panel Photovoltaic cell tilted at an angle of 8° in a East or West direction. The Solar Panel cell is modelled as a solid high gloss black reflectance, which is then artificially interpreted as a RED colour for visual clarity.
The high gloss surface has been attributed values similar to solid glass type with standard optical glass values (reflection, refraction and transmission). The specific material values of the solar panel surface qualities have not been investigated in this preliminary Stage 1 assessment as the "generic" high gloss glass like surface is considered to produce very similar or worst case scenario reflectance. It carries the recommendation if areas of concern for reflectance are found then additional investigation and modelling of the glass surface or panel surface will be required to determine the actual energy (glare and veiling intensity) of the reflectance in question.

The design calls for a perimeter fence (2.1m high), to which the concept drawings indicate a 2m high hedge planting. From consultation with the clients it is determined that the nature and detail of this fence and hedge design is suitable for revision if reflectance or other controls deem suitable. For this instance the fence is modelled as a solid structure (ie taking into consideration the potential for hedge planting) however is only modelled at a height of 1.4m .

1.2 Site Location

1.2.1 Location and Environs

The project is located on a clear open site that presents as open grass paddock from aerial images. From discussions with the client it has been assumed that the terrain and surrounds should be considered as "Flat Terrain" and no slope or contour profiles have been modelled in the design. From preliminary setup it has been determined that this assumption is suitable up to approximately a 1:8 slope profile .

Traffic axis around the site is from one local road to the South.
A residence is located to the West approximately 370m away from the nearest solar panels.
Benalla Airport is located 2.3km away in a South West direction. Some discussion will include the likely approach axis directions to this airport.

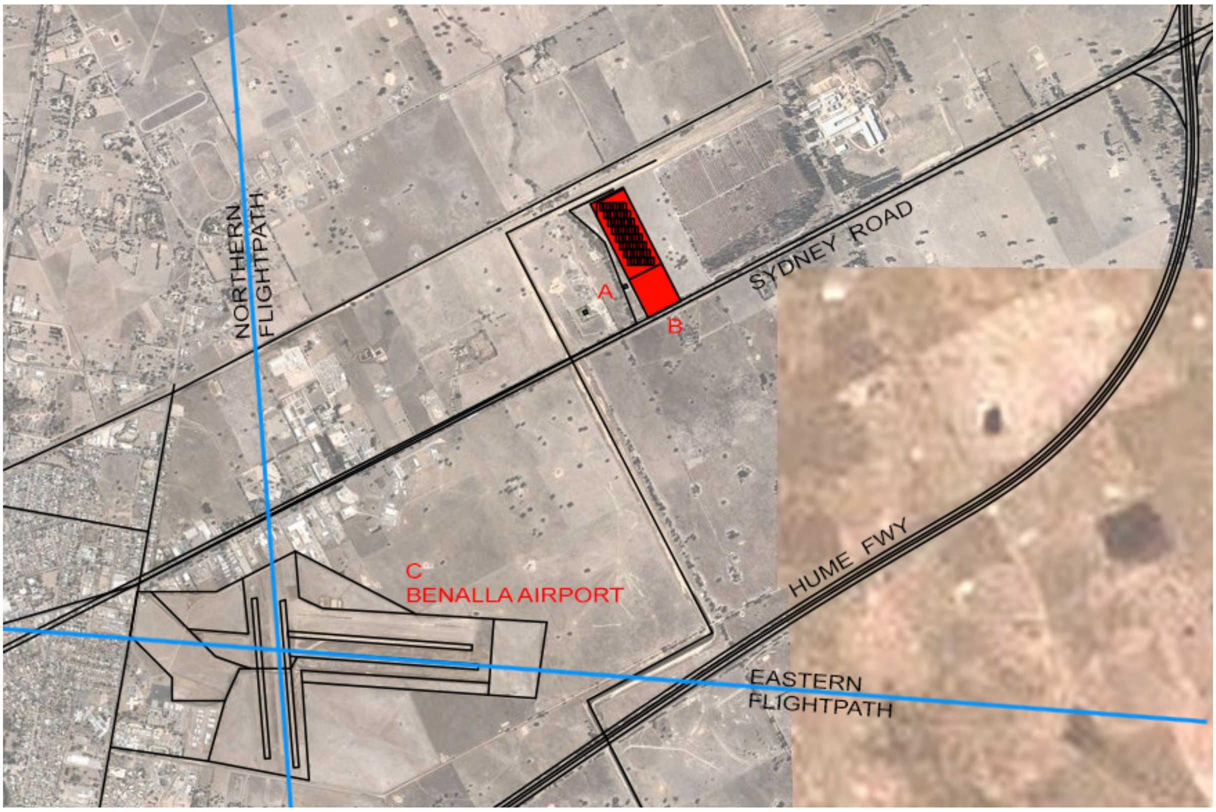
Trees and other structures have not been modelled in this analysis as these will have a reducing influence over any sources of reflectance. This report is therefore presenting a worst case scenario.

1.2.2 Areas of Interest

Areas of interest include the road, airport (flight paths) and local residences. Whilst pedestrian traffic may be considered unlikely , all forms of use of these transport corridors have been included up to a height plane of 2.5m above the road surface. The Benalla airport will be discussed in an overall capacity, noting that a specific FAA Airport analysis (SGHAT) can be carried out if required.

Refer to the Figure below and a higher resolution version is available in the Annexure 7.0 RA169701 File.

Fig 1.2.1 Areas of Interest Map .



AREA A – Residence
Local neighbouring residence .

AREA B – Sydney Road
East – West direction of travel. The solar array is below the height of the perimeter fence, with the panels setback from the road, as such reflectance from the panels cannot intersect the roadway. This includes a calculated height tolerance of at least 2m above the surface of the road – and thus self-shielding of all road users.

Fig 1.2.2 Sydney Road – Adjacent to Site (Google Maps)

AREA C – Benalla Airport
Refer to following section.

INTERNAL AREAS –
Considering the relative autonomous nature of the Solar Farm, the incidence of glare hazard within the confines of the site boundary have not been considered as an indicator of area of key interest, although the presence of such reflectance may promote other work safe practices when entering the site (beyond the scope of this report).

1.2.3 Benalla Airport

A specific FAA Approved airport reflectivity report , using a SGHAT style analysis, is beyond the commissioned scope of this report, however the general discussion with respect to relative location and geometry will enable an understanding of any potential considerations to pilots line of vision on approach and departure to Benalla Airport.
Based on the anticipated traffic into this airport and the distance from the Solar Array, it is the opinion of this report that the FAA – SGHAT style report may not be necessary and that this preliminary stage 1 assessment should be sufficient.

The Benalla Airport has only been reviewed based from aerial images, with a indicative direction of flightpaths drawn based on runways visible. Generally the concern for pilots with regard to reflectivity from ground based sources is during final approach. With the location of 2.3km away to the NNE , the solar array will only be of consideration on final approach when using the North South (approx.) runway.
In take-off the pilot's line of sight is towards the sky, and the nose up orientation shields very quickly any ground based reflections.
Likewise the East West flight paths aligning to this runway orientation , will see any potential reflection from the solar array entering the side of the cockpit, and thus not directly interfering with the line of sight of the pilot. Consideration of veiling glare (as discussed in greater detail in this report) should not be of significance – primarily as pilots and cockpits are more attuned to potential reflectance from the Sun itself, and thus secondary lower intensity potential reflectance from the solar array will be negligible.
As such the only consideration is likely to be from an aircraft on final approach from the North as it passes by the solar array to the East. Final approach path trajectory (as defined as 2 miles from 50 feet above landing threshold using a standard 3° degree glide path) has not been calculated.

1.3 Scope

Deneb Design has been engaged to provide preliminary assessment using Stage 1 methodology to provide a reflectivity report with indicative recommendations as required. Information used in the analysis of the reflectivity is listed in the following table and the capacity of this report and any recommendations is limited to the scope of service , and does not constitute a interdisciplinary design or planning service. For instance the recommendation of street planting to assist with reflectivity mitigation is solely a recommendation based on the reflectivity scope and not a landscaping, planning or design decision.

Data	Classification	Source / Details
Commission of Report	Defining of scope of service – Horizontal Reflectivity assessment	Vipac Engineers – Feb 2020
Design files	Proposed Design and surrounding context	Layout and Concept Drawings, Revision V5.1 Dated Jan 2020
Environs	Limited survey (Site Plan) , Aerial Image	As provided by PDF from client
Scientific Methodology	Analysis protocols and methodology	Hassall 1991

2.0 Reflectivity

2.1 Glare and Reflection

2.1.1 Overview

Importance of Reflection Analysis

Human vision is highly subjective and understandably highly valued and critical to the conduct of our lives. Situations may arise in which vision is adversely impacted. The strobing of a artificial light, or spotlight , or more naturally the sunrise all are situations in which human vision is impaired at that particular time. Mitigation of the impact often involves looking away or shielding. Glare and Reflection in the context of this report are situations in which there is a presence of potentially vision impairment circumstances. The likelihood of these situations causing a hazardous situation is dependent on factors such as the person's ability to look away, shield, or the intensity or duration of the light source.
This report will briefly outline some of the considerations and conduct a review of reflection generated light from the sun.

Glare

Glare is considered to be the presence of strong and disconcerting light, often dazzling or disorientating. It is often perceived differently due to individual's preference, lighting conditions, activity being undertaken, intensity and colour, movement of light (ie strobing), angle of incidence (direction and height), exposure (ie sunglasses, windscreen). As levels of luminance increase to an amount that the eye can no longer discern differences in contrast between objects, adequate lighting becomes too bright and glare phenomena now exists.
Three classifications of glare can be considered:

1. Sensory Overload – luminance values are greater than the eye's ability to process
2. Optical Degradation – Veiling glare, in which the contrast of the view is reduced to degrade the quality of the image
3. Psychological - Discomfort Glare – can be a combination or part therefore of the above two conditions

The first two classes of glare can be considered as disability glare.
Refer to the Human Vision section for Glare in the human eye.

Reflection

Reflection is the reflected light from a surface, having a direct relationship to the angle of incidence, and the physical properties of the material , including the reflective and specular properties – such that diffuse surfaces , like a rendered matt painted white wall can have a reflectance of 80% but scatters the light in all directions leading to a reflection luminance of less than 2 Cd/cm2, and is considered to be highly diffuse. Glass on the other hand , being glossy and reflective, does not scatter light but rather reflects a high percentage and is considered specular.

A building is often made up of various materials of different reflective characteristics. It is the interaction of the diffuse nature at the surface which has the most significant impact on the reflective energy or luminous intensity (Cd/m2) which is of concern for this report. Parts of a building , typically Glass, can create a "virtual second sun" such that the reflected sun can present significant intensity to present eyesight impairment.

The human eye operates between 1 and 2 Cd/cm2, whilst the sun's luminance ranges from 600 Cd/cm2 near horizon (sunrise / sunset) to over 150,000 Cd/cm2 at noon.

Clear glass has a reflectance of around 8% measured at normal (90°) , thus can reflect from 46 Cd/cm2 to over 12,000 Cd/cm2 depending on time of day. Thus at any given time of day, sun reflected from glass has the potential to exceed the capabilities of the human eye and thus cause vision impairment.

2.1.2 Sun

The sun follows a known solar trajectory and can be plotted in a number of ways. In building design resources such as "Sunlight and Shade" by CSIRO's Ralph Phillips provide solar protractors to determine sun position – Altitude and Azimuth.

This report uses the extensive computer algorithm known as the IES Daylight system embedded into the Autodesk software 3D Max, using the Ray tracing of the "Mental Ray" processing. This is a certified Internationale Engineering Society algorithm that determines the position of the sun, intensity of the sun, sky vault luminance and atmospheric conditions (Cloudy, Clear Sky) and provides a computer simulation of the sun and sky as an interrelated daylight system.
The location of the proposed design is determined by Latitude and Longitude and a daylight system is created in which any time of day, time of year is available.
The scope of this report is to examine direct beam solar radiation, and as such only the Sun's direct rays are used in analysis, discounting the diffuse and reflected radiation from other sources (including geography, built environment, atmosphere).
The sky itself contributes from 1000 Cd/m2 (away from the sun in a dark patch of blue sky), up to around 30, 000 Cd/m2 nearer the sun circle. The effects of the sky-vault have been removed from the calculation of solar reflectance, as the impacts of sky-vault generally reduce the potential glare and veiling effects that we are investigating – ie we are looking at worse case scenario with high contrast conditions.

Precise values of the sun's illumination can be provided however as a guide, from Hopkinson et al 1966:

Sun Altitude	Illumination (Lux)
5°	12,900
15°	56,800
30°	86,800
50° +	100,000 +

Azimuth and Altitude angles of the sun path can be provided as required or can often be found in the Annexure report.

2.1.3 Human Vision

The human eye's normal conditions operate in a luminance of 1 to 2 cd/cm2. *(Hassall 1991)*
Any light source that exceeds this luminance will cause vision impairment, with the intensity (luminance) of the source and duration being factors. A concept known as Veiling Glare can also impinge human vision, in which a bright light source is not directly shining into the retina of the eye but surrounding areas of the eye, which then scatter the bright light causing vision impairment. This is often the case when reflective glass is used. The eye can be actively shielded from bright light by way of normal activity – for instance not looking up at the bright sun, casting vision aside or down during sunrise, or protective measures such as sunglasses, windscreen shades, hand shielding and so on. Of importance are situations in which it is likely the human eye's vision will be impaired due to a set of conditions that render these normal activity's impractical. For instance when stopped at traffic lights, the driver is obligated to look towards the traffic signal, and cannot selectively lower their vision.

Glare

A value of 500 Cd/m2 as calculated by the Holladay formula *(Hassall 1991) (refer to methodology section)* is considered as a practical limit to the amount of reflected solar glare a driver should be exposed to.

As discussed the activity required also becomes a factor in consideration of thresholds for the determination of reflective interference. The surrounding environs, and time of day and weather all have an influence on this threshold value – ie the point at which a reflection becomes a problem.

Visual Acuity is the eye's ability to distinguish four key factors

1. Size
2. Luminance – Brightness is a subjective evaluation of luminance
3. Contrast – the difference in luminance of an object against a background
4. Time

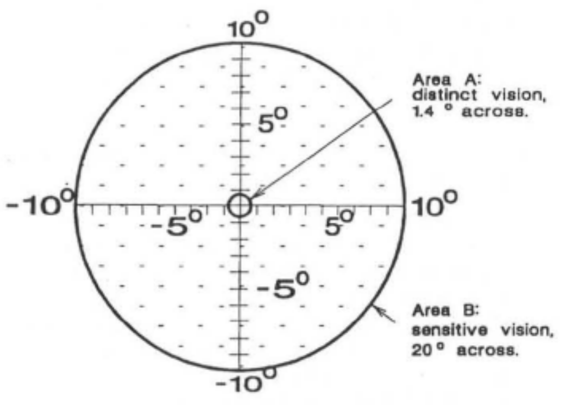
Items 2 and 3 contribute to form the classifications of Glare as discussed in previous section, whilst "time" considers the physiological response and recovery of the eye as it adapts to different luminance levels.
The Traffic Authority of NSW *(Hassall 1991)* quotes

> "It is important to note that the effects of glare on visual efficiency do not cease at the instant that glare ceases

to enter the eyes - there is a recovery period which may be several seconds in the case of sun glare (Dobrash and Saur 1952). Sensitivity to glare and the amount of time it takes the visual system to recover after glare ceases to enter the eyes are both affected by a number of factors such as age of the individual, their health, and whether certain drugs have been taken
(Moser and lind 1980) - including alcohol (Banchevska 1981)" (Hassall 1991)

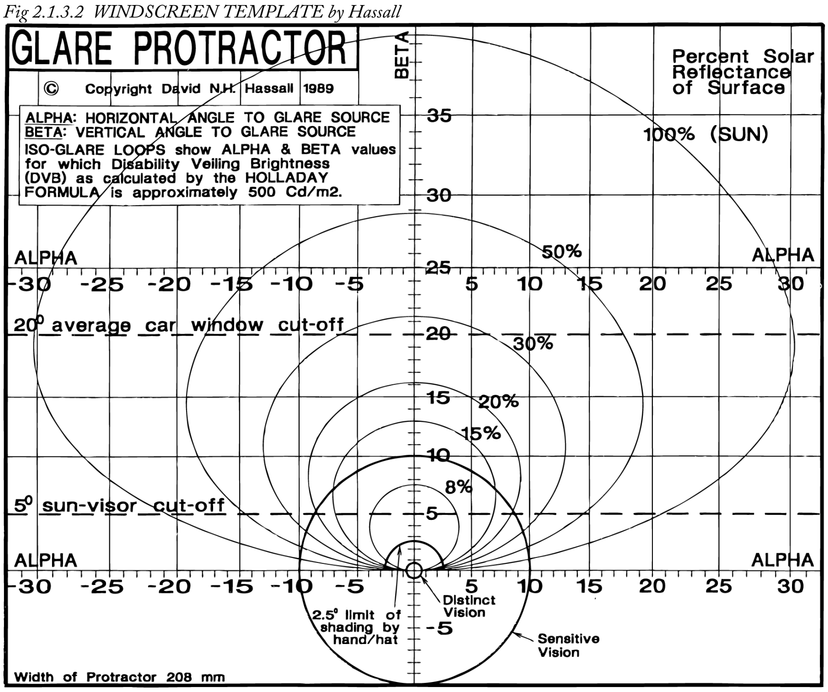
Field of View

PEDESTRIAN:
The field of view can be influenced by the activity such as pedestrians using the range of binocular vision as determined by Helms.
Showing the "Stationary" Human eyes field of view and the areas of key importance.
Area A is the most sensitive part of the vision , the foveal vision in which light focuses on the fovea aspect of the retina.
Area B is the area of sensitive vision, beyond this field movement but not colour can be distinguished.
Fig 2.1.3.1 HUMAN FIELD OF VIEW by HELMS



VEHICLE FIELD OF VIEW:
The measurements as described by Schreuder, using 95% of vehicles measured produces a field of vision template that can be used to provide CUT OFF values to the pedestrian field of view, to account for windscreen design and even sun visor design.

