Waterloo Integrated Station Development

A Joint Venture Project

JOHN HOLLAND mirvac

WATERLOO METRO QUARTER OVERSTATION DEVELOPMENT

Environmental Impact Statement
Appendix Z Reflectivity Statement

SSD-10441 Amending Concept DA

State Significant Development
Development Application

Prepared for **WL Developer Pty Ltd**

30 September 2020

Reference	Description
Applicable SSD Applications	SSD-10441 Amending Concept DA
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1. Glossary and abbreviations

Reference	Description
ACHAR	Aboriginal Cultural Heritage Assessment Report
ADG	Apartment Design Guide
AHD	Australian height datum
AQIA	Air Quality Impact Assessment
BC Act	Biodiversity Conservation Act 2016
BCA	Building Code of Australia
BC Reg	Biodiversity Conservation Regulation 2017
BDAR	Biodiversity Development Assessment Report
CEEC	critically endangered ecological community
CIV	capital investment value
CMP	Construction Management Plan
Concept DA	A concept DA is a staged application often referred to as a 'Stage 1' DA. The subject application constitutes a detailed subsequent stage application to an approved concept DA (SSD 9393) lodged under section 4.22 of the EP&A Act.
Council	City of Sydney Council
CPTED	Crime Prevention Through Environmental Design
CSSI approval	critical State significant infrastructure approval
CTMP	Construction Traffic Management Plan
DA	development application
DPIE	NSW Department of Planning, Industry and Environment
DRP	Design Review Panel
EP&A Act	Environmental Planning and Assessment Act 1979
EPA	NSW Environment Protection Authority
EPA Regulation	Environmental Planning and Assessment Regulation 2000
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999

Reference	Description
ESD	ecologically sustainable design
GANSW	NSW Government Architect's Office
GFA	gross floor area
HIA	Heritage Impact Assessment
IAP	Interchange Access Plan
LGA	Local Government Area
NCC	National Construction Code
OSD	over station development
PIR	Preferred Infrastructure Report
POM	Plan of Management
PSI	Preliminary Site Investigation
RMS	Roads and Maritime Services
SEARs	Secretary's Environmental Assessment Requirements
SEPP	State Environmental Planning Policy
SEPP 55	State Environmental Planning Policy No 55—Remediation of Land
SEPP 65	State Environmental Planning Policy No. 65 – Design Quality of Residential Apartment Development
SRD SEPP	State Environmental Planning Policy (State and Regional Development) 2009
SREP Sydney Harbour	State Regional Environmental Plan (Sydney Harbour Catchment) 2005
SSD	State significant development
SSD DA	State significant development application
SLEP	Sydney Local Environmental Plan 2012
Transport for NSW	Transport for New South Wales
TIA	Traffic Impact Assessment

Reference	Description
The proposal	The proposed development which is the subject of the detailed SSD DA
The site	The site which is the subject of the detailed SSD DA
VIA	Visual Impact Assessment
WMQ	Waterloo Metro Quarter
WMP	Waste Management Plan
WSUD	water sensitive urban design

2. Executive summary

This report has been prepared by RWDI Anemos Ltd. (RWDI) to accompany a concept State significant development (SSD) development application (DA) for the Waterloo Metro Quarter over station development (OSD). This concept SSD DA is submitted as an 'amending DA', that modifies the previously approved concept SSD DA issued for the site (SSD 9393). The modifications contained within the amending DA relate to the northern precinct and central building only. No change is proposed to the original concept SSD DA as it relates to the southern precinct of the Waterloo Metro Quarter site.

This report has been prepared to address the Secretary's Environmental Assessment Requirements (SEARs) issued for the amending concept SSD DA (SSD 10441).

This report concludes that the proposed Southern Precinct Central Precinct and Northern Precinct OSD complies with local requirements with respect to solar reflectivity so long as the nominal visible reflectivity of the glazing remains at 20% or lower.

3. Introduction

This report has been prepared to accompany a concept SSD DA for the over station development (OSD) at the Waterloo Metro Quarter site. The concept DA seeks consent for an amended building envelope and description of development for the northern precinct and central building of the Waterloo Quarter site approved under SSD 9393. For clarity, this concept DA (formerly referred to as a 'Stage 1' DA) is made under Section 4.22 of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

The Minister for Planning, or their delegate, is the consent authority for the SSD DA and this application is lodged with the NSW Department of Planning, Industry and Environment (DPIE) for assessment.

The concept DA seeks to modify the approved building envelope for the northern precinct (previously comprising 'Building A', 'Building B', 'Building C' and 'Building D' under SSD 9393) through:

- increasing the maximum building height for the southern portion of the building envelope from RL56.2 to RL72.60
- removing the 'tower component' of the northern precinct, reducing the overall height of the tower envelope from RL116.9 to RL90.40, to enable the redistribution of floor space to commercial office floor plates
- amending the description of development to refer to a mid-rise (approximately 17 storey) commercial office building, comprising approximately 34,125sqm of commercial office floor space within the northern portion of the site, rather than a third residential tower.

The concept DA seeks to modify the central building approved building envelope (previously comprising 'Building E' under SSD 9393) through:

- modifying the eastern extent of the podium envelope.

This proposal will not exceed the permissible building height for the site under the Sydney Local Environmental Plan 2012 (SLEP) or the maximum height approved under SSD 9393. Separate detailed SSD DA (s) will be lodged concurrently for the detailed design, construction and operation of the northern precinct and central building. No changes are proposed to the original concept DA as it relates to the southern precinct.

This report has been prepared in response to the requirements contained within the Secretary's Environmental Assessment Requirements (SEARs) dated 9 April 2020 and issued for the detailed SSD DA. Specifically, this report has been prepared to respond to the SEARs requirements summarised below.

Item	Description of Requirement	Section Reference (this report)
6 Visual and Amenity Impacts	provide a reflectivity analysis demonstrating that external treatments, materials and finishes of the development do not cause adverse or excessive glare.	8, 9, 10, 11

Table 1 - SEARs Requirements

4. The site

The site is located within the City of Sydney Local Government Area (LGA). The site is situated approximately 3.3 kilometres south of Sydney CBD and approximately 8 kilometres northeast of Sydney International Airport within the suburb of Waterloo.

The Waterloo Metro Quarter site comprises land to the west of Cope Street, east of Botany Road, south of Raglan Street and north of Wellington Street (refer to Figure 1). The heritage listed Waterloo Congregational Church located at 103–105 Botany Road is within this street block but does not form a part of the Waterloo Metro Quarter Site boundaries.

The Waterloo Metro Quarter site (the site) is a rectangular shaped allotment and an overall site area of approximately 1.287 hectares.

The Waterloo Metro Quarter site comprises the following allotments and legal description at the date of this report. Following consolidation by Sydney Metro (the Principal) the land will be set out in deposited plan DP1257150.

- 1368 Raglan Street (Lot 4 DP 215751)
- 59 Botany Road (Lot 5 DP 215751)
- 65 Botany Road (Lot 1 DP 814205)
- 67 Botany Road (Lot 1 DP 228641)
- 124–128 Cope Street (Lot 2 DP 228641)
- 69–83 Botany Road (Lot 1, DP 1084919)
- 130–134 Cope Street (Lot 12 DP 399757)
- 136–144 Cope Street (Lots A-E DP 108312)
- 85 Botany Road (Lot 1 DP 27454)
- 87 Botany Road (Lot 2 DP 27454)
- 89–91 Botany Road (Lot 1 DP 996765)
- 93–101 Botany Road (Lot 1 DP 433969 and Lot 1 DP 738891)
- 119 Botany Road (Lot 1 DP 205942 and Lot 1 DP 436831)
- 156–160 Cope Street (Lot 31 DP 805384)
- 107–117A Botany Road (Lot 32 DP 805384 and Lot A DP 408116)
- 170–174 Cope Street (Lot 2 DP 205942).

The boundaries of the site the subject of the amending concept DA is identified at Figure 5.1. The site is reasonably flat with a slight fall to the south.

The site previously included three to five storey commercial, light industrial and shop top housing buildings. All previous structures except for an office building at the corner of Botany Road and Wellington Street have been demolished to facilitate construction of the new Sydney Metro Waterloo station. As such the existing site is predominately vacant and being used as a construction site.

Construction of the Sydney metro is currently underway on site in accordance with critical State significant infrastructure approval (CSSI 7400).

Figure 1 - Aerial of the site
Source: Urbis

The area surrounding the site consists of commercial premises to the north, light industrial and mixed-use development to the south, residential development to the east and predominantly commercial and light industry uses to the west.

5. Background

5.1 About Sydney Metro

Sydney metro is Australia's biggest public transport project. Services started in May 2019 in the city's North-west with a train every four minutes in the peak. A new standalone railway, this 21st century network will revolutionise the way Sydney travels. There are four core components:

5.1.1 Sydney Metro North West

This project is now complete and passenger services commenced in May 2019 between Rouse Hill and Chatswood, with a metro train every four minutes in the peak. The project was delivered on time and $1 billion under budget.

5.1.2 Sydney Metro City & Southwest

Sydney Metro City & Southwest project includes a new 30km metro line extending metro rail from the end of Metro Northwest at Chatswood, under Sydney Harbour, through new CBD stations and southwest to Bankstown. It is due to open in 2024 with the ultimate capacity to run a metro train every two minutes each way through the centre of Sydney.

Sydney Metro City & Southwest will deliver new metro stations at Crows Nest, Victoria Cross, Barangaroo, Martin Place, Pitt Street, Waterloo and new underground metro platforms at Central Station. In addition, it will upgrade and convert all 11 stations between Sydenham and Bankstown to metro standards.

5.1.3 Sydney Metro West

Sydney Metro West is a new underground railway connecting Greater Parramatta and the Sydney CBD. This once-in-a-century infrastructure investment will transform Sydney for generations to come, doubling rail capacity between these two areas, linking new communities to rail services and supporting employment growth and housing supply between the two CBDs.

The locations of seven proposed metro stations have been confirmed at Westmead, Parramatta, Sydney Olympic Park, North Strathfield, Burwood North, Five Dock and The Bays.

The NSW Government is assessing an optional station at Pyrmont and further planning is underway to determine the location of a new metro station in the Sydney CBD.

5.1.4 Sydney Metro Greater West

Metro rail will also service Greater Western Sydney and the new Western Sydney International (Nancy Bird Walton) Airport. The new railway line will become the transport spine for the Western Parkland City's growth for generations to come, connecting communities and travellers with the rest of Sydney's public transport system with a fast, safe and easy metro service. The Australian and NSW governments are equal partners in the delivery of this new railway.

The Sydney Metro project is illustrated in Figure 2.