Fig 2.1.3.2 WINDSCREEN TEMPLATE by Hassall



2.1.4 Glass

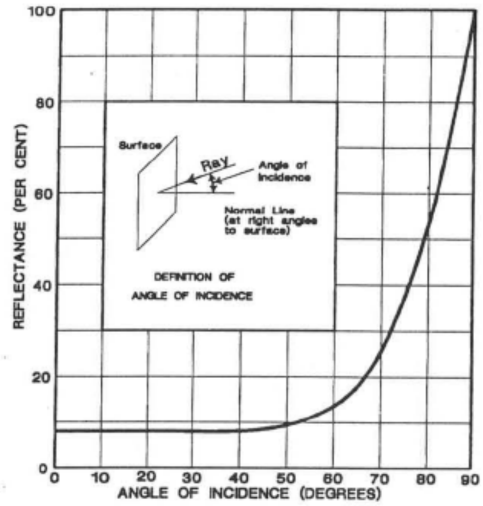
Highly reflective materials used in buildings present the most interest when analysing reflectivity concerns. Whilst polished metal and highly polished materials like stone , ceramic etc, may present glossy surfaces that contribute to reflectivity , by and large the most important consideration is the location and areas of glazing, type of glazing and the sun's path to the glazed areas (ie shade systems).

Glass properties consists of Absorptance (a), Transmittance (t) and Reflectance (r) given as

$$a + r + t = 1$$

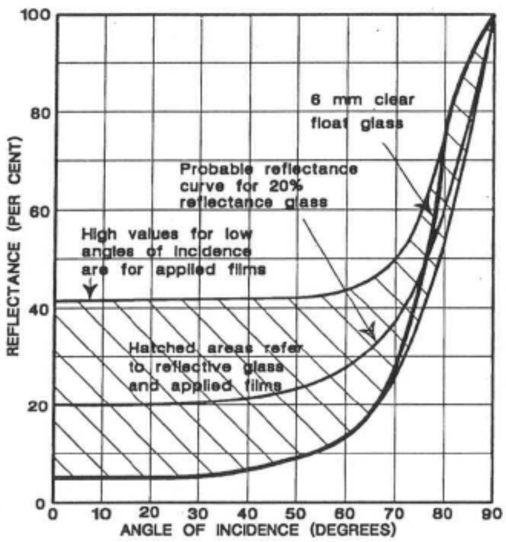
The value of Reflectance is greatly influenced by the angle the light beam strikes the surface, ranging from 8 % at 0° incidence angle, to over 50% at 80°.

Fig 2.1.4.1 Angle of Incidence of Standard Clear Glass



Glass systems use the above formulae to balance the Absorptance and Transmittance and Reflectance to modify the visual and thermal properties. As the graph below suggests, most glass treatments have greatest impact when the angle of incidence is low (ie at 90° to the surface) and as the angle increases the reflective properties of most glass tends to become highly reflective.

Fig 2.1.4.2 Reflectance for different types of Glass - Hassall



2.2 Reflectivity Analysis

The Methodology used to assess a building design is provided in the following section. It should be noted that not all stages of assessment may be required to form recommendations, and that it is common for Stage 1 assessments to be conducted only.
The assessment protocol requires a sequential process from Stage 1 to 2 and 3.

2.2.1 STAGE 1 Reflectivity Heat Map

STAGE 1 assessment uses the ray tracing capability of 3D MAX (Autodesk) to trace back reflected light rays (known as photons in the software) to determine the location and intensity of reflected light from a light source. The material characteristics of the surface are physically accurate, such that Glass and rendered painted surfaces each take on the correct physical attributes in respect to reflectance, diffuse scattering, IOR (Index of Refraction – for transparent materials) and colour.
For a given time , the IES Sunlight shoots photons towards the target surface and ray tracing algorithm traces these reflections and captures them on the return – typically on the surrounding terrain plane or neighbouring buildings.
Colour coding may be employed to provide visual ability to assess various components of the design – ie a typical situation is a high rise tower may be colour coded per level, in order to determine the impact of various heights, OR colour coding of various orientations or types of windows in order to better understand the propagation of reflections according to the design.

Some post processing for the addition of graphics, overlay of aerial images, points of interest or amalgamation of time sequences may be present in a Stage 1 Heat Map.

The process of computer rendering requires some settings in order to produce suitable images – such as:

1. Resolution of Image (pixel count)
2. Rays traced (photons) typically 10 – 50 000 rays are produced for the sun light source
3. Filter size of Rays – this is essentially the allocation of ray to a surface area – ie rather than showing as a small pin prick the size of the ray is magnified, typically to be 1 – 5 m diameter.
4. Exposure – similar to photographic exposure the image produced requires a dynamic range that crops the light values. Exposure generally adjusts to provide neutral results across the day – suitable that bright reflected light rays remain visible. As such it is typical for the exposure of white surfaces to be rendered grey.
5. Colour rendition – as mentioned colour coding is used to indicate areas of interest, and the influence of the colour temperature and its ability to influence light quality is not in consideration for this section of the analysis.
6. 3D Modelling – the 3D data – ie the physical geometry of the design and the environs influences the analysis – in particular it is often that landscaping and trees are not included in the analysis due to the variation in representation of this information. For instance a generic tree may have significantly different foliage and height to what actually is specified , and the industry may not necessary appreciate the relationship between landscape plan, reflectance analysis and on site planting.
7. IES Daylight system requires suitable Latitude and Longitude and True North.

Stage 1 Heat Maps show areas in which reflected light will be located. They therefore represent the first stage in determining the impact of reflections and glare hazard by locating specific areas of concern or interest that may require further investigation.

They enable a relatively comprehensive review of the entire 3D design in numerous time periods throughout the year. Typically Mid Winter and Equinox daylight hours are the most common analysis periods.

Stage 1 Heat Maps cannot determine the existence of GLARE HAZARDS, but merely suggest the location and time in which to conduct further reviews of reflectivity.

Fig 2.2.1 Sample of Heat Map

2.2.2 STAGE 2 Detail Review – Calculation of Glare Hazard

Upon review of Stage 1 analysis, specific locations around the site may require more detailed investigation. Likely situations occur in which one or more of the following situations occur:

1. Location of reflection is on a significant position – such as a traffic intersection
2. Duration of reflection is such that a Glare Hazard may be of significance
3. Intensity of reflection is such that a Glare Hazard may occur

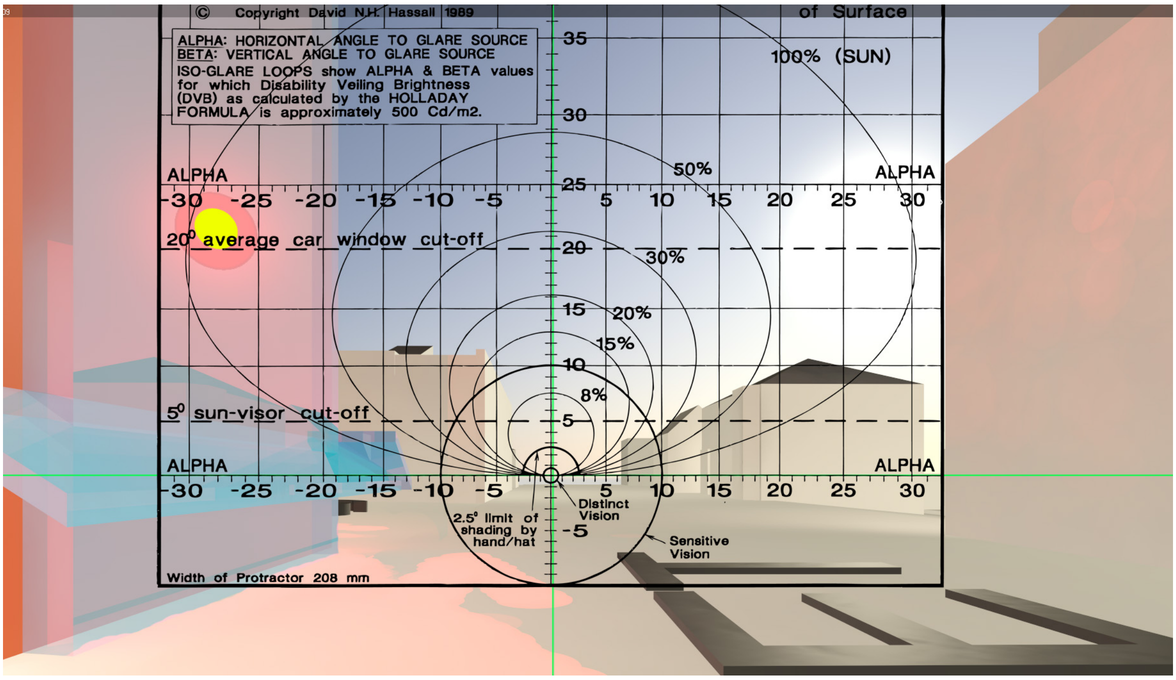
Depending on the design and scope of service, as well as the specific locations required for further review several methods may be used to answer the question:

"How much Reflection constitutes a glare, and how much Glare is too much"?

2.2.2.1 GLARE PHOTOMONTAGE

To determine the presence of GLARE, the intensity and position relative to the field of view of the activity and the contrast are required to be calculated. The following workflow determines the analysis of the glare:
Deneb Design almost exclusively use the Photomontage Method. A digital image (computer render of the proposed view – proposed design and environs) and OR a photomontage (refer to Deneb Design Photomontage certification – if applicable) is aligned with the HASSALL GLARE PROTRACTOR and the reflected virtual sun is plotted. Reading of the values from the protractor will determine the existence of potential glare and if required a glare intensity (Veiling Glare) table calculation is run to determine if the intensity threshold constitutes a Glare Hazard.

Fig 2.2.2.1 Sample of Glare Photomontage (Digital Image)



2.2.2.2 VEILING GLARE

Upon review of the location of the reflection using the above method of Glare Photomontage the next step is to determine the intensity of the Glare to determine if it is to be considered a disability glare. The following workflow can be used but more often the Veiling Luminance can be calculated from spreadsheet which is an electronic version of Hassall Veiling Glare Calculations.

1. Holladay Formula for Calculating Glare. Provides a numerical table for interpreting flat plane surfaces and applying first principles to determine glare intensity. using Hassall section 5.1.
2. Illumination value from the sun, using Hassall section 5.2 considering the luminance efficiency of the sun for a given altitude, and the angle of incidence to the reflecting surface. Angle relative to the human viewing position is referred to in Section 5.3 Hassall.
3. Veiling Luminance – to determine if the value of glare luminance is above the threshold of 500 Cd/m2 (the definition adopted to refer to the existence of GLARE).

If this method is applicable a reference to the formulae and worksheets will be made in the Appendix.

Fig 2.2.2.2 Sample of Veiling Glare Worksheet

CALCULATION OF GLARE									
Location		A1							
Month		Winter							
Time		900							
Façade Aspect Orientation	ASP	105	°	Degrees relative to Solar North					
View Line Bearing	BRG	348	°						
Sun Pos	AZI	42	°						
	ALT	19	°						
GLASS	Type	2	Class	1 CLEAR 2 20%Reflective 3 40 % Reflective (tint)					
Fraction of Façade that is reflective		1		Decimal number - 1 is 100% Glass					
Solar Power	W	635	W/m2	If Alt 0 - 10 then W = 50*ALT					
				If Alt 10-33 then W=500+(ALT-10)*15					
Luminous Efficacy	n	117	lm/W	If ALT<10 then n=90					
				If ALT 10 - 20 then n = 117					
Solar Illumination	E	74295	Lux	If ALT 20 - 30 then n = 125					
	Normal Beam								
Sun Position with Façade									
	H.S.A	-63	Degrees	Azi - ASP			Tan	Cos	
	V.SA	37.17838	Degrees	Atn(Tan ALT / Cos H.S.A)			0.344328	0.45399	
Angle of Incidence	I	65	Degrees	Atn(Sqr(Tan2 H.SA + Tan2 V.S.A)			3.85184	0.575241	
		60	Rounded						
Virtual Suns Position				VERTICAL ONLY					
Virtual Altitude	VALT	19	Degrees						
Virtual Azimuth	VAZI	-12	Degrees	ASP - H.S.A - 180					
Glare Position with Observer									
	ALPHA	-360		VAZI-BRG					
	BETA	19		VALT					
	THETA	19.0		ATAN(SQR(SIN2ALPHA + TAN2 BETA)) / COS ALPHA					
							SIN	TAN	COS
							6E-32	0.118562	1
REFLECTIVITY OF GLASS									
Look Up suitable Reflectance Curves for Glass			%		13	27	44		
Normal Incidence	RN	5	0.05	Angle of Inc	Clear Float	20% Reflec	Film Tint		
Reflectivity at Angle of Incidence	R	27	0.27	0	5	20	42		
				10	5	20	42		
				20	5	20	42		
				30	6	21	42		
				40	7	22	42		
				50	9	24	43		
				60	13	27	44		
				70	25	37	50		
				80	70	60	75		
				90	99	99	99		
Illumination at eye									
				Illumination at observers eye due to glare source in plane normal to Lin					
E.G		18966.77	LUX	EG = E*R%*F*COSTHETA					
				0.945519					
Equivalent VEILING LUMINANCE									
(Holladay Formula)		525	cd/m2	LV = 10*EG/THETA2					
Provisional Limit to VEILING LUMINANCE									
500	cd/m2	considered threshold		C					
Is Situation ACCEPTABLE	GLARE PRESENT								

2.2.3 STAGE 3 Design Iteration

Upon review of Stage 2 Calculations of Glare Hazards, design recommendations and various techniques such as but not limited to the following may be explored and therefore tested:

1. Reduction in glazing
2. Introduction of shading devices or other mechanisms to physically block the suns path into or from the point of reflectance
3. Reflectance of material adjustments – ie glass type.

The Stage 3 workflow generally forms a feedback loop in which recommendations are tested and reviewed in Stage 2 tests.

2.3 Generic Analysis

The following brief descriptions is based on the research by Hassall , and serves as a generic overview of conditions for designs based on their orientation.

NORTHERN ELEVATION
Drivers (whose line of vision is usually approximately horizontal) will not see solar reflections in the north facade unless the sun is very low in the sky in the east or the west in the winter half of the year.
At the low sun angles it is likely that the driver will already be aware of the sun itself and that the real sun and the virtual reflected sun will not be too far apart in the drivers vision – thus mitigating surprise and this should be considered as having a low impact. However it should be noted that at low angles a high angle of incidence occurs and that different glass types all approximately perform the same, exhibiting a high percentage reflectance.

The reflection in the northern elevation façade will show as a second virtual sun in the southern direction, opposite the actual sun. In summer the solar altitude is such that this will only be visible when looking upwards at the elevation in question. In Winter the lower sun altitude may make this more noticeable however it will be relatively weak
At low sun angles the same effects as experienced by the drivers will be applicable to the pedestrians.

Conclusion – Low hazard .

SOUTHERN ELEVATION
The reflected sun will only be visible in the low sun angles and as such the viewer will be already aware of the sun itself and the impact will be low and minor.

Conclusion – Low hazard .

EASTERN and WESTERN ELEVATIONS
Observers will experience the reflected sun approximately when travelling towards the target building at an angle of 30° to the East or West Elevation. Therefore any direction of travel North East away from the West elevation or South West away from the East Elevation will have no impact. Of consideration needs to be for the neighbouring environs which are likely to shield parts of the proposed design elevations from overshadowing.

Conclusion – Limited hazard opportunity specific to direction and alignment .

NORTH WEST and NORTH EAST ELEVATION
High likelihood of further analysis when travelling within 30° of **south** near **sunset** only. Otherwise no consideration.

SOUTH WEST and SOUTH EAST ELEVATION
High likelihood of further analysis when travelling within 30° of **north** near **sunrise** only. Otherwise no consideration.

3.0 ANALYSIS

3.1 STAGE 1 – ANNEXURE RA169701

Analysis is determined from the review of document RA169701 "Reflectivity Study" – which is a ray traced reflectivity study for specific time periods and date periods. A guide to understanding the graphical information presented as well as pertinent technical information is included in the annexed document. It is not this reports intention to replicate or substitute the information contained in the annexed document , but rather provide an analytical interpretation of the data and present findings.

Colour coding of specific areas of reflective materials has been undertaken in order to quantify the areas that cast the reflections for critique.

Several areas of interest have been selected in the environs to assist with classification and analysis of the reflection in respect to the suitability (if any) of glare / reflections, such as Traffic intersections , access corridors and residences.

Daylight hours have been assessed from early sunrise (typically around 10° altitude) to sunrise for three significant periods – being Mid Winter, Mid Summer and Equinox. This spread of time periods and hours will enable a sufficient sample size of integration to provide preliminary findings and determine if additional scope of service is advisable.

Key comments are provided in each time frame as required which will be further discussed in the following section.

3.2 STAGE 1 – FINDINGS

3.2.1 STAGE 1 – GENERAL

The solar farm generally has very low incidence of reflectance that intersect with the surrounding environs , and has no recorded incidence of reflectance when considering the key areas of interest.
A summary of the key findings is shown in the following Table.

Table 3.2 Summary of Key Findings

SUMMARY OF KEY FINDINGS			
Areas of Interest	FINDINGS PER TIME PERIOD (AEST – not daylight savings time)		
	MID WINTER	EQUINOX	SUMMER
ALL AREAS A – residence B – Sydney Road C – Benall Airport (on Ground)	NONE	NONE	NONE
Within Site Boundary	1600 Minor local incidence within confines of site No Hazard	1700 Minor local incidence within confines of site No Hazard	0600 Minor local incidence within confines of site No Hazard

Areas of interest that show any potential interaction with reflections are limited to those shown in the above table.

ALL AREAS

- General comments across all time periods.

At no times has the area of the road (or verge) been subjected to potential reflectance illumination from the solar panels.

LOW RISK HAZARD.

- Recommendations

A 1.6m high fence of solid opaque transmittance has been shown in the modelling. There may present certain site irregularities or construction methods that may result in solar panels orientated at a greater angle of 8°. To safe guard against any possible reflectance from these irregularities an optional recommendation of maintaining the proposed screen /fence design of 2.1m tall is considered appropriate.

3.2.2 STAGE 1 – BENALLA AIRPORT – FLIGHT PATH

The Stage 1 assessment has not shown any reflectance carried across the Benalla Airport. However, this shows that ground users are not going to experience any reflectance from the solar array. For Pilots in the air, this stage 1 assessment is limited.

Using angle of reflections from the solar panels, and direction of flight paths, only one area of the flight path is of any consideration.

The Northern Final Approach is the only area in which reflectance may intersect from mid morning sun angles reflecting from the solar array. The geometry of the final flight path has not been analysed. (Final Approach Path as defined as 2 miles from 50 feet above landing threshold using a standard 3° degree glide path.)

It is likely that if reflectance was carried from the solar panels, then it would be of a very short duration, from the side of the cockpit, and thus would only present in the worse case situation as a brief veiling glare. Further this situation would be limited to approximately less than 1 hour a day.

This is considered to be a low risk, based on the likely lower intensity of the reflected light, the brief area of exposure and the direction away from the Pilot's direct line of sight and finally the very brief duration (a few seconds as the plane passes through the distance equivalent to the width of the solar panel at approach landing speed).

Further, pilots landing in regional airports are likely to be experienced in dealing with similar potential glare hazards such as lakes and dams which can present greater reflectance areas and intensity than the solar panel arrays in this proposal.

3.3 STAGE 1 – CONCLUSION

In consideration of all items of key findings, this report has not found reason for further Stage 2 analysis to be conducted. The possibility of glare hazard is very low, and no evidence of possible reflectivity issues have been found when considering the use of the road networks and residential lots in proximity to the site.

4.0 RECOMMENDATIONS

4.1 Perimeter fence

To enable a greater tolerance in angle and solar panel placement (to safe guard against installation and or maintenance alignment) the maintaining of the proposed screen /fence design of 1.8m tall is considered appropriate , with a full height mature canopy of trees providing a suitably opaque shield. For clarity this report has modelled such fence at only 1.6m high only, with no adverse implications, but it stands as this reports recommendation to maintain the 1.8m tall fence/hedge as per the design documentation.

4.2 Internal Areas

A secondary recommendation relates to the possible incidence of glare hazard within the confines of the site boundary – and particularly with pedestrian egress near and above the horizontal plane of the solar panel array. In such circumstances it should be considered a requirement for suitable work place operations to warn and prepare OH&S operations to protect against likely and significant glare hazard. The nature, extent and presence of this glare hazard is beyond the scope of this report, however it should be considered in context with the design applicants site procedures.

4.3 Flight Path – SGHAT Assessment

This scope of this report has not included advanced Solar Glare Hazard Analysis Tool (SGHAT) assessment as required by the FAA when considering solar arrays in close proximity to significant airports in the USA and as adopted as a defacto standard when reviewing reflectivity in airports in other countries , including Australia.

The only perceived possible interaction of reflected light from the solar array intersecting the Northern Final Approach Flight Path is during mid morning sun angles. As discussed these will likely have a very limited duration and will be very unlikely to present as a glare hazard.

Nevertheless, this report must draw attention to the advanced review capabilities available in the SGHAT analysis when providing more definitive glare review to this flight path.

Given the information and scope of this report, there is no findings that recommend the conducting of further analysis using the SGHAT. The SGHAT advanced assessment is not recommended at this stage.

5.0 CONCLUSION

Given the design documentation and assumption of Flat Terrain , the solar farm does not present any reflectance and thus no incidence of glare hazard for surrounding environment, specific to road users and residential lots.
It is advised the recommendations pertaining to the interior glare mitigation and the perimeter fence in this report form part of the design procurement process.

6.0 REFERENCE

HASSALL 1991	REFLECTIVITY – Dealing with Rogue Solar Reflections David N H Hassall Faculty of Architecture, University of New South Wales 1991
FAA Solar Guide	"Technical Guidance for Evaluating Selected Solar Technologies on Airports" Federal Aviation Administration Office of Airport Planning and Programming Washington DC 20591 Version 1.1 April 2018
IES	Illuminating Engineers Society IESANZ Chapter Practice Notes 2001 – 2015 Membership – Associate "Deneb Design"
CIE 215	"Standard general Sky Guide" International Commission on Illumination 2014
CIE 139	"The Influence of Daylight and artificial light variations in humans." International Commission on Illumination 2001
CIE 112	"Glare evaluation system for use within outdoor sport and area lighting" International Commission on Illumination 1994
CIE 110	"Spatial distribution of daylight - Luminance distributions of various reference skies" International Commission on Illumination 1994
CIE 095	"Contrast and Visibility" International Commission on Illumination 1992
CIE 203	"A Computerized Approach to Transmission and Absorption Characteristics of the Human Eye" International Commission on Illumination 2012
SCHREUDER 1985	"The Visual Cut-Off Angle of Vehicle Windscreens" Lighting Research and Technology Vol 17 1985
HELMS 1980	"Illumination Engineering for Energy Efficient Luminou Environments" USA 1980 – from Hassall 1991
HOLLADAY 1927	"Action of Light Source in the Field of View in Lowering Visibility" USA 1927 – from Hassall 1991

7.0 ANNEXURE

RA169701_STAGE 1 ANALYSIS

REFER TO ANNEXURE 7.1 – STAGE 1 HEAT MAP – SEPARATE FILE (A3 Format)
Known as RA169701_STAGE 1 ANALYSIS

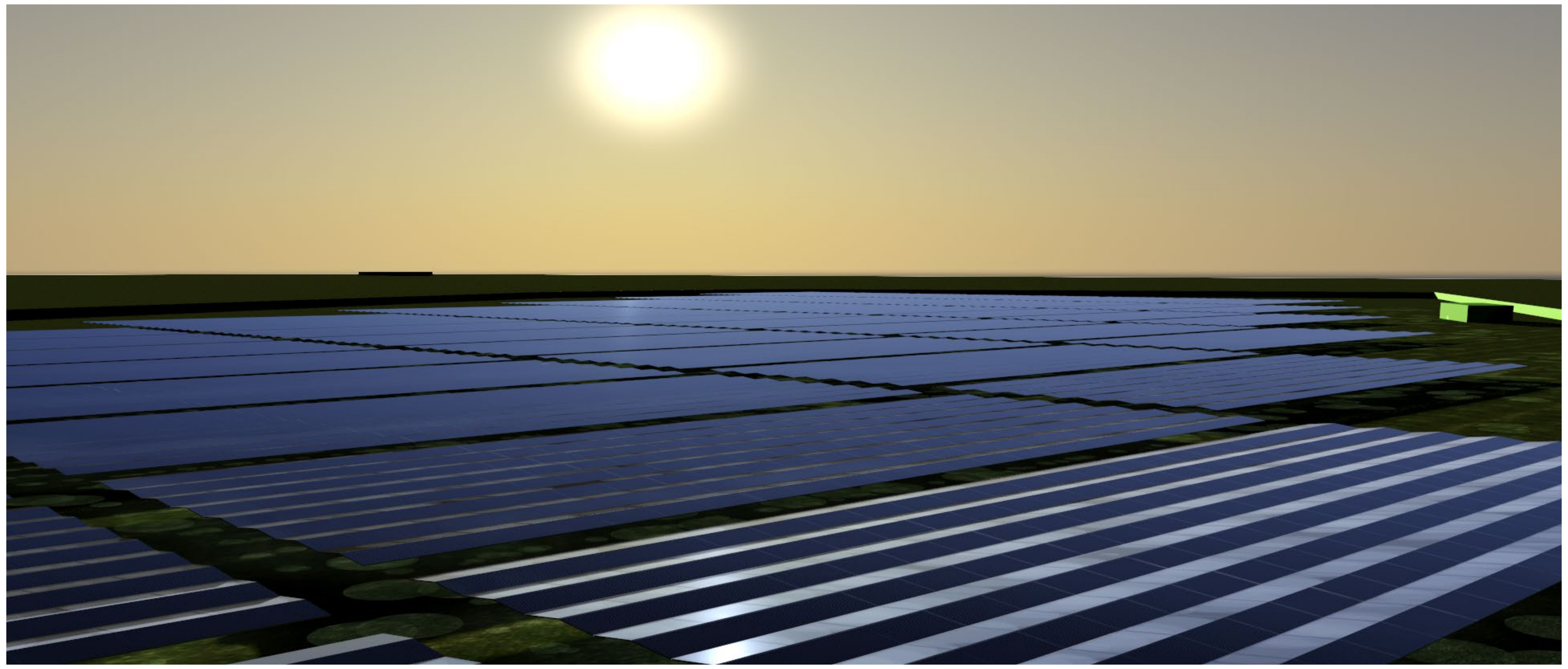
8.0 GLOSSARY

ABSORPTANCE	The ratio of the amount of energy that is absorbed at a surface compared to the total striking the surface.
ANGLE OF INCIDENCE	The angle of a ray striking the surface measured from a line perpendicular (90°) to the surface (ie the surface normal).
AZIMUTH	Direction of the sun in plan relative to True North
BRIGHTNESS	Subjective evaluation of surface luminosity or luminance
DIFFUSE REFLECTANCE	A form of reflection in which rays are scattered in all directions , such as a Matt Surface
LUMINANCE	The luminous flux or brightness of a surface, measured in candelas per square meter (Cd/m2)
NUISANCE GLARE	defined as glare that may be of distraction or cause mild discomfort and not present a significant disability or rendering a reduced capacity of normal vision .
REFLECTANCE	The ratio of the amount of energy striking a surface to the amount reflected
SPECULAR REFLECTANCE	A form of reflection in which the ray reflected is equal and opposite to the angle of incidence. Such as Glass or mirror.

APPENDIX B- RAY TRACED REFLECTIVITY MAPS & IMAGERY

REFLECTIVITY STUDY
RAY TRACED REFLECTIVITY

ANNEXURE TO
RA1696 REFLECTIVITY REPORT



CONTENTS

REFLECTIVITY STUDY
No : RA169601 - Refer to attached Report.

Architect: C McFadzean B Arch BA (Arch) IES ABSA AAAI
Member of IES (The Illuminating Engineers Society of Australia)

TITLE
REFLECTIVITY STUDY
RAY TRACED REFLECTIVITY

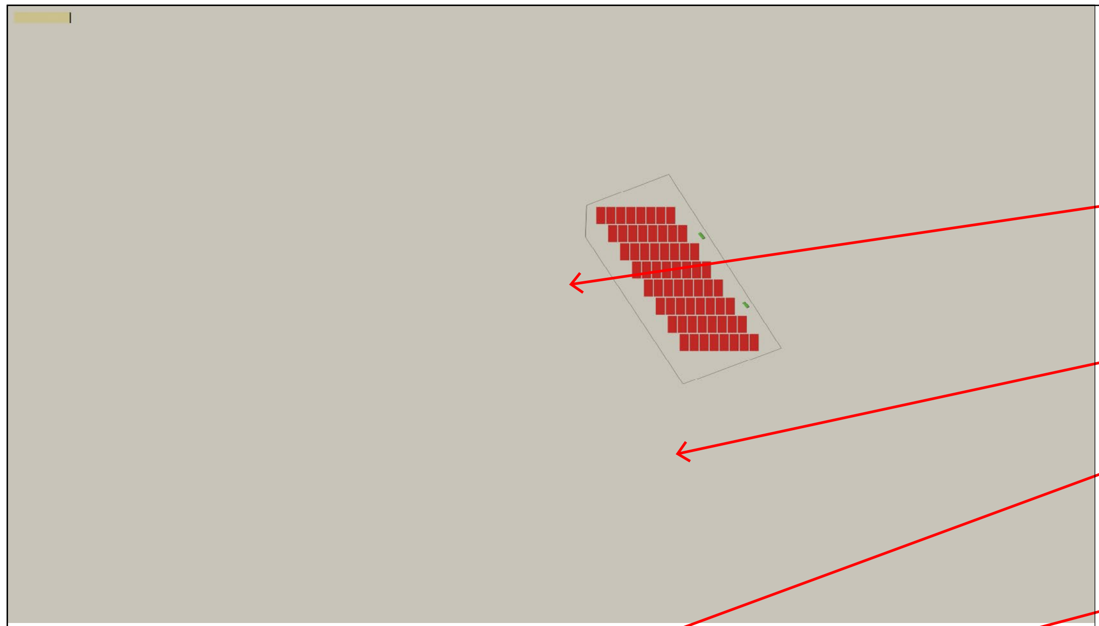
PROJECT
RAYWOOD SOLAR FARM
McQualters Rd
Raywood Vic 3570
(Lat 36.54° S , LONG 144.18°)

DATA SOURCE (In order of precedence)
- Layout and Concept Drawings, (Ref G.1000846) dated JAN 2020
- AEST TIME (Aust Eastern Standard Time - not daylight savings)

VIPAC Engineers & Scientists Lt
279 Normanby Rd, Port Melbourne 3207
Ph 0396479718

PAGE No : RA 01
SCALE : 1:8000 (A3)
DATE : 07.02.19
VERSION : 01
REF : 1696

3D SHADOW DIAGRAMS /
VISUALISATION + ANALYSIS
DENEB DESIGN
PO BOX 539 MONA VALE 1660
Ph 02 9997 7480 Fx 9940 0772
info@denebdesign.com.au
www.denebdesign.com.au



SAMPLE TIME SLOT - 1200 MID WINTER

1. Reflection zone over AREA C - Residential Housing - cast predominately from PODIUM Glass
2. Low duration scattered reflection to AREA A - Low time duration and alignment similar to actual Sun -pre adaptation to luminance.

HIGH RISK

HOW TO READ GUIDE

IMAGE - The image is a ray traced plot of light reflected from the surfaces selected (typically glass) . The Colour coding correlates to areas of glass that have been designated colour differentiation to assist in evaluation of reflection source

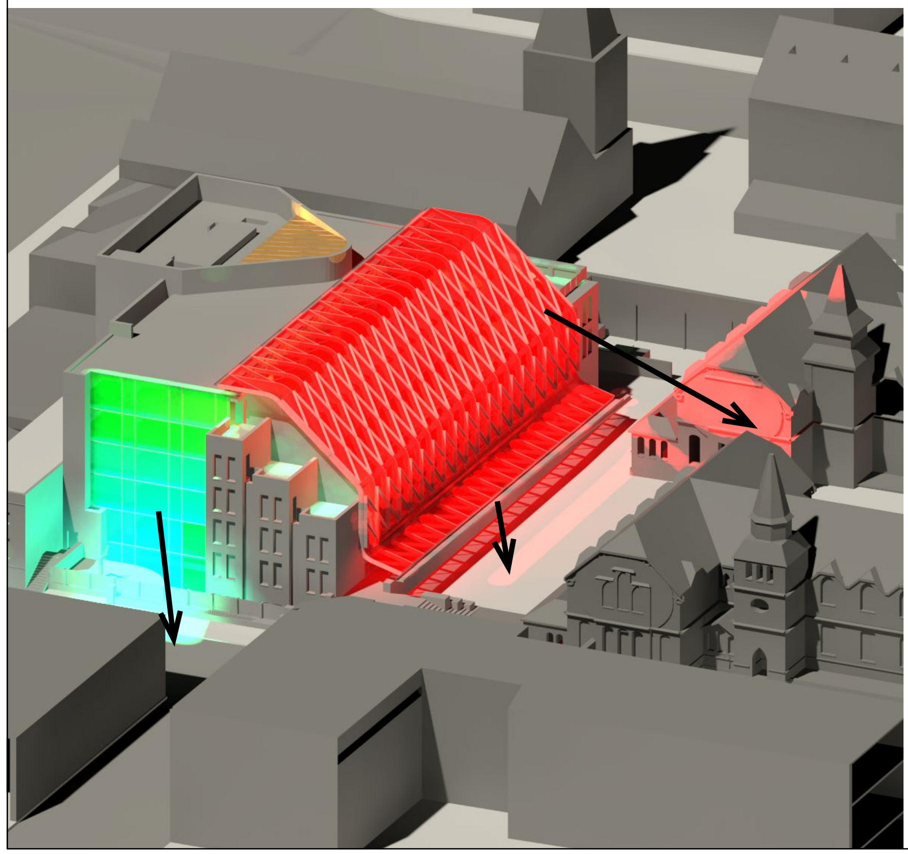
AREAS - Area Keys may be shown on the image to assist with classification of area use and sensitivity to glare.

SCALE - Each image is the same scale as noted otherwise.

TIME - Time and Date of the processed image. This represents the sun angle and intensity as per IES Daylight system. Solar Data is often provided as a table elsewhere in the report

COMMENTS -
These are point form comments specific to the time frame. Comments to which Low Risk or Reflection mitigation has already been determined are not classified.
Comments can be classified as
MEDIUM OR HIGH RISK.

GENERALLY:
Each time frame image and comment provides information to be read in conjunction with the main report findings.



RAY TRACED REFLECTED LIGHT

In this example Black Arrows indicate the reflected light from the various colour coded surfaces.

These reflected rays terminate in a paint spot.

Refer to DATA page for settings used..

Further details are outlined in the accompanying report.

REFLECTIVITY STUDY
No : RA169601 - Refer to attached Report.