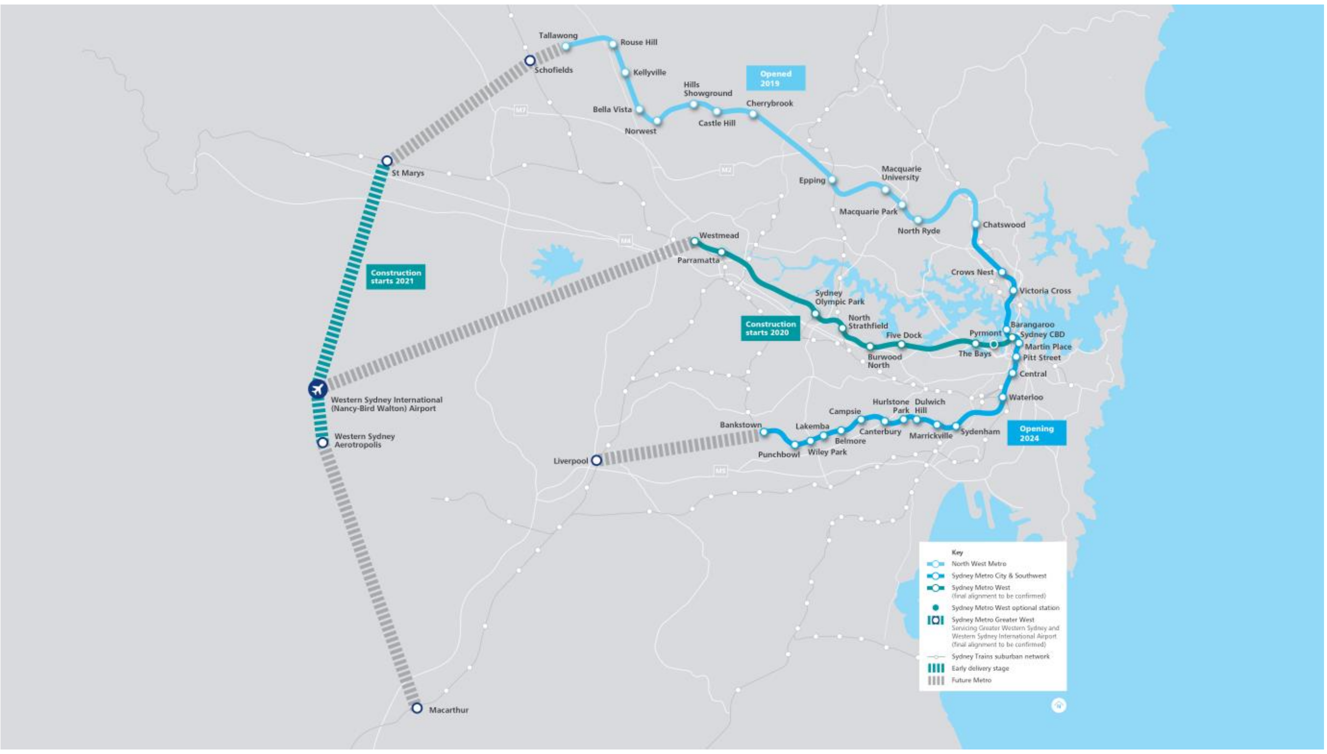

Figure 2 - Sydney Metro alignment map
Source: Sydney Metro

5.2 Sydney Metro CSSI Approval (SSI 7400)

On 9 January 2017, the Minister for Planning approved the Sydney Metro City & Southwest - Chatswood to Sydenham project as a critical State significant infrastructure (CSSI) project (reference SSI 7400) (CSSI approval). The terms of the CSSI approval includes all works required to construct the Sydney Metro Waterloo Station. The CSSI approval also includes the construction of below and above ground works within the metro station structure for appropriate integration with the OSD.

With regards to CSSI related works, any changes to the ‘metro station box’ envelope and public domain will be pursued in satisfaction of the CSSI conditions of approval and do not form part of the scope of the concept SSD DA or detailed SSD DA for the OSD.

Except to the extent described in the EIS or Preferred Infrastructure Report (PIR) submitted with the CSSI application, any OSD buildings and uses do not form part of the CSSI approval and will be subject to the relevant assessment pathway prescribed by the EP&A Act.

The delineation between the approved Sydney metro works, generally described as within the two ‘metro station boxes’ and surrounding public domain works, and the OSD elements are illustrated in Figure 3.

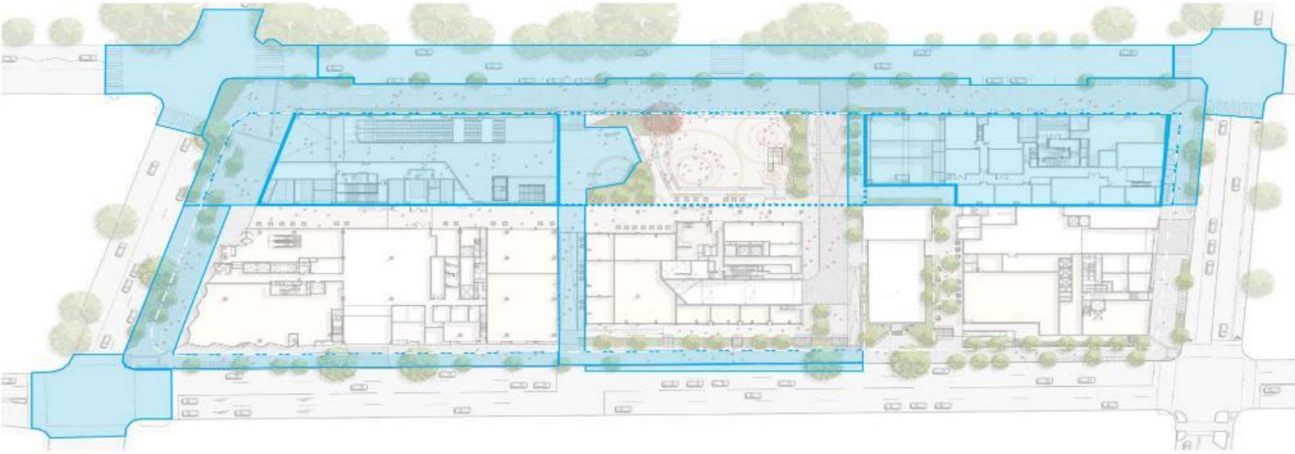

Figure 3 - CSSI Approval scope of works
Source: WL Developer Pty Ltd

5.3 Concept Approval (SSD 9393)

As per the requirements of clause 7.20 of the *Sydney Local Environmental Plan 2012* (SLEP), as the OSD exceeds a height of 25 metres above ground level (among other triggers), development consent is first required to be issued in a concept DA (formerly known as Stage 1 DA).

Development consent was granted on 10 December 2019 for the concept SSD DA (SSD 9393) for the Waterloo Metro Quarter OSD including:

- a maximum building envelope for podium, mid-rise and tower buildings
- a maximum gross floor area of 68,750sqm, excluding station floor space
- conceptual land use for non-residential and residential floor space
- minimum 12,000sqm of non-residential gross floor area including a minimum of 2,000sqm of community facilities
- minimum 5% residential gross floor area as affordable housing dwellings
- 70 social housing dwellings
- basement car parking, motorcycle parking, bicycle parking, and service vehicle spaces.

This concept DA has been prepared and submitted to the DPIE and proposes to make modifications to the approved building envelopes at the northern precinct and central building. This amending concept SSD DA does not impact the proposed development within the southern precinct.