Architect: C McFadzean B Arch BA (Arch) IES ABSA AAAI
Member of IES (The Illuminating Engineers Society of Australia)

COLOUR CODE KEY
(Reflected Colour shown in Key, Surface colour may differ)

● SOLAR PANEL

NORTH

HOW TO READ GUIDE

TITLE
REFLECTIVITY STUDY
RAY TRACED REFLECTIVITY

PROJECT
RAYWOOD SOLAR FARM
McQualters Rd
Raywood Vic 3570
(Lat 36.54° S , LONG 144.18°)

DATA SOURCE (In order of precedence)
- Layout and Concept Drawings, (Ref G.1000846) dated JAN 2020
- AEST TIME (Aust Eastern Standard Time - not daylight savings)

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PAGE No : RA 02
SCALE : 1:8000 (A3)
DATE : 07.02.19
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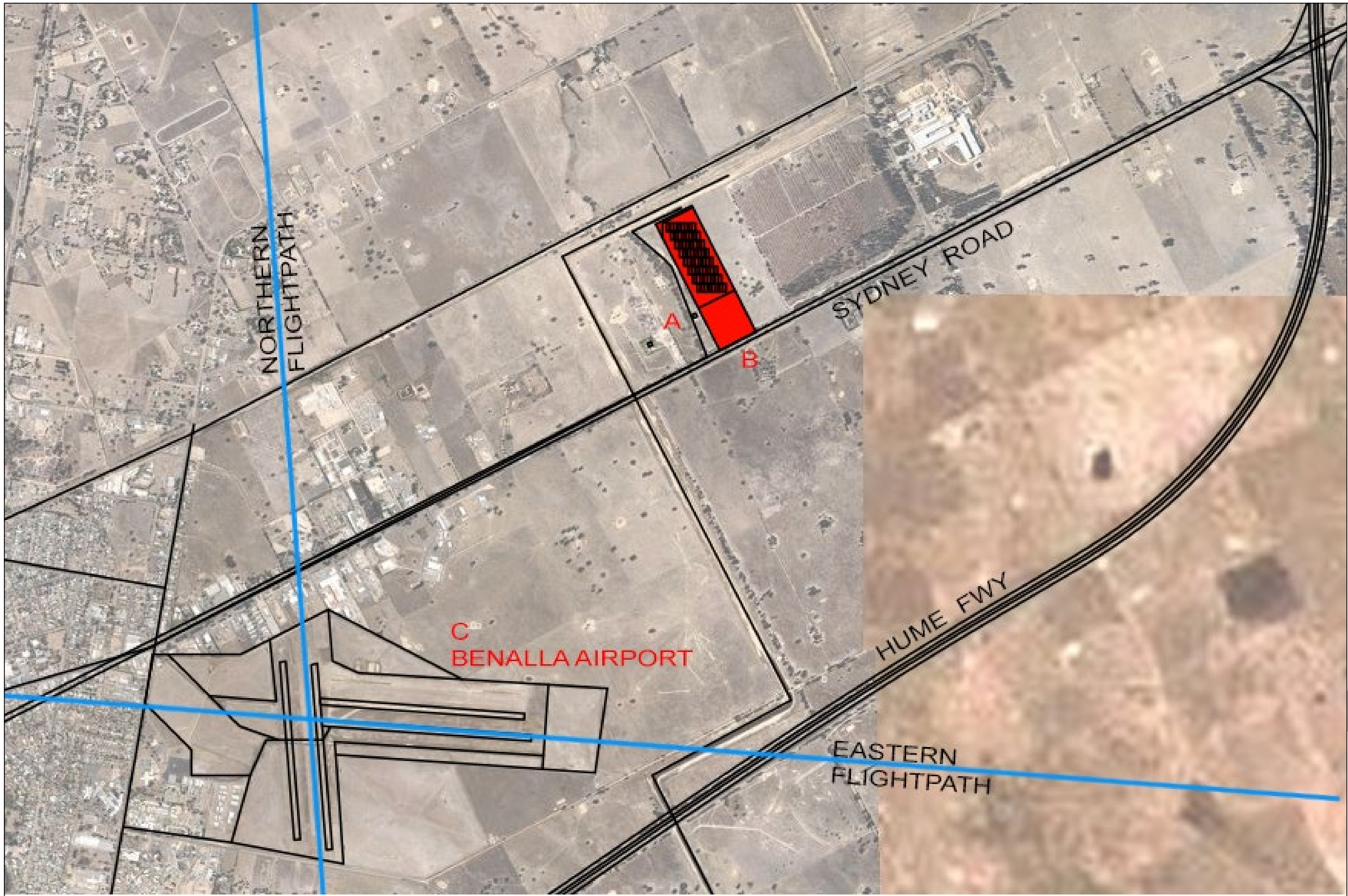

REFLECTIVITY STUDY
No : RA169601 - Refer to attached Report.

Architect: C McFadzean B Arch BA (Arch) IES ABSA AAAI
Member of IES (The Illuminating Engineers Society of Australia)

COLOUR CODE KEY
(Reflected Colour shown in Key, Surface colour may differ)

SOLAR PANEL

NORTH

KEY : AREAS OF INTEREST

AREAS OF INTEREST

A LOCAL RESIDENCE

B SYDNEY ROAD - NE and SW Direction

C BENALLA AIRPORT
FlightPath - Arrival from North
FlightPath - Arrival from East

TITLE
REFLECTIVITY STUDY
RAY TRACED REFLECTIVITY

PROJECT
RAYWOOD SOLAR FARM
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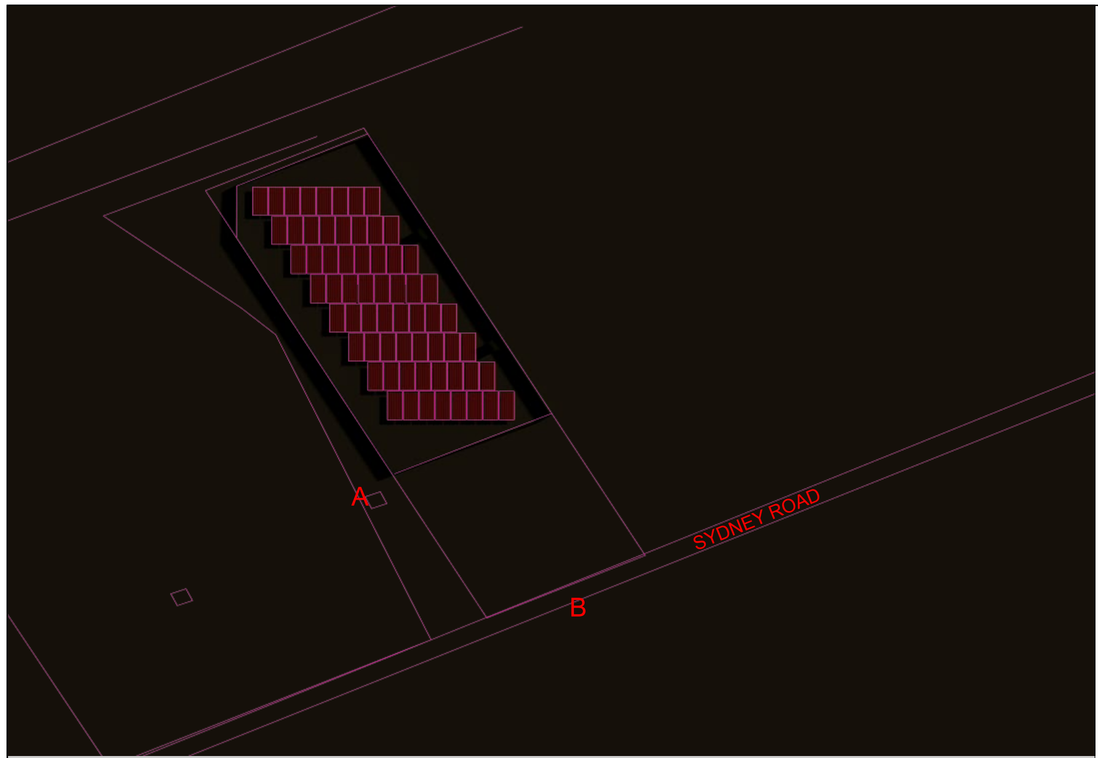
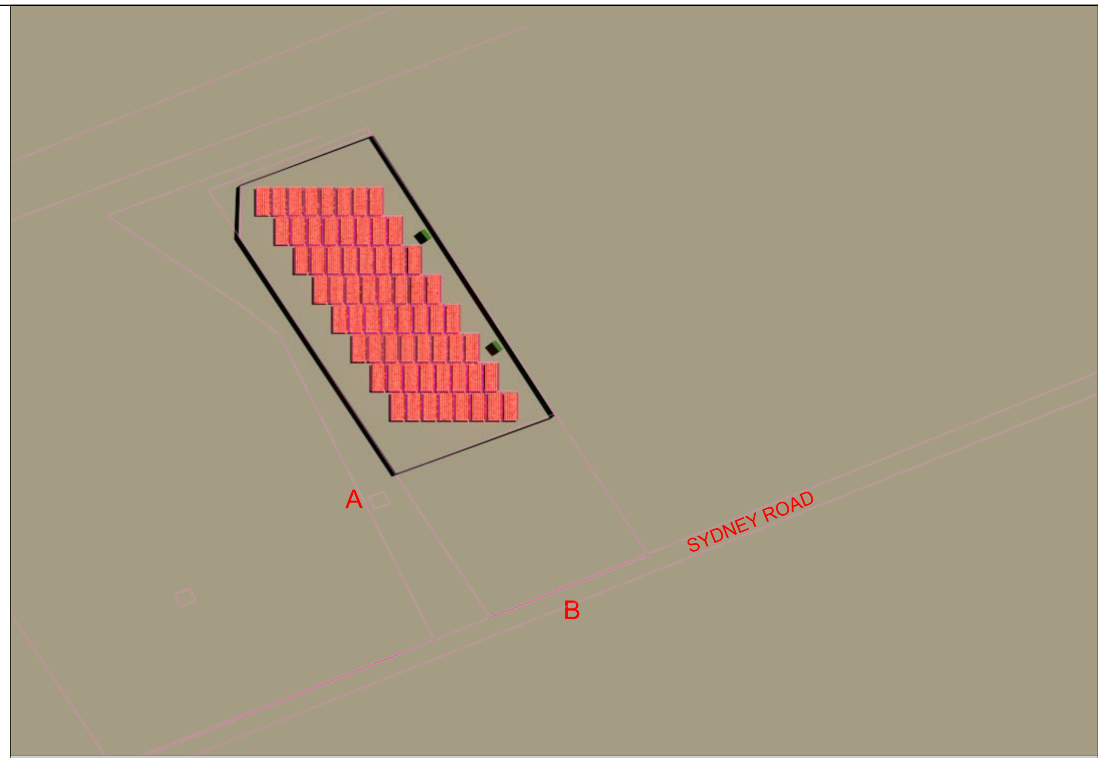
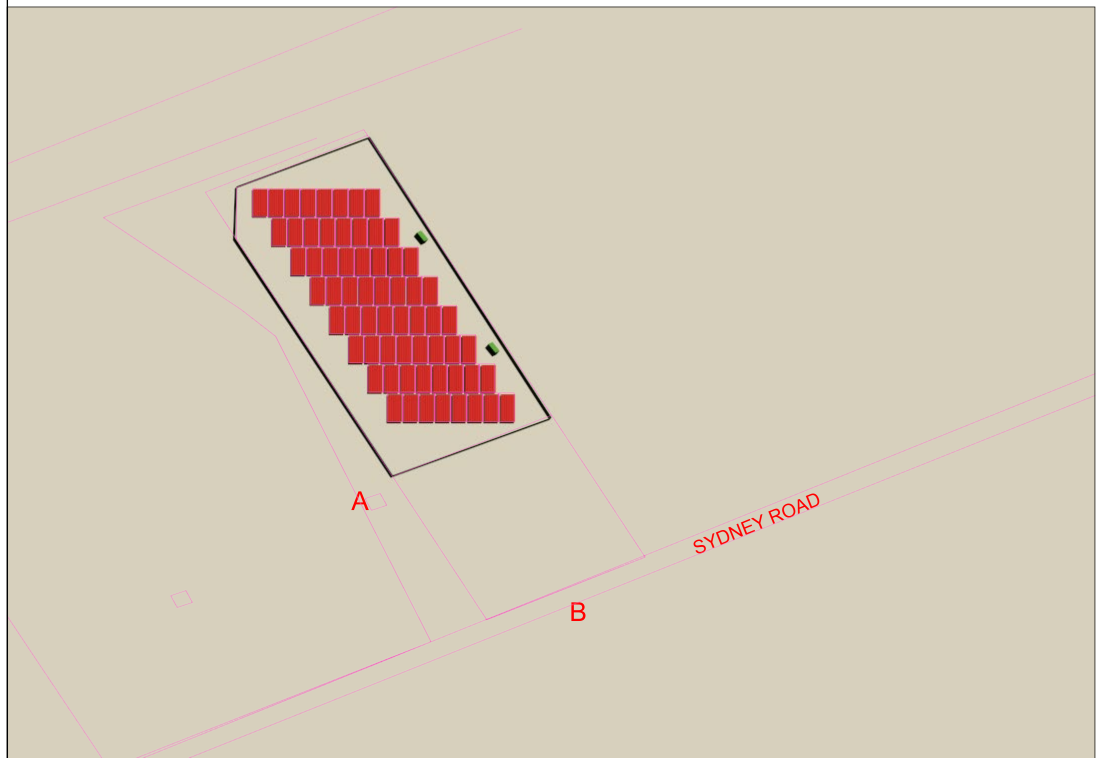


0800 MID WINTER

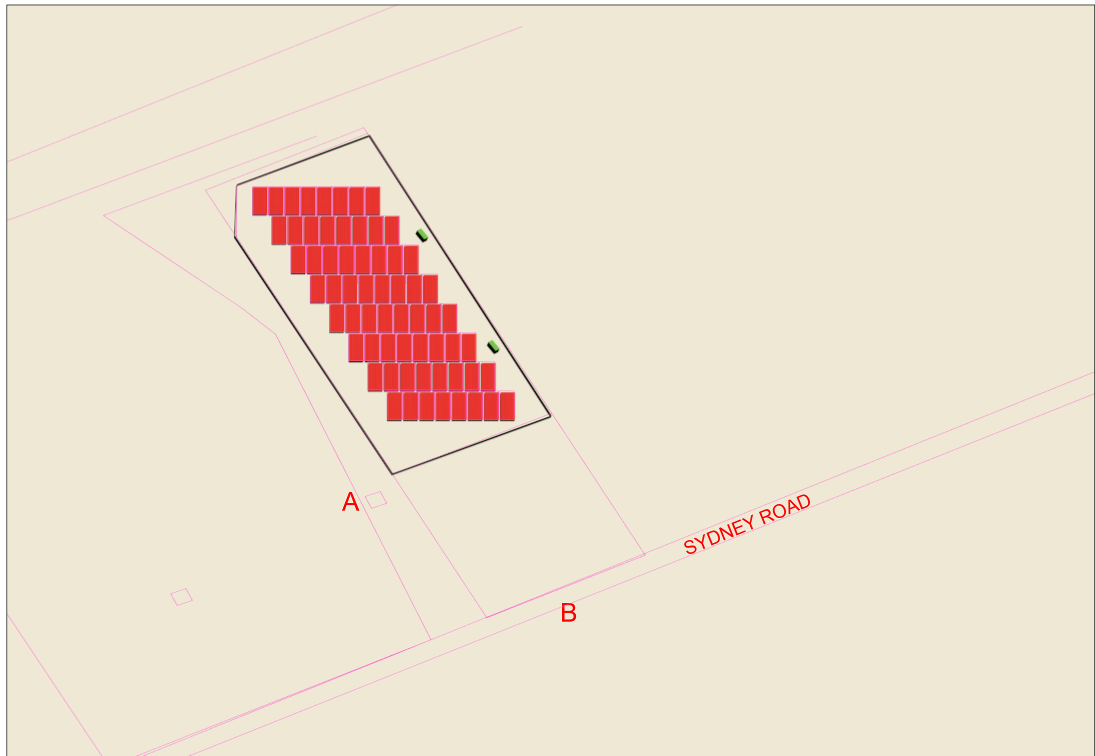
1. Low Sun (just above horizon)



0900 MID WINTER



1000 MID WINTER



1100 MID WINTER

REFLECTIVITY STUDY
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SOLAR PANEL

NORTH

MID WINTER

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RAY TRACED REFLECTIVITY

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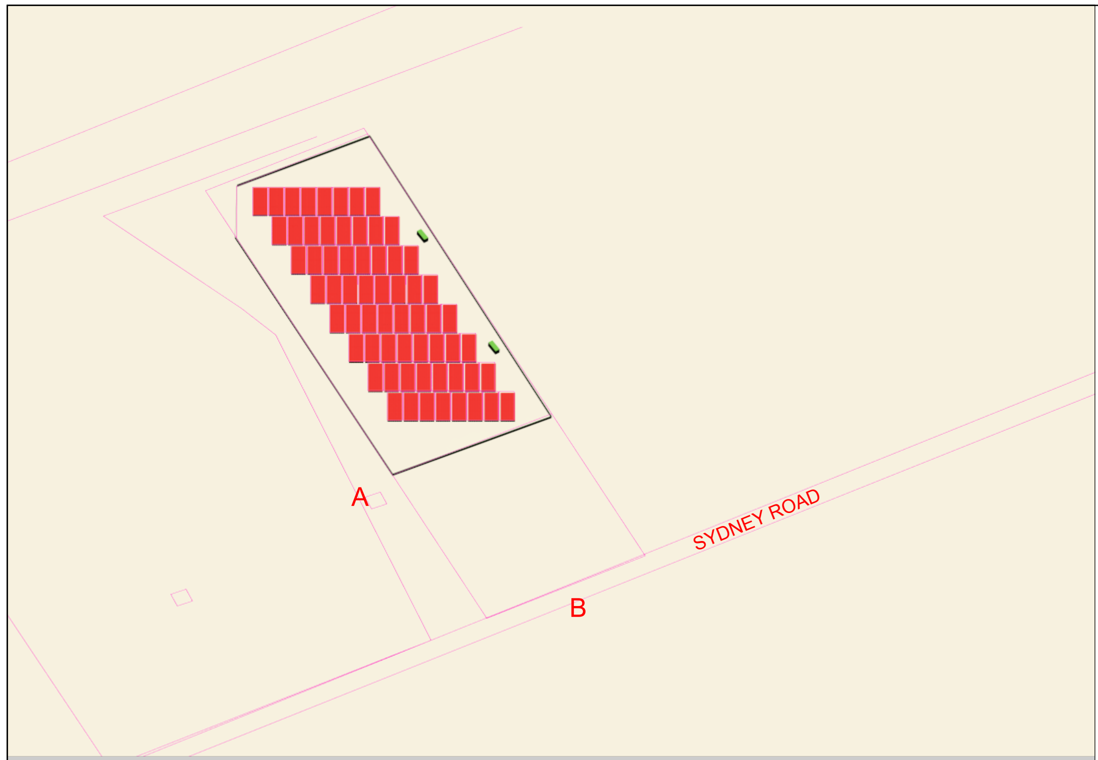
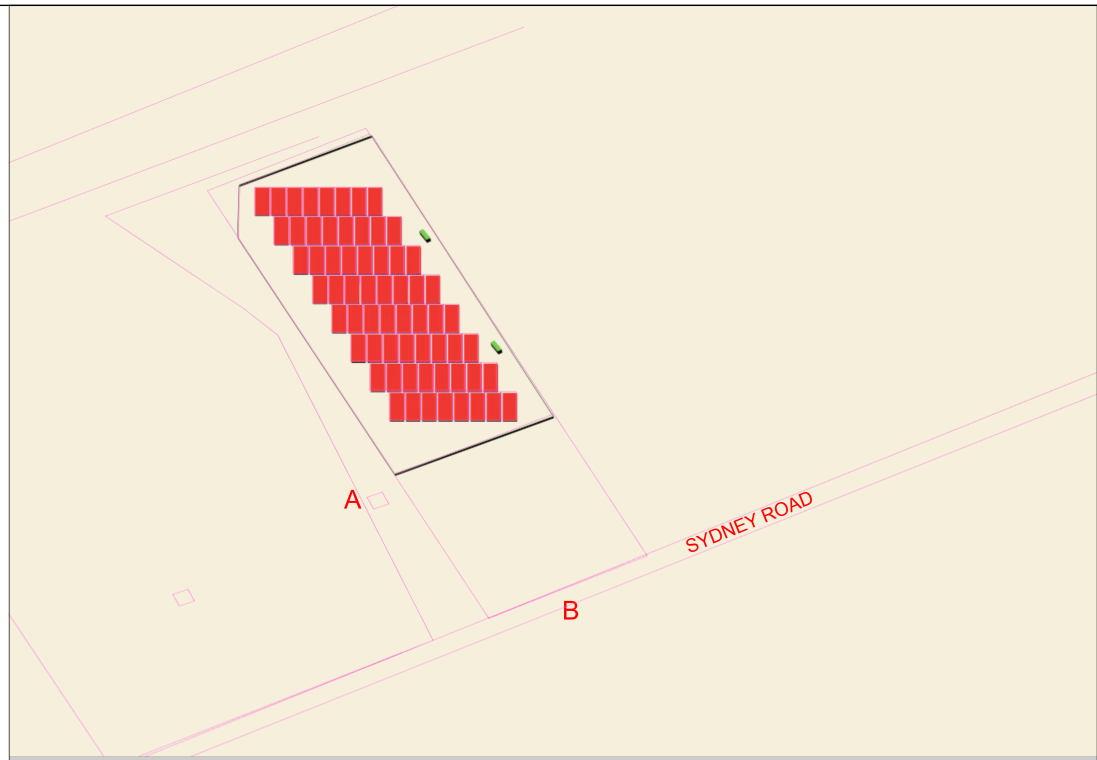
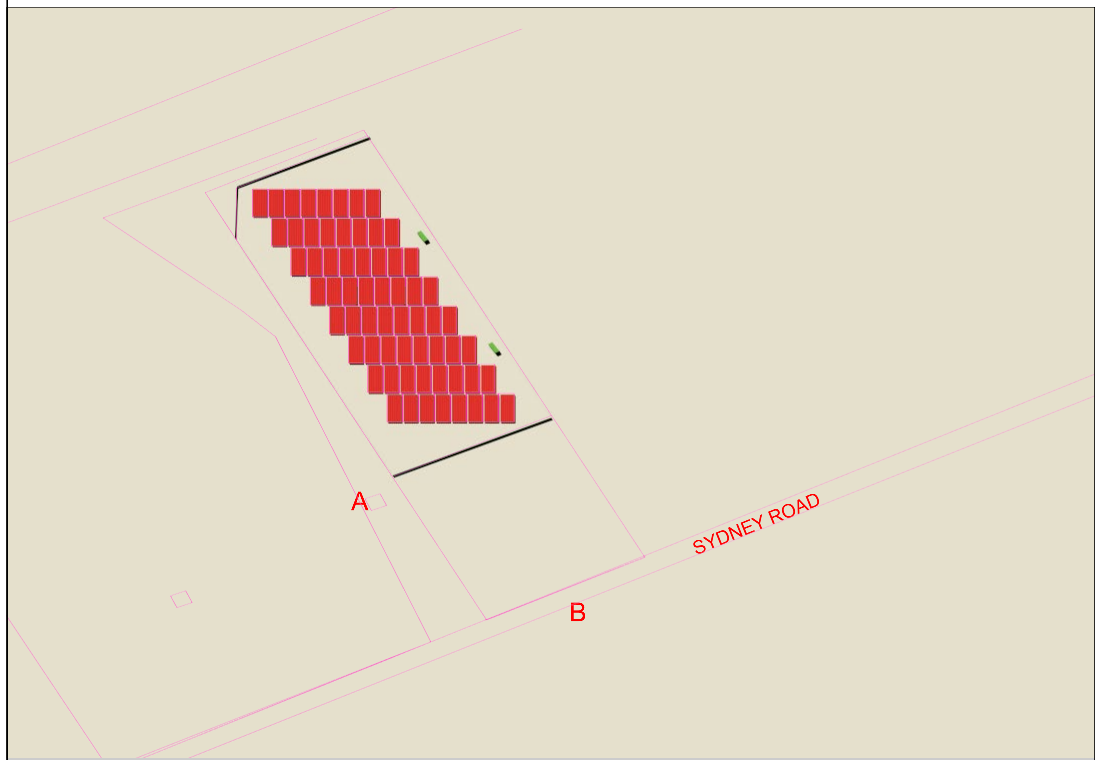


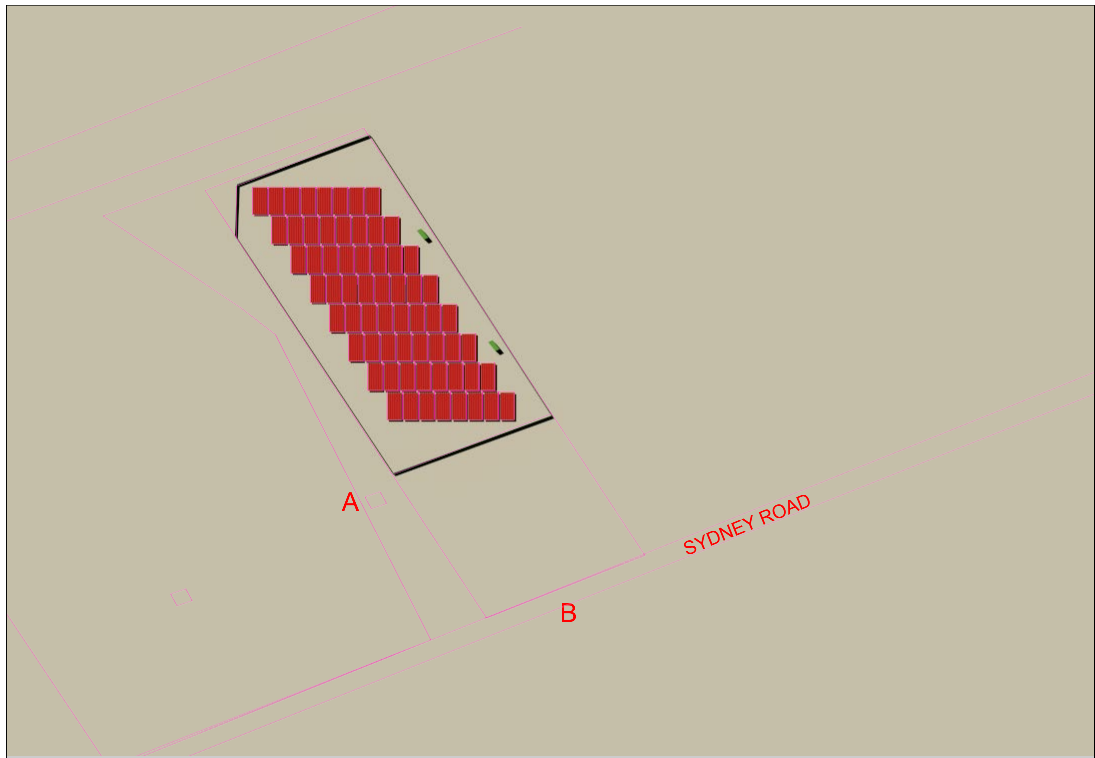
1200 MID WINTER



1300 MID WINTER



1400 MID WINTER



1500 MID WINTER

REFLECTIVITY STUDY
No : RA169601 - Refer to attached Report.

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● SOLAR PANEL

MID WINTER

TITLE
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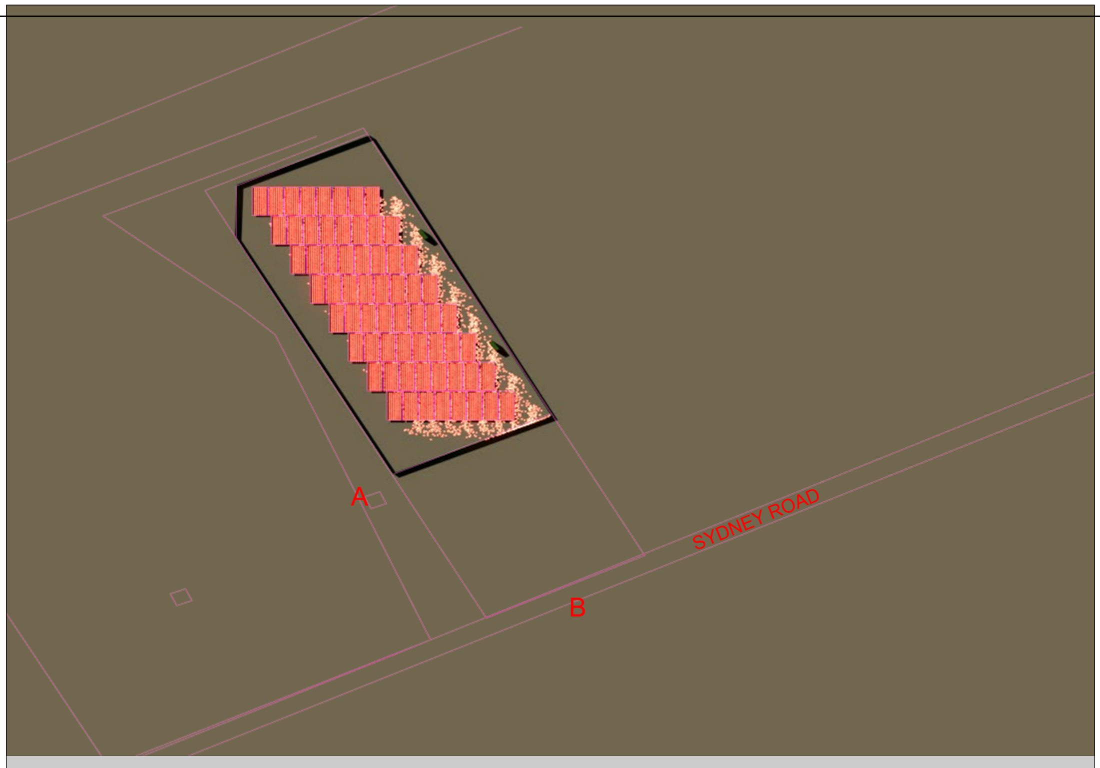

1600 MID WINTER

1. Reflection zone within site boundary.
2. NO IMPACT to vehicle traffic on Road

REFLECTIVITY STUDY
No : RA169601- Refer to attached Report.

Architect: C McFadzean B Arch BA (Arch) IES ABSA AAAI
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SOLAR PANEL

NORTH

MID WINTER

TITLE
REFLECTIVITY STUDY
RAY TRACED REFLECTIVITY

PROJECT
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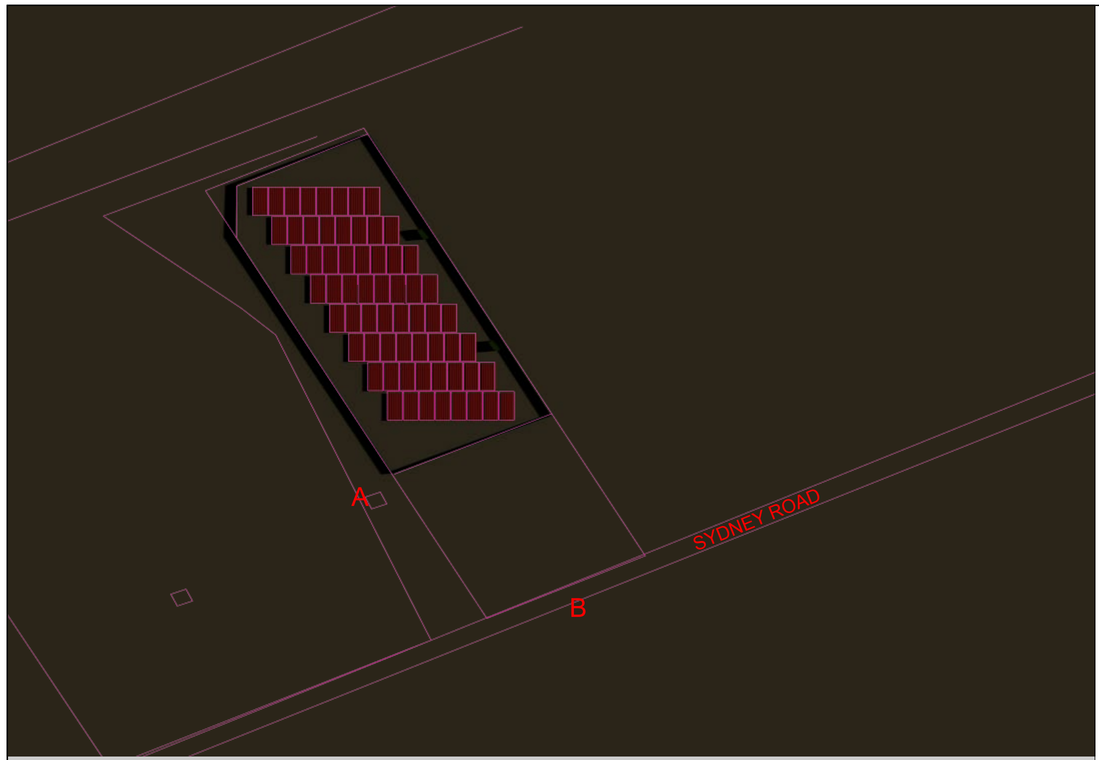
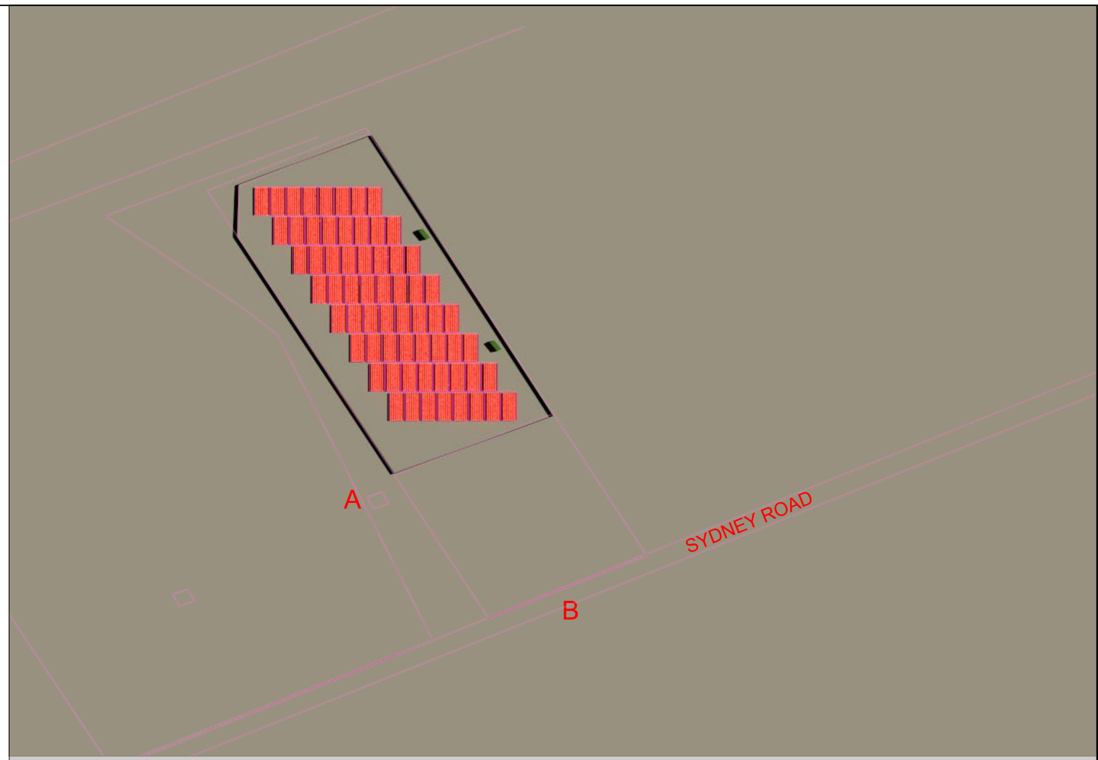
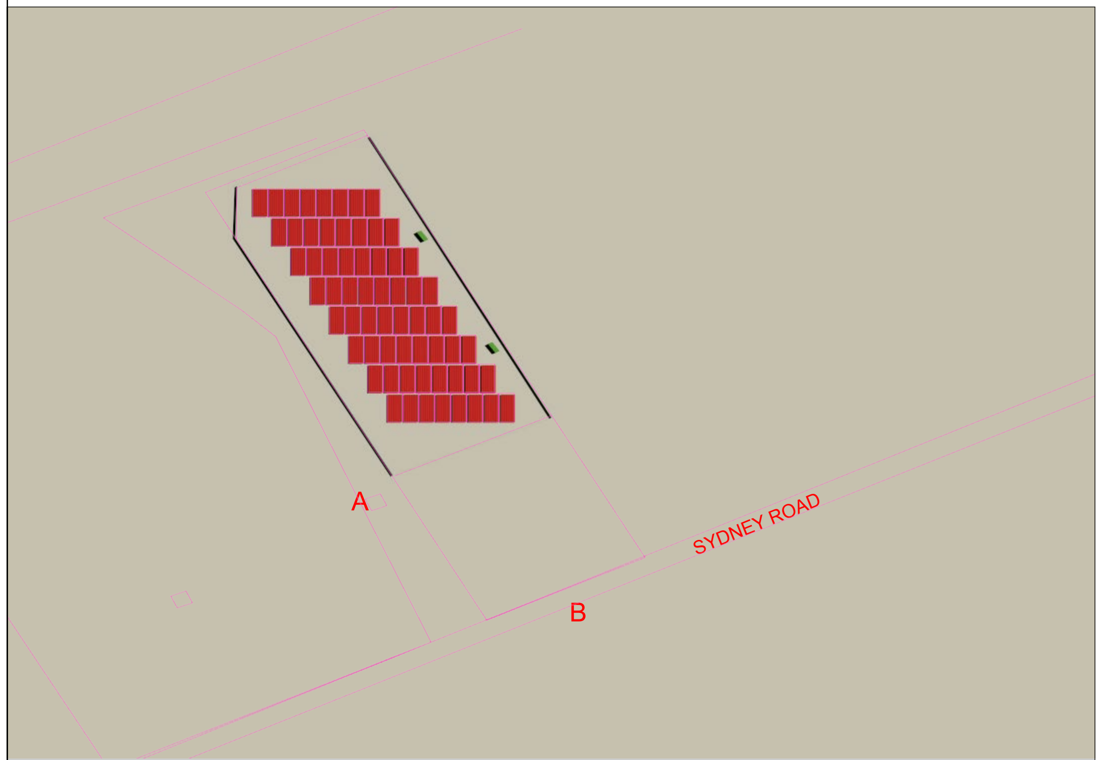