A concurrent detailed SSD DA will seek development consent for the OSD located within the southern precinct of the site, consistent with the parameters of the original concept approval. Separate SSD DAs have been prepared and will be submitted for the northern precinct, central building, and basement proposed across the Waterloo Metro Quarter site consistent with the amending concept DA.

6. Proposed development

The amending concept DA seeks consent for an amended building envelope and description of development for the northern precinct of the Waterloo Metro Quarter site approved under SSD 9393. Specifically, the proposal seeks to modify the approved building envelope for the northern precinct (previously comprising ‘Building A’, ‘Building B’, ‘Building C’ and ‘Building D’ under SSD 9393) through:

- increasing the maximum building height for the southern portion of the Northern Precinct from RL56.2 to RL72.60
- removing the ‘tower component’ of the Northern Precinct, reducing the overall height of the tower envelope from RL116.9 to RL90.40, to enable the redistribution of floor space to commercial office floor plates
- amending the description of development to refer to a mid-rise (approximately 17 storey) commercial office building, comprising approximately 34,125sqm of commercial office floor space within the northern portion of the site, rather than a third residential tower.

The concept DA seeks to modify the central building approved building envelope (previously comprising ‘Building E’ under SSD 9393) through:

- modifying the eastern extent of the podium envelope.

The modification of the approved concept SSD DA will enable the detailed design of a new commercial building (comprising office and retail premises) to be pursued on the site, significantly increasing the proportion of employment generating floor space on the Waterloo Metro Quarter site. This new commercial building is proposed in replacement of four building envelopes approved under SSD 9393, which comprised one residential tower, and three mid-rise residential buildings.

This proposal will not exceed the permissible building height for the site under the SLEP or the maximum height approved under SSD 9393. As noted above, separate detailed SSD DA(s) will be lodged concurrently for the detailed design, construction and operation of the northern precinct, and central building.

This amending concept DA does not propose to the amend the original concept approval as it relates to the southern precinct.

7. Methodology

An assessment has been undertaken to investigate the impact that solar reflections emanating from the development will have on the surrounding urban terrain. This assessment was based on a Proposed Detailed Scheme that is wholly contained within the Amended Concept Envelope given that it is sunlight reflected off of reflective elements (e.g., glazing) of a detailed scheme that is important, rather than a massing envelope.

This analysis was conducted in two parts. First a 'screening' simulation estimated peak reflection intensities and the frequency of occurrence of reflections which may cause glare for a broad area around the development. This was done in order to understand the potential for thermal and visual impacts to people and property due to the reflections.

The screening analysis intentionally assumed a very conservative direction in which the viewer is facing (horizontal, but directly towards the building). In the event that reflections are predicted on roadways, a second 'detailed' analysis was undertaken. This investigates the potential for glare at select locations in greater temporal detail and also included the effect of the direction in which the viewer is likely to be facing.

7.1 Urban Reflections

While a common occurrence, solar reflections from buildings can lead to numerous visual and thermal issues.

Visual glare can:

- Impair the vision of motorists and others who cannot easily look away from the source;
- Cause nuisance to pedestrians or occupants of nearby buildings; and,
- Create undesirable patterns of light throughout the urban fabric.

Heat gain can:

- Affect human thermal comfort;
- Be a safety concern for people and materials, particularly if multiple reflections are focused in the same area; and
- Create increased cooling needs in conditioned spaces affected by the reflections.

The most significant safety concerns with solar reflections occur with concave facades (Figure 4) which act to focus the reflected light in a single area. The current design does not feature concave elements. As such, the focusing of energy is not expected from this project.

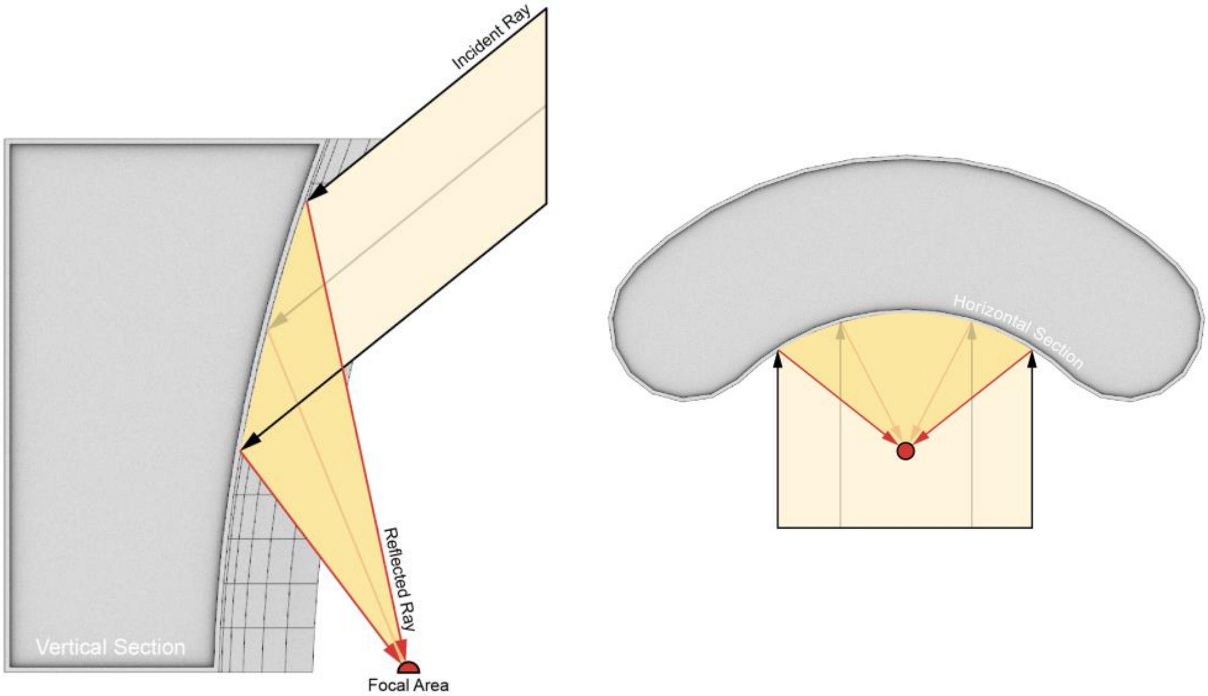

Figure 4 – Illustration of Reflection Focusing Due to Concave Facade

7.2 Analysis Methodology

The analysis was conducted using RWDI's in-house proprietary Eclipse software, as per the steps outlined below:

- The assessment began with the development of a 3D model of the area of interest (as shown in Figure 5). This was then subdivided into many smaller triangular patches (see Figure 6).
- For each hour in a year, the expected solar position was determined, and "virtual rays" were drawn from the sun to each triangular patch of the 3D model. Each ray that was considered to be "unobstructed" was reflected from the building surface and tracked through the surrounding area. The study domain included the entire urban realm within 380 m of the proposed building.
- The total reflected energy at that hour from all of the patches was computed and its potential for visual and thermal impacts was assessed.
- Finally, a statistical analysis was performed to assess the frequency, and intensity of the glare events occurring throughout the year. The criteria used to assess the level of impact can be found in Appendix 1 of this report.
- In the event that the potential for glare exists on roadways, the detailed analysis phase is triggered.
- This analysis works similarly to the screening simulation, except glare is tested at one minute increments and a direction of view is explicitly prescribed.
- The detailed study also provides the locations on a building where the glare emanates from and the level of reflectivity reduction required to comply with local criteria.

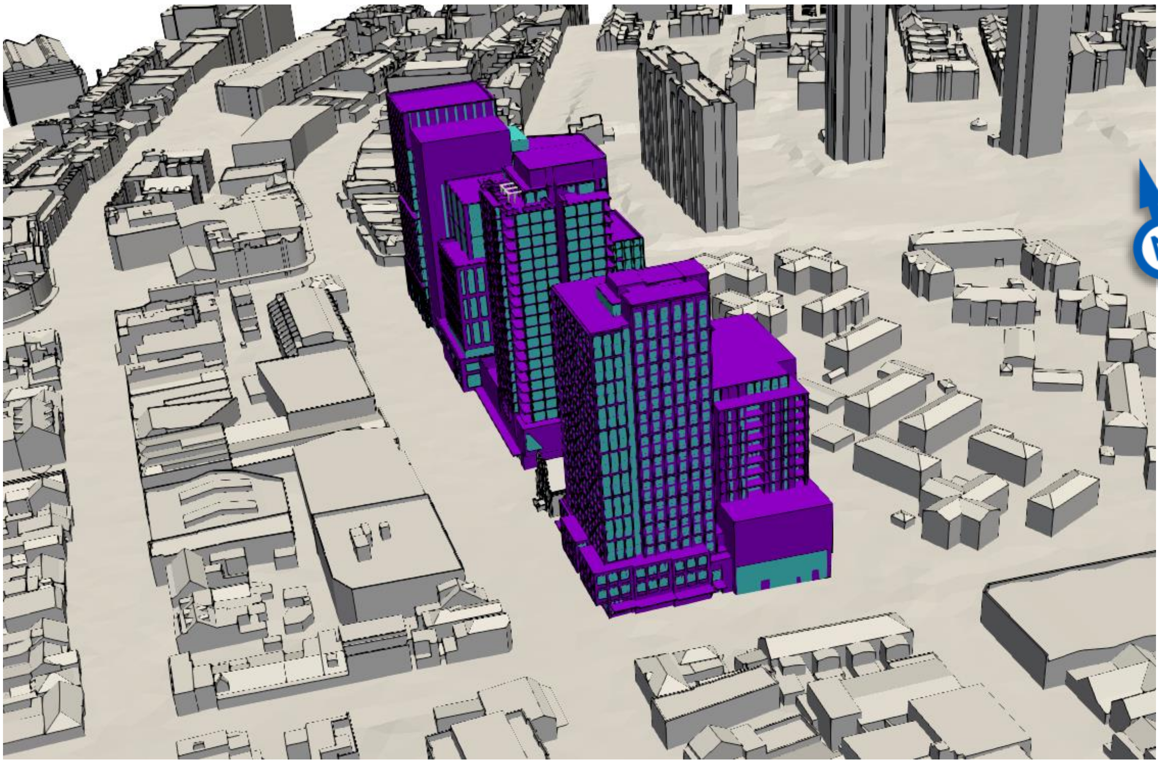

Figure 5 – 3D Computer Model of the Proposed Building and Surrounding Context

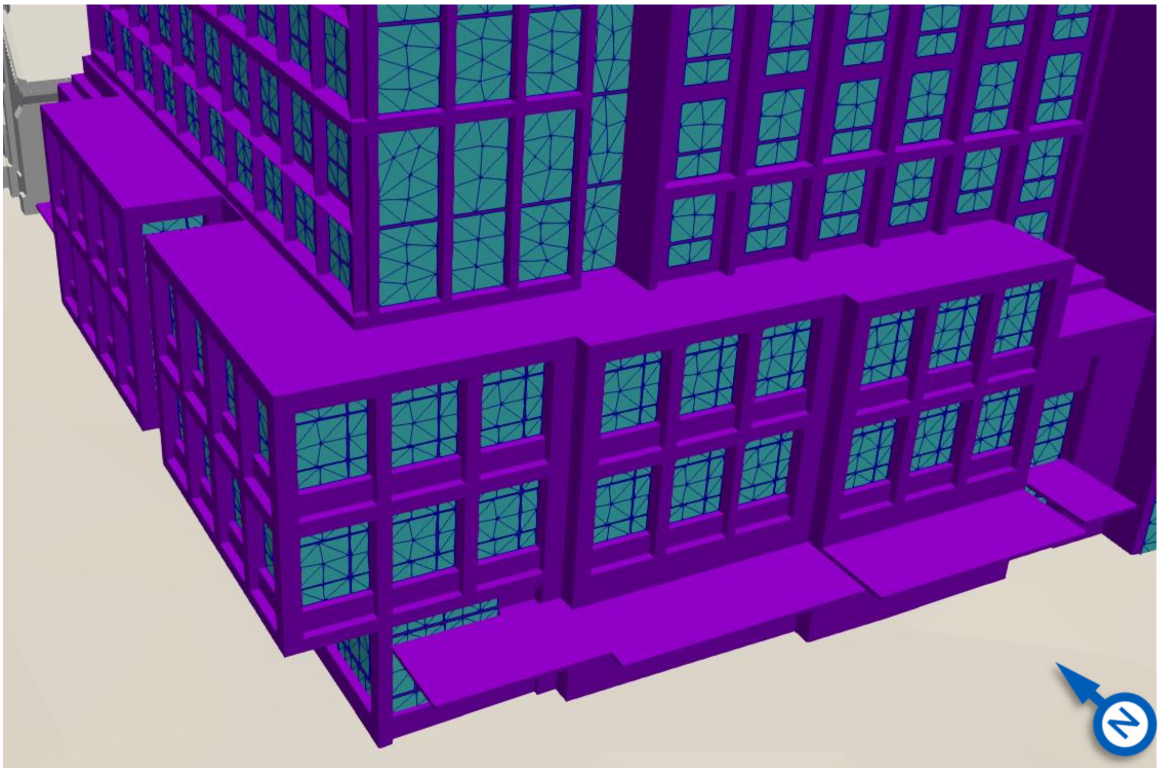

Figure 6 – Close-up View of the Model, Showing Surface Subdivisions

7.3 Assumptions and Limitations

Meteorological Data
This analysis used 'clear sky' solar data computed at the location of Sydney Airport. This approach uses mathematical algorithms to derive solar intensity values for a given location, ignoring local effects such as cloud cover. This provides a 'worst case' scenario showing the full extent of when and where glare could ever occur.

Radiation Model
RWDI's analysis is only applicable to the thermal and visual impacts of solar radiation (i.e. ultraviolet, visible and infrared wavelengths) on people and property in the vicinity of the development. It does not consider the impact of the building related to any other forms of radiation, such as cellular telephone signals, RADAR arrays, etc.

Potential reductions of solar reflections due to the presence of vegetation or other non-architectural obstructions were not included, nor are reflections from other buildings. Light that has reflected off several surfaces is assumed to have a negligible impact. As such, only a single reflection from the development was included in the analysis.

Study Building and Surrounds Models
The analysis was conducted based information provided to RWDI as listed in Section 10 of this report.