0700 EQUINOX

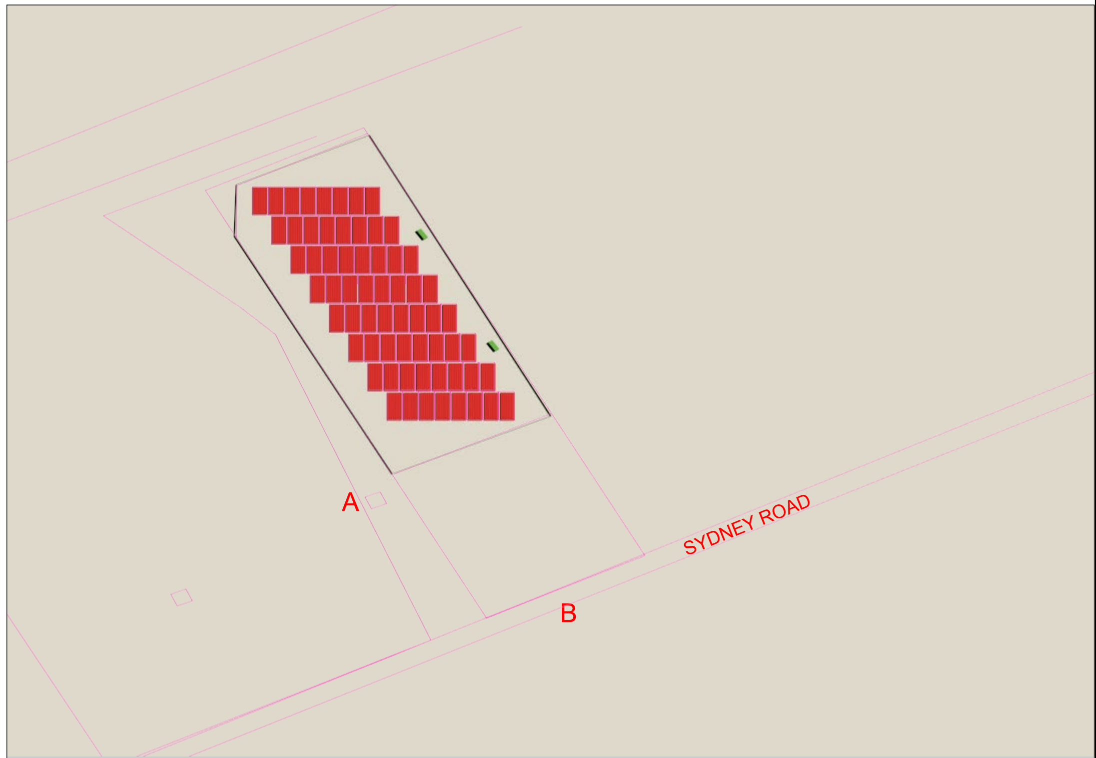
1. Low Sun (just above horizon)



0800 EQUINOX



0900 EQUINOX



1000 EQUINOX

REFLECTIVITY STUDY
No : RA169601 - Refer to attached Report.
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Architect: C McFadzean B Arch BA (Arch) IES ABSA AAAI
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SOLAR PANEL

NORTH

EQUINOX

TITLE
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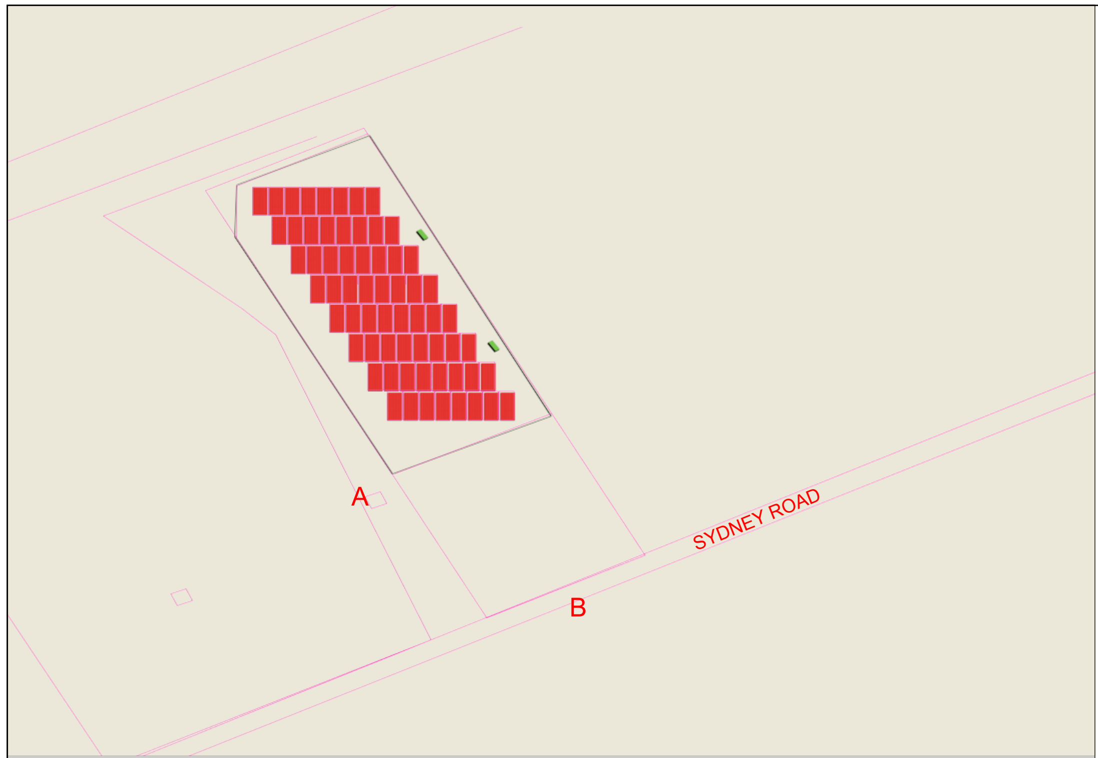
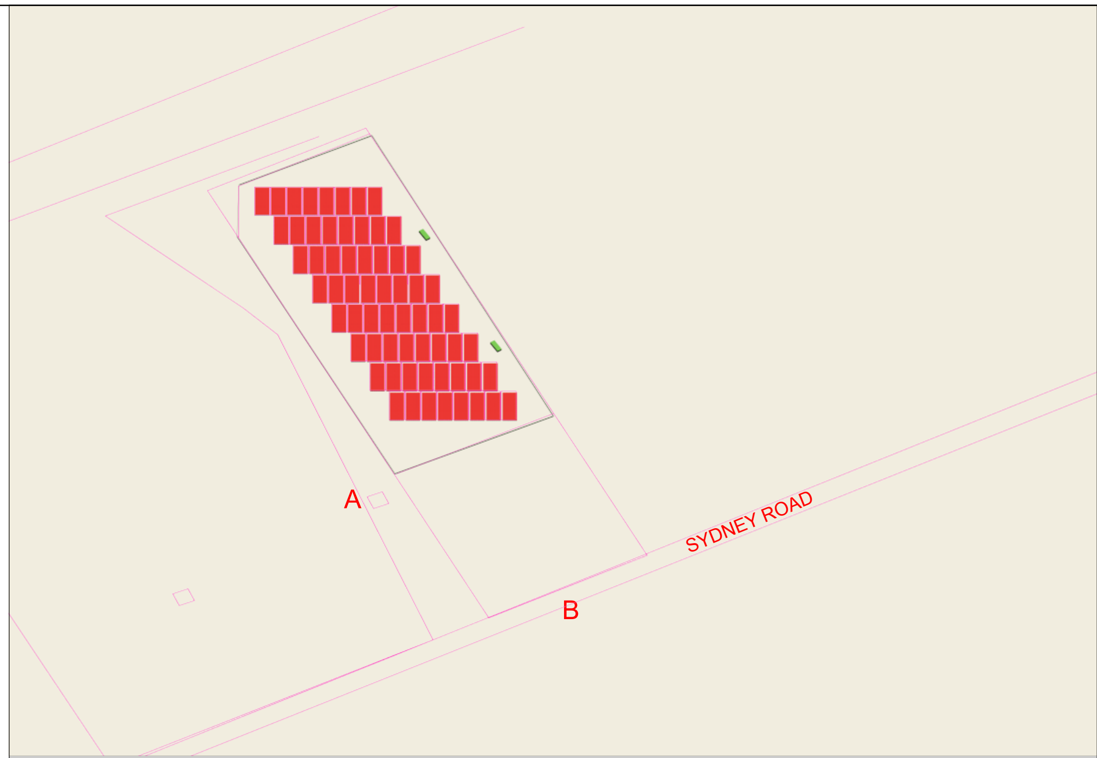
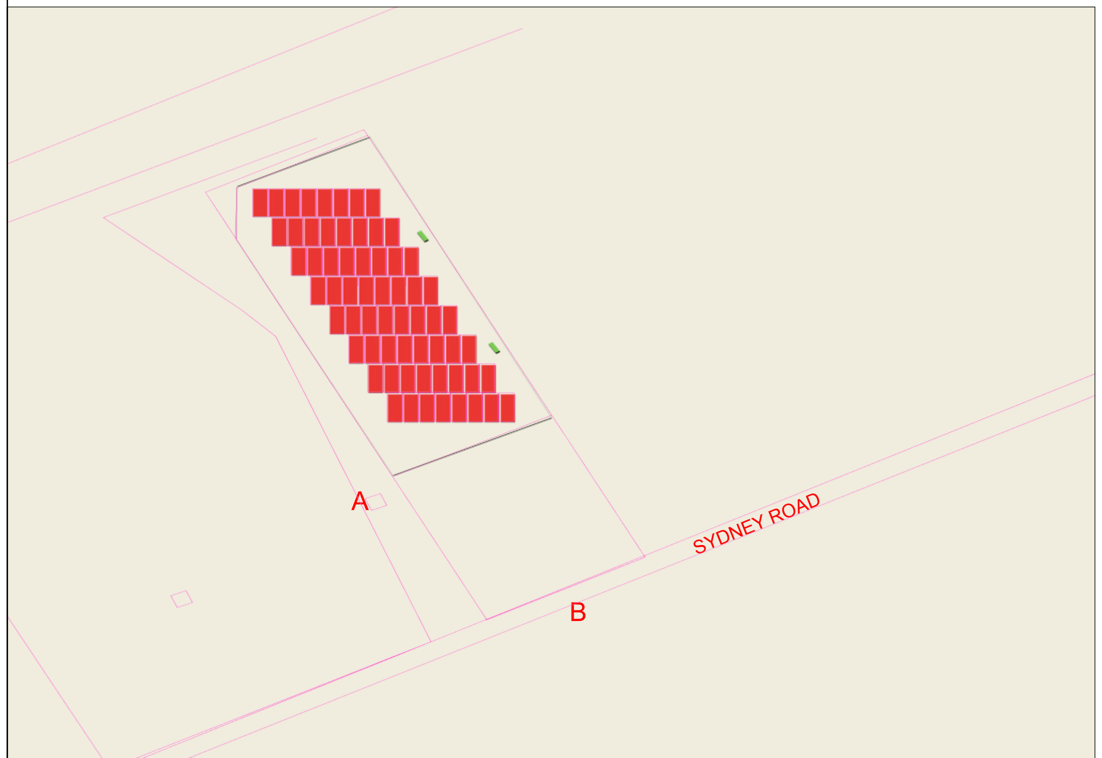


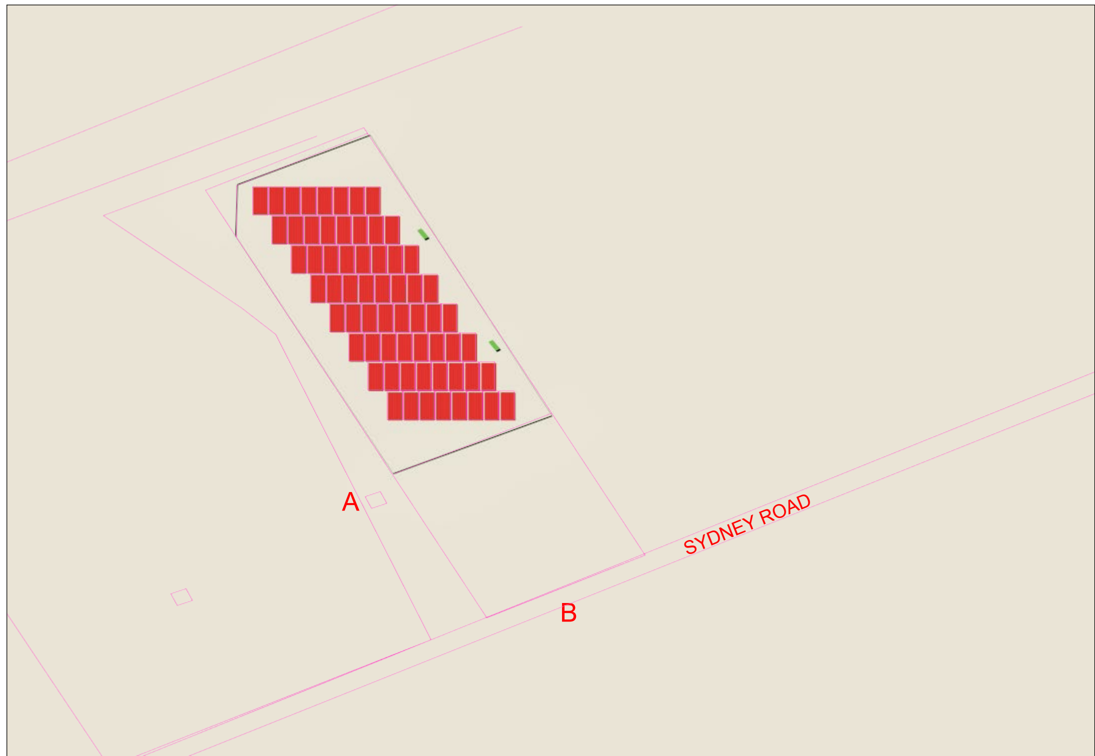
1100 EQUINOX



1200 EQUINOX



1300 EQUINOX



1400 EQUINOX

REFLECTIVITY STUDY
No : RA169601 - Refer to attached Report.

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COLOUR CODE KEY
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● SOLAR PANEL

EQUINOX

TITLE
REFLECTIVITY STUDY
RAY TRACED REFLECTIVITY

PROJECT
RAYWOOD SOLAR FARM
McQualters Rd
Raywood Vic 3570
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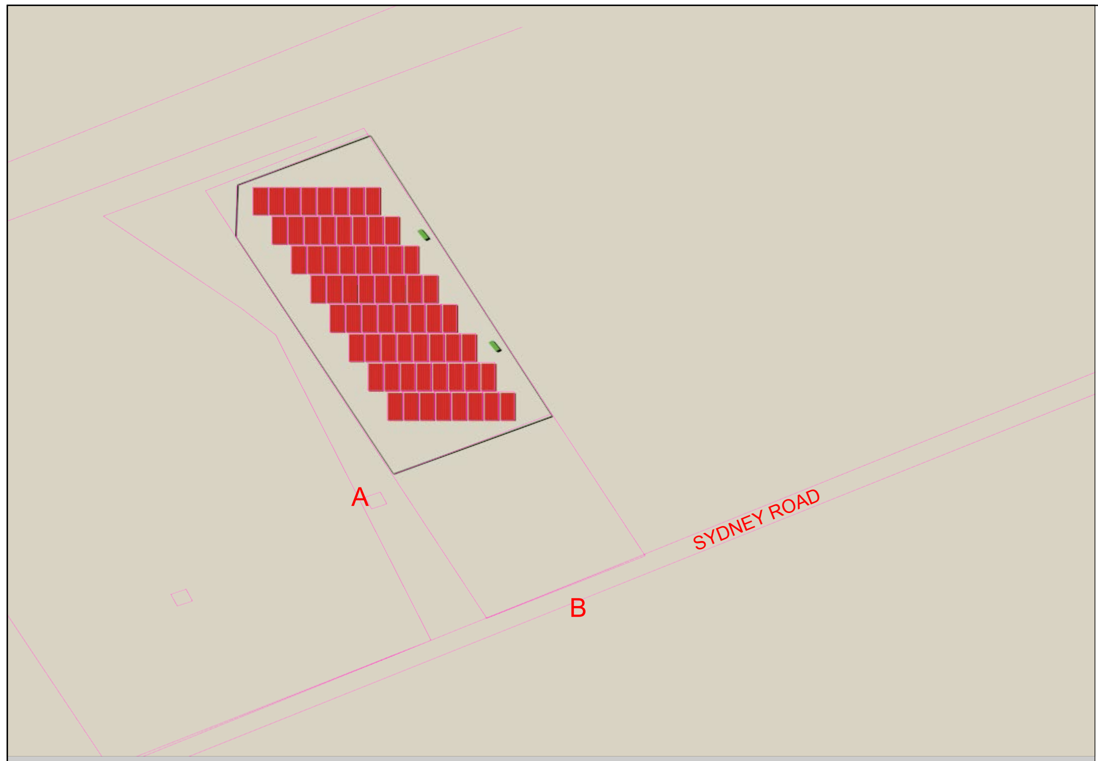
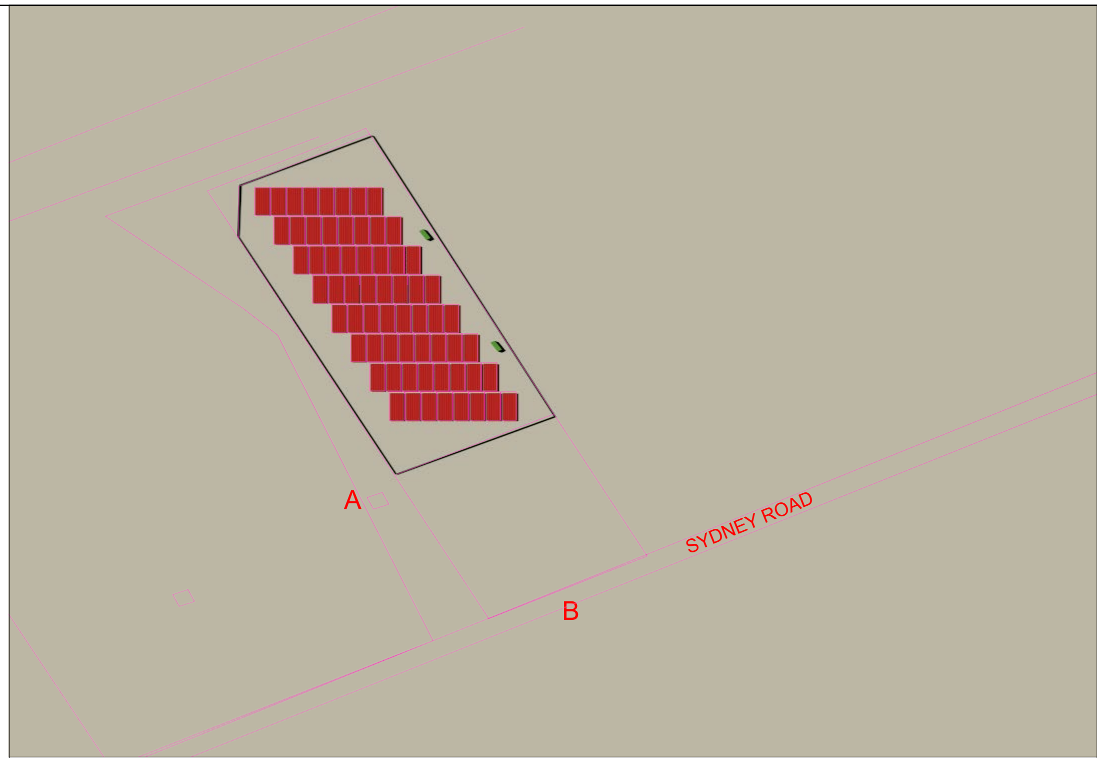


1500 EQUINOX



1600 EQUINOX

1700 EQUINOX

1. Reflection zone within site boundary.
2. NO IMPACT to vehicle traffic on Road

A

SYDNEY ROAD

B

REFLECTIVITY STUDY
No : RA169601 - Refer to attached Report.