Facade Material Reflectance
RWDI assumed a generic glazing unit with a nominal reflectivity of 20% has been used for all envelope glazing. For the rooftop photovoltaic (PV) panels, a nominal reflectivity of 4% was assumed. This is a conservative assumption, representative of PV panels with smooth glass and no anti-reflective coating.

The reflectivity of both surface types increases with increasing angle of incidence. It is RWDI's understanding that no other elements on the building envelope will be significantly reflective.

Applicability of Results
The results presented in this report are highly dependent on the form and materiality of the facade of the proposed building.

Should there be any substantial changes to the design of the building or the reflectivity of the glazing, it is recommended that RWDI be contacted and requested to review their potential effects on the findings of this report.

This report has endeavoured to provide a robust and suitably conservative analysis of the potential effects of reflected sunlight, contextualised based on current industry and academic research, and common best practice principles. Regulation and enforcement of performance requirements is the responsibility of the relevant regional regulatory authority.

8. Assessment and Findings

8.1 Screening Analysis Results

This section presents the screening results pertaining to the solar impacts of the development on the surrounding urban area. The following plots are presented:

- **Peak Annual Reflected Irradiance:** Figure 7 displays the maximum intensity of solar energy reflected from the building at any point in the year. The plot identifies any areas where solar energy may be concentrated and create thermal risks. As a reference point, 800 W/m² is a typical maximum intensity of direct sunlight.

- **Percentage of Time Above the Veiling Luminance Threshold:** Figure 8 identifies the percentage of daytime hours where the veiling luminance was predicted to exceed the 500 cd/m² limit proposed by Hassall. Note that as a conservative assumption, at each location it is assumed a viewer is facing horizontally in the direction of the building.

Note that the veiling luminance computation assumes a viewer age of 60 years old. This represents approximately the 80th percentile age of the residents of New South Wales.

The intention of the following plots is to illustrate the general characteristics of reflections from the development.

In order to attain a complete understanding of the impact that reflections may have on people, other factors must be considered, including where the viewer is looking, which is explored in the detailed study noted in Section 9.2

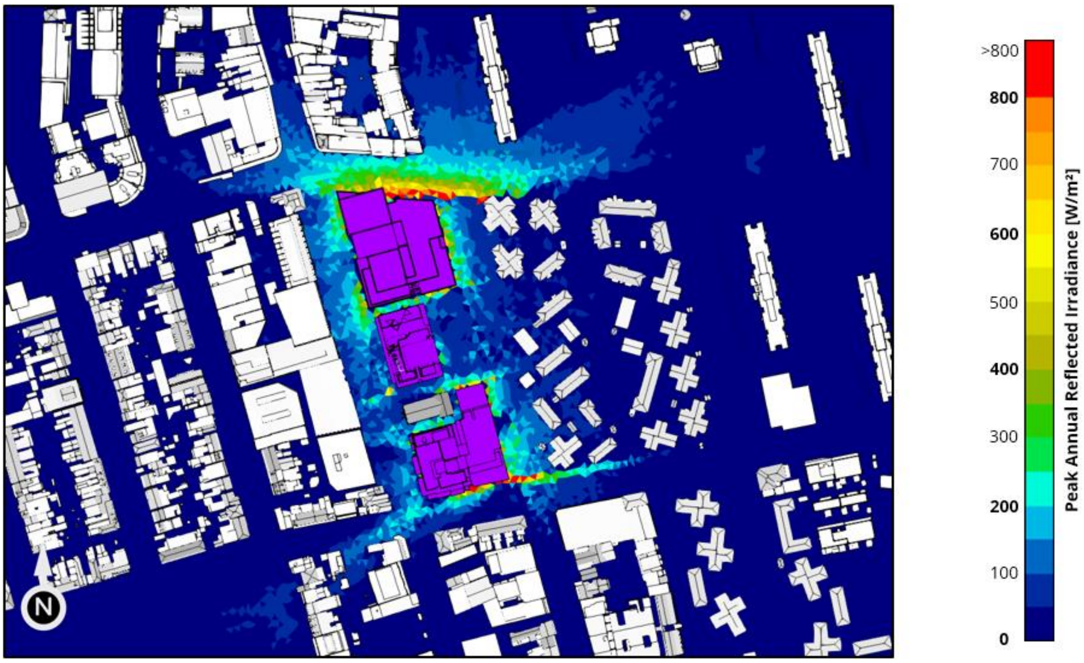

Figure 7 – Maximum Annual Intensity of Reflections at Ground Level (eye height)