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COLOUR CODE KEY
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SOLAR PANEL

NORTH

EQUINOX

TITLE
REFLECTIVITY STUDY
RAY TRACED REFLECTIVITY

PROJECT
RAYWOOD SOLAR FARM
McQualters Rd
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(Lat 36.54° S , LONG 144.18°)

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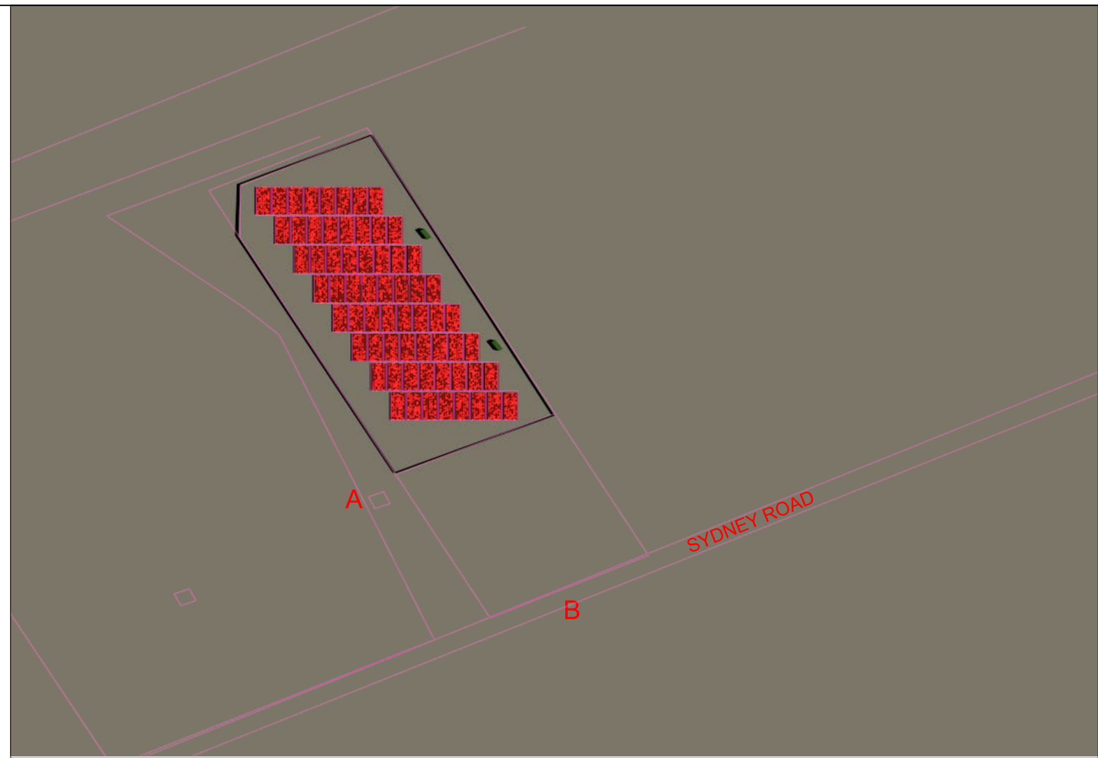
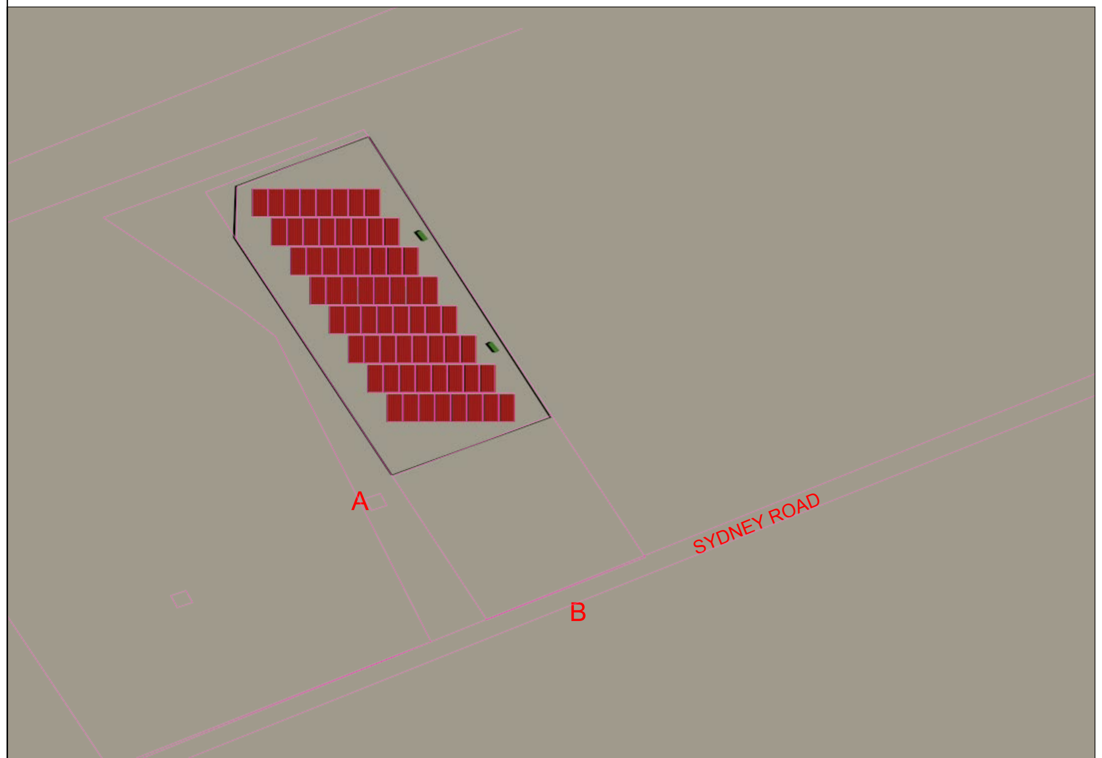
0600 MID SUMMER

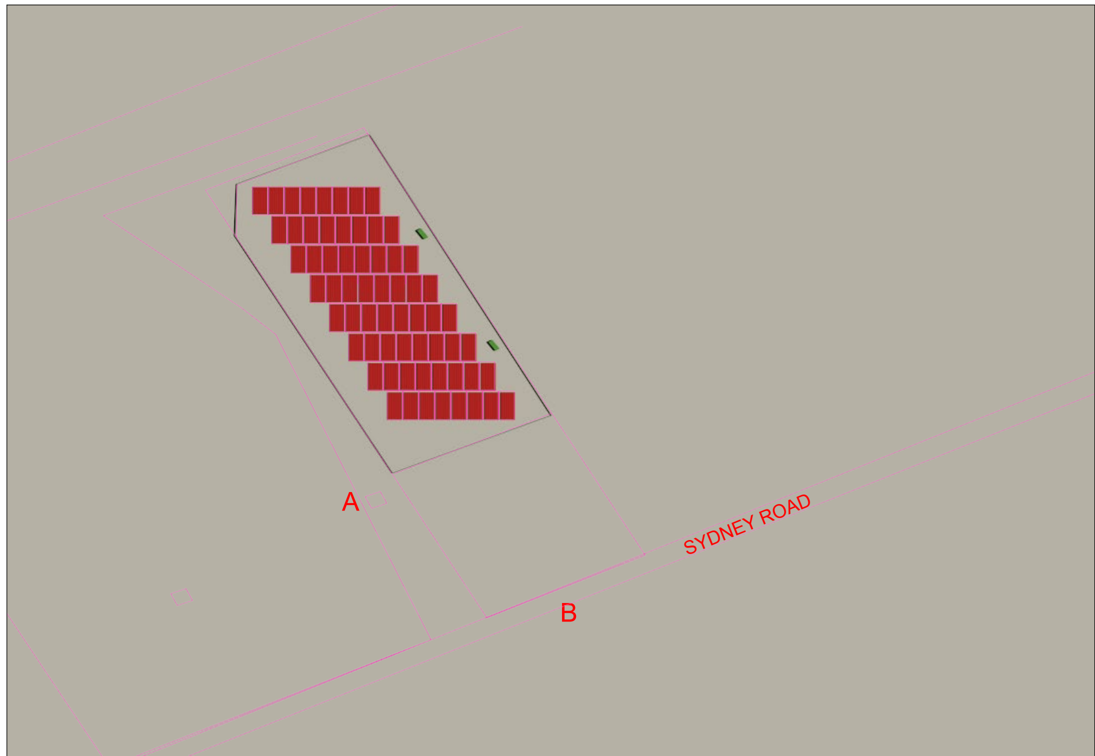
1. Reflection zone within site boundary.
2. NO IMPACT to vehicle traffic on Road
3. Low Risk Hazard.



0700 MID SUMMER



0800 MID SUMMER



0900 MID SUMMER

REFLECTIVITY STUDY
No : RA169601 - Refer to attached Report.

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SOLAR PANEL

NORTH

MID SUMMER

TITLE
REFLECTIVITY STUDY
RAY TRACED REFLECTIVITY

PROJECT
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McQualters Rd
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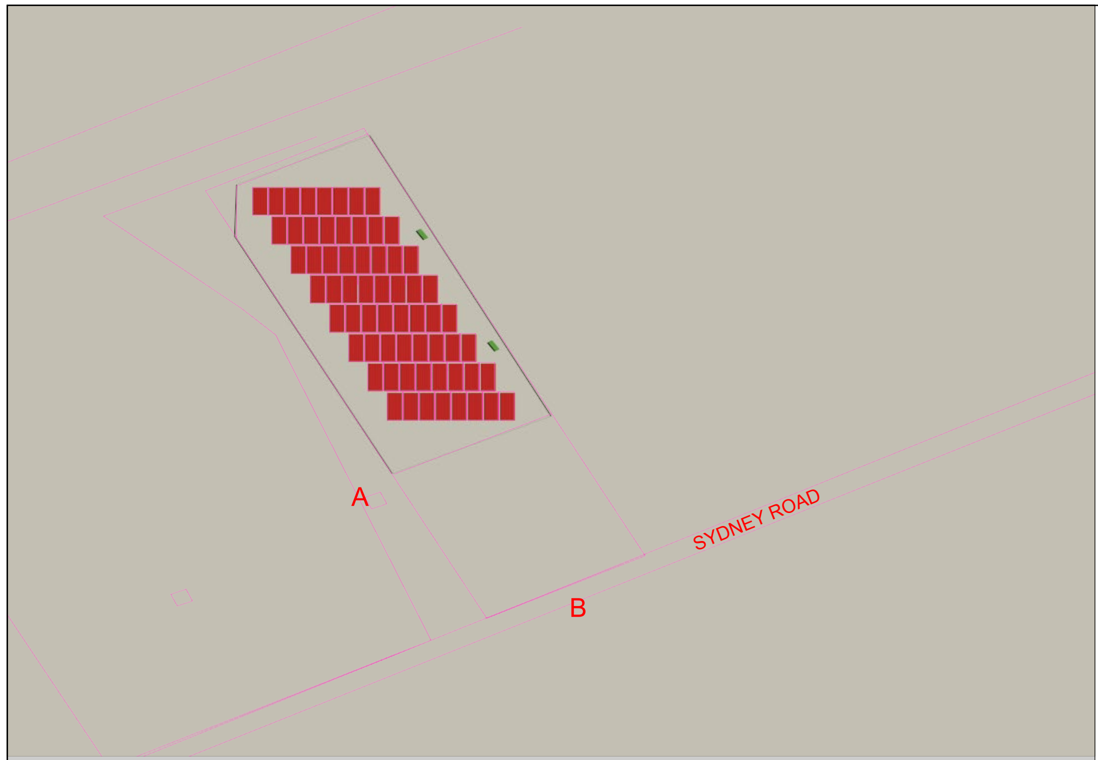
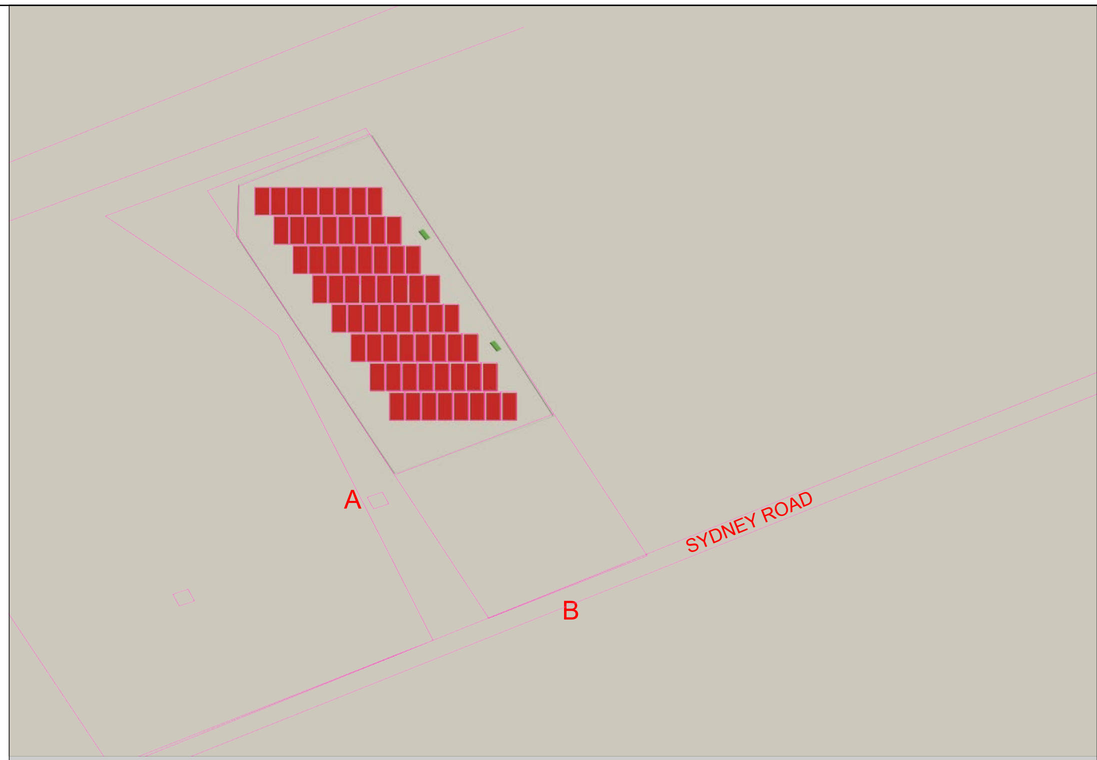
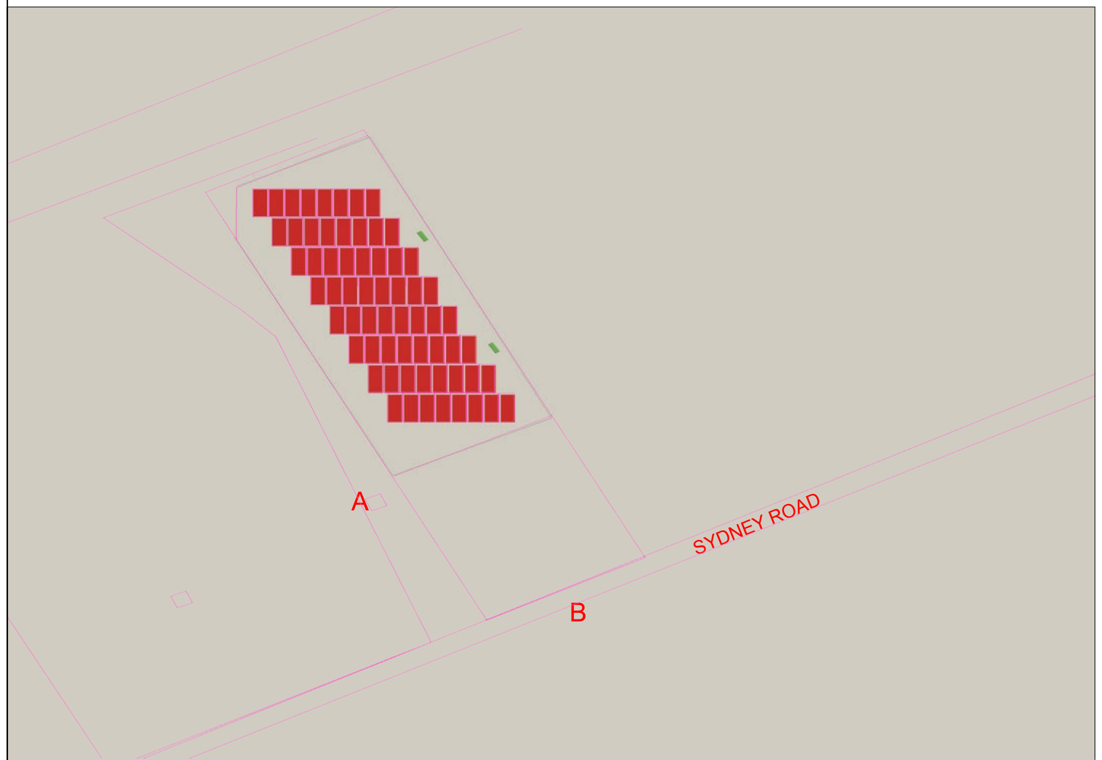