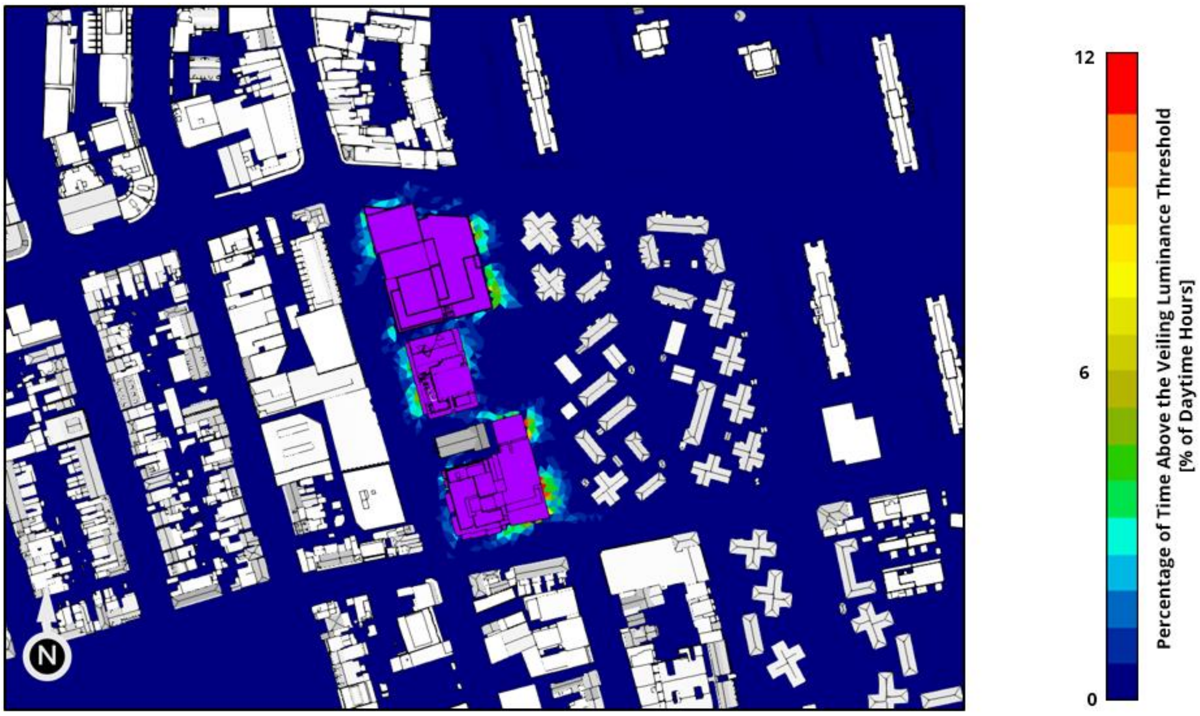

Figure 8 – Frequency (% of Daylit Hours) Where Veiling Luminance is Above Threshold at Ground Level (eye height) for an 80th Percentile Resident (Age 60)

8.2 Detailed Analysis Results

Based on the findings of the Screening Analysis and the risk levels associated with reflections effecting specific areas, 5 representative points were selected for the Detailed Analysis. These points are described in Table 2 and illustrated in Figure 9.

The direction of view is indicated by the arrows in Figure 9.

Receptor Number	Receptor Description
D1	Northbound drivers on Cope Street at Raglan Street
D2	Eastbound drivers on Raglan Street at Botany Road
D3	Northbound drivers on Botany Road
D4	Eastbound drivers on Wellington Street at Botany Road
D5	Northbound drivers on Cope Street near crosswalk

Table 2 - Receptor Description

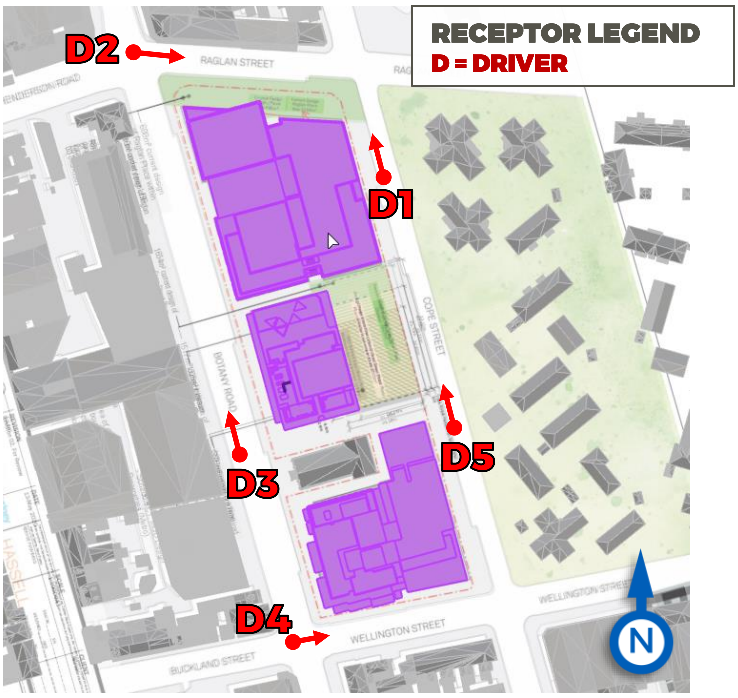

Figure 9 – Receptor Locations (Map Underlay Credit: Microsoft Bing Maps)