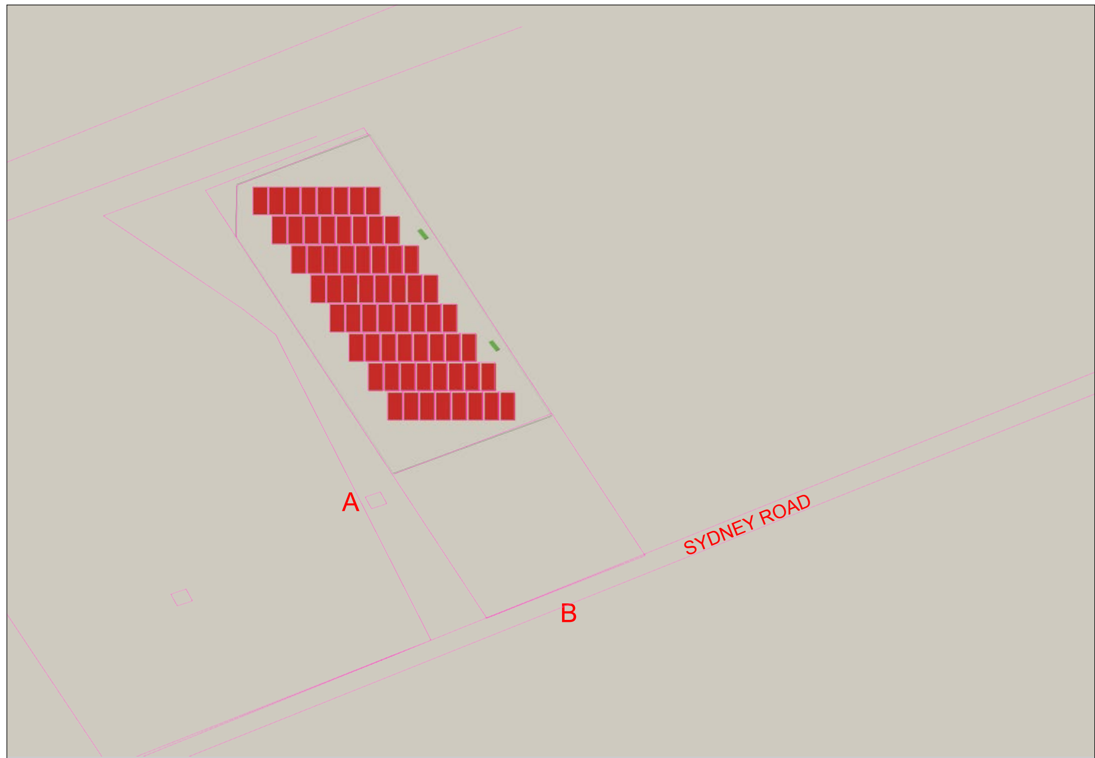
1000 MID SUMMER



1100 MID SUMMER



1200 MID SUMMER



1300 MID SUMMER

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SOLAR PANEL

NORTH

MID SUMMER

TITLE
REFLECTIVITY STUDY
RAY TRACED REFLECTIVITY

PROJECT
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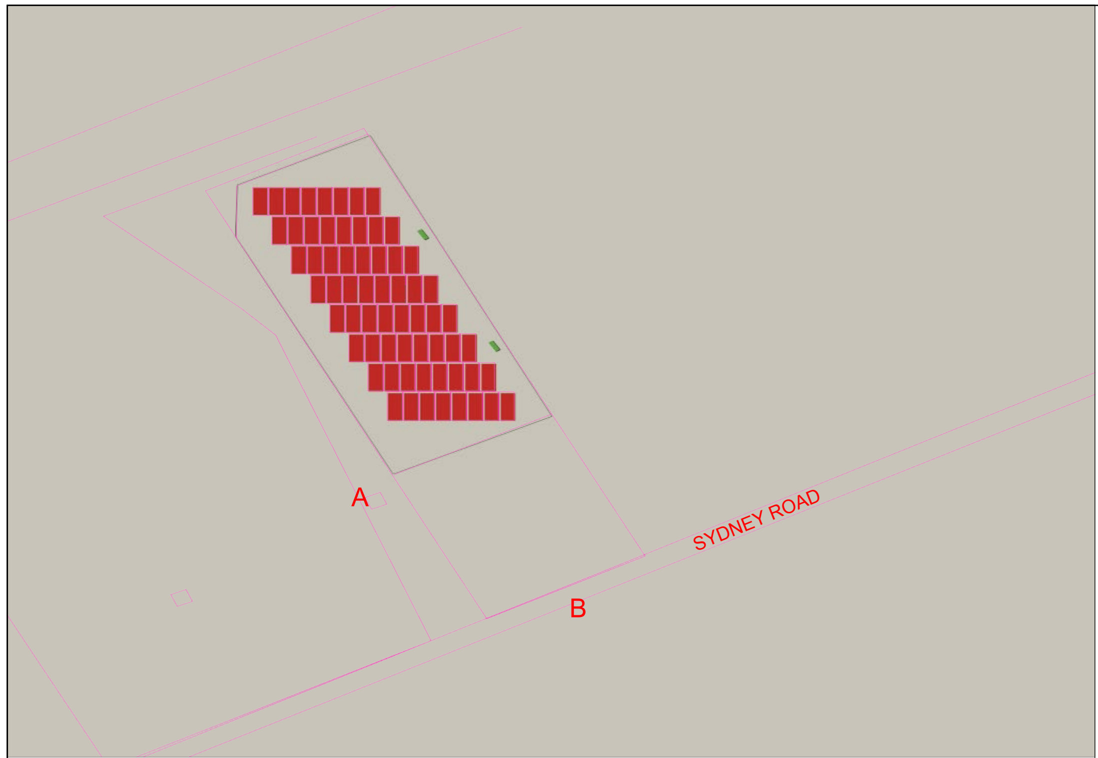
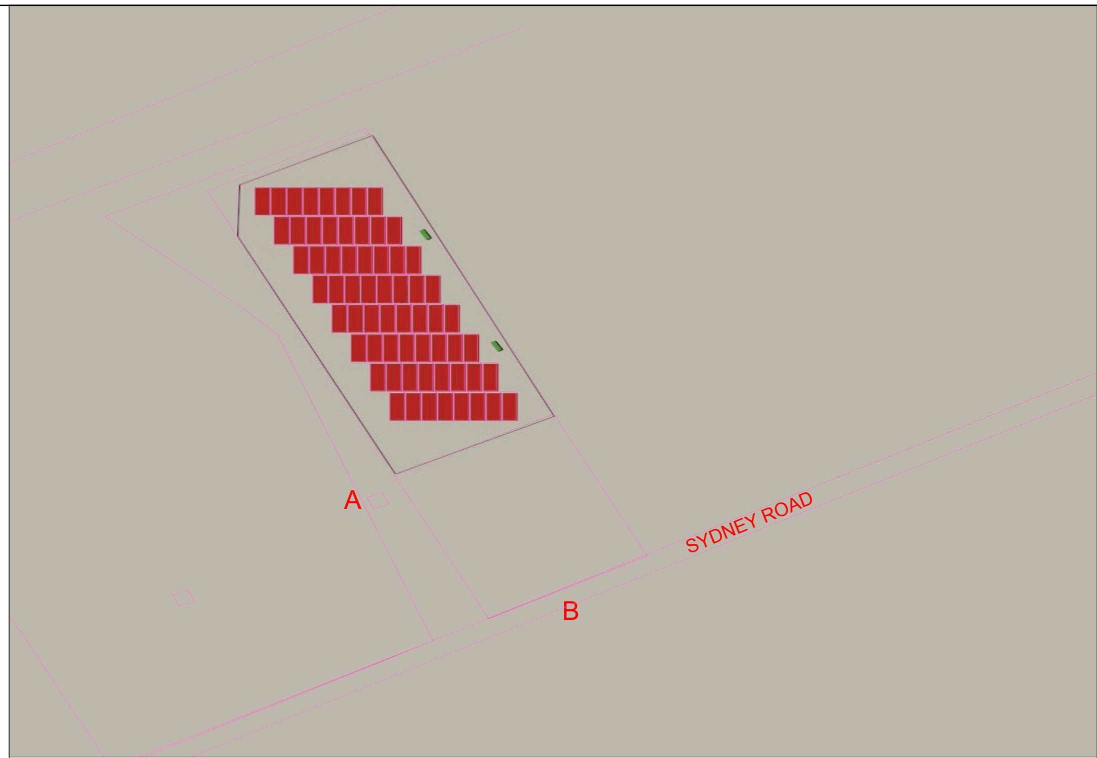
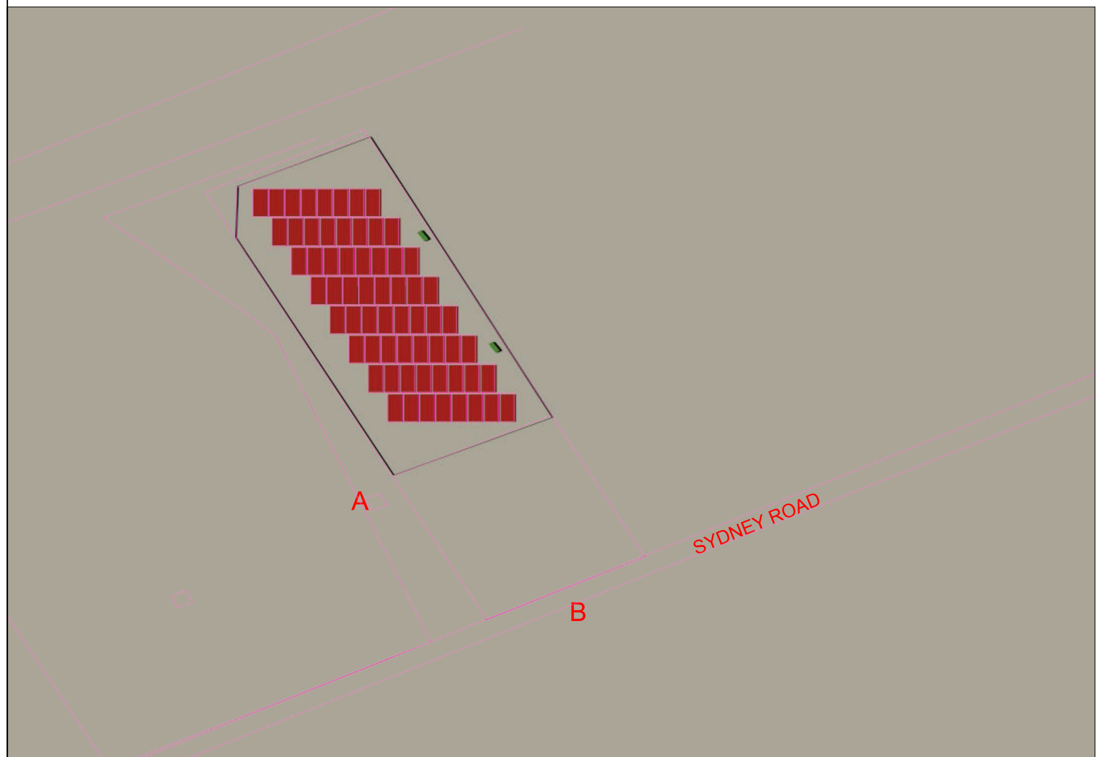


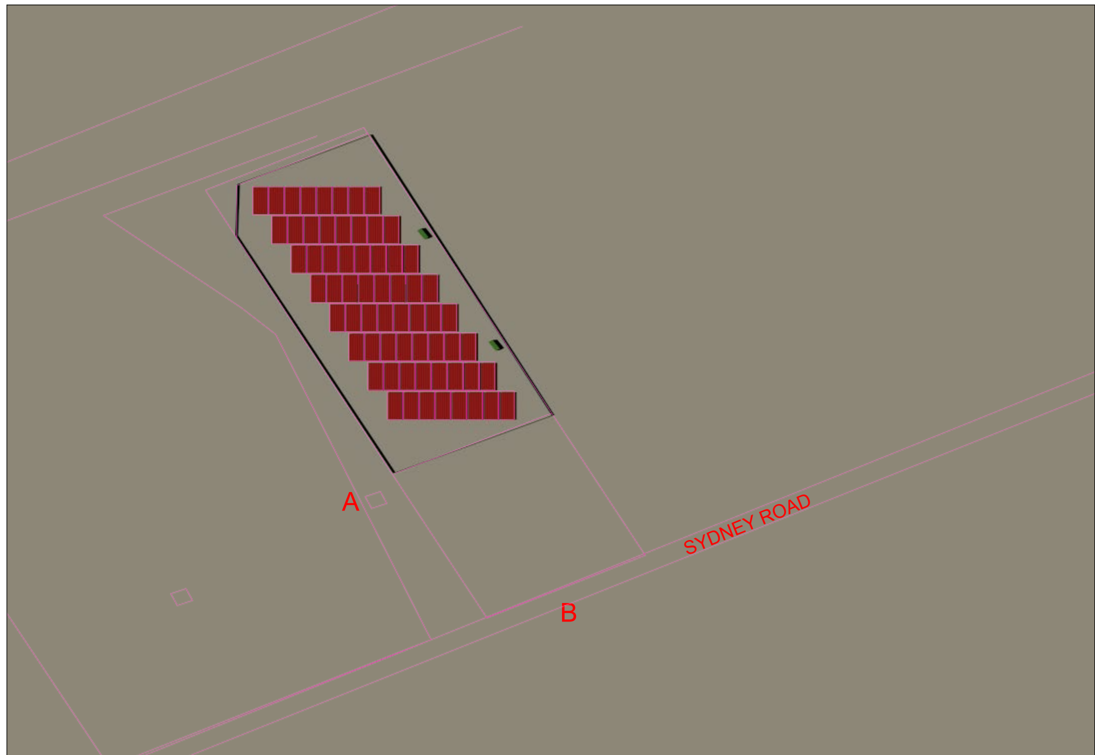
1400 MID SUMMER



1500 MID SUMMER



1600 MID SUMMER



1700 MID SUMMER

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The Lighting Society

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SOLAR PANEL

NORTH

MID SUMMER

TITLE

REFLECTIVITY STUDY
RAY TRACED REFLECTIVITY

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RAY TRACING SETTINGS

Software: 3D MAX (Autodesk) 2013 build : Mental Ray are registered trademarks of NVIDIA ARC GmbH, licensed for use by Autodesk, Inc

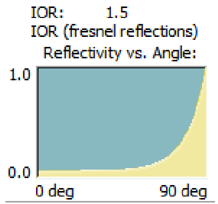
Ray Tracing Engine: Mental Ray , Caustics Ray Tracing , Final Gather on (Low), GI off.

Resolution per image frame: 1100 x 734
Light Source: 1 (Sun)
Light System: IES certified Daylight System

Ray Accuracy: 20,000 Photons per Light
Sample size of Rays: 2m Radius per 500 photons

Exposure: Winter: 13 EV (1/128, f8.0, ISO 100)
Equinox: 14EV (1/256, f8.0, ISO 100)
Summer: 15EV (1/512, f8.0, ISO 100)

Materials:
Glass typical: IOR 1.5 , certified realistic Glass (Mental Ray photorealism)
Transparency 50% to enable reflectivity strength in graphics.
Reflectance intensity 1000 X to enable visualisation.
Note these adjustments enhance the intensity and not the ray trajectory.



Other Solid: Diffuse Matt neutral grey (no reflectivity generation)

Target Planes: Bitmap painted and darkened for contrast

SUN POSITION DATA

LOCATION : Latitude -36.53 , Longitude 146.03 (BENALLA , Victoria)

Frame #	Time	DATE	Azimuth °	Altitude °
8	0800	MID WINTER JUNE 21	56	4
9	0900		46	14
10	1000		34	22
11	1100		20	27
12	1200		4	30
13	1300		348	29
14	1400		334	25
15	1500		320	19
16	1600		309	10
27	0700	EQUINOX March / Sept 22	84	7
28	0800		75	19
29	0900		64	30
30	1000		50	40
31	1100		33	48
32	1200		10	53
33	1300		344	52
34	1400		322	47
35	1500		306	38
36	1600		293	28
37	1700		282	16
41	0600	MID SUMMER DEC 21	111	10
42	0700		103	22
43	0800		95	34
44	0900		86	46
45	1000		75	58
46	1100		56	69
47	1200		14	76
48	1300		318	73
49	1400		291	63
50	1500		277	52
51	1600		268	40
52	1700		260	28
53	1800		252	16

ies The Lighting Society

REFLECTIVITY STUDY
No : RA169601 - Refer to attached Report.

Architect: C McFadzean B Arch BA (Arch) IES ABSA AAAI
Member of IES (The Illuminating Engineers Society of Australia)

NORTH

DATA

TITLE
REFLECTIVITY STUDY
RAY TRACED REFLECTIVITY

PROJECT
RAYWOOD SOLAR FARM
McQualters Rd
Raywood Vic 3570
(Lat 36.54° S , LONG 144.18°)

DATA SOURCE (In order of precedence)

- Layout and Concept Drawings, (Ref G.1000846) dated JAN 2020
- AEST TIME (Aust Eastern Standard Time - not daylight savings)

VIPAC Engineers & Scientists Lt
279 Normanby Rd, Port Melbourne 3207
Ph 0396479718

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3D SHADOW DIAGRAMS / VISUALISATION + ANALYSIS
DENEB DESIGN
PO BOX 539 MONA VALE 1660
Ph 02 9997 7480 Fx 9940 0772
info@denebdesign.com.au
www.denebdesign.com.au