Note that the direction of travel of interest along Botany Road and Cope Street is northbound. Due to the development consisting of three buildings (Building 1, Building 2, and Building 3/4) in a row and due to the design of the northern most face of Building 1, the potential impacts from the development as a whole are quite low. This can be seen in the screening results shown in Figures 7 and 8. The impacted areas are adjacent to the east and west facing façades, meaning that the impacts are either happening in the mornings or evenings, in which case the impact will be minimal since the reflections impact a driver from the side, or during winter when the sun is low and in the north and causes glancing angle reflections onto the road. This latter case has a greater potentially to be problematic since these reflections are much more likely to be in a driver's line of sight, but only if they are travelling northbound. Therefore, receptor points D1, D3, and D5 were oriented northbound to confirm if those glancing angle impacts were occurring.

Results are illustrated using "annual impact diagrams". These plots condense the minute-by-minute annual dataset into a single image. The vertical axis represents the time of the day and the horizontal axis indicates the day of the year.

Please note that the referenced times are in local standard time, so in jurisdictions where Daylight Savings Time is used, the time should be shifted by an hour when appropriate.

The colours on this plot indicate when all reflections falling on a specific point can occur and if the predicted veiling luminance exceeds the disability glare threshold (500 cd/m²). Hatching (darker green areas) indicates when the sun would be within 20° of a motorists' direction of view.

8.2.1 Receptor D1

Receptor D1 was chosen to assess the visual impact associated with solar reflections affecting drivers travelling northbound on Cope Street at Raglan Street.

The simulations indicate that reflections fall on this point intermittently during the winter months between 7:00 am AEST and 10:00 am AEST. Reflections are also possible between 11:00 am and noon from September through early April.

None of the reflections were predicted to result in a veiling luminance above 500 cd/m²

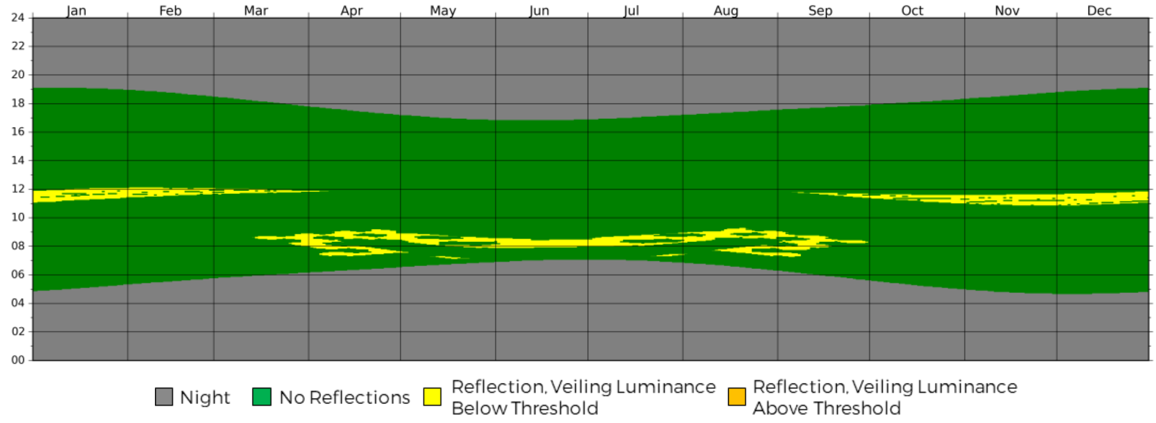

Figure 10 – Annual Reflection Impact Diagram for Driver Receptor D1

8.2.2 Receptor D2

Receptor D2 was chosen to assess the visual impact associated with solar reflections affecting drivers travelling eastbound on Raglan Street at Botany Road.

The predicted reflection conditions at D2 indicate that reflections mainly fall between 9:00 am AEST and noon between March and mid-October.

Again, no reflections are expected to exceed the veiling luminance threshold.

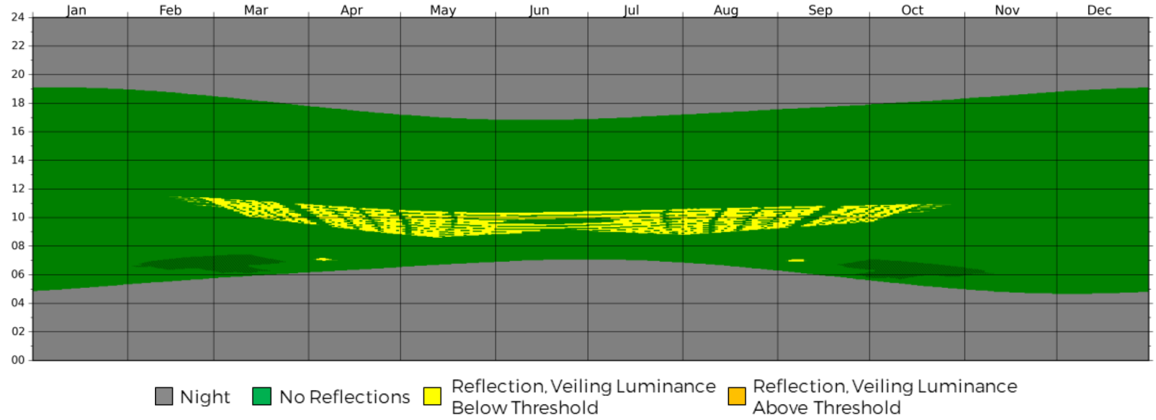

Figure 11 – Annual Reflection Impact Diagram for Driver Receptor D2

8.2.3 Receptor D3

Receptor D3 was chosen to assess the visual impact associated with solar reflections affecting drivers travelling northbound on Botany Road.

The simulations indicate that reflections can fall onto this location infrequently with short duration throughout the year. These reflections are very sporadic and infrequent and the predicted veiling luminance of all reflections falls below the 500 cd/m² threshold.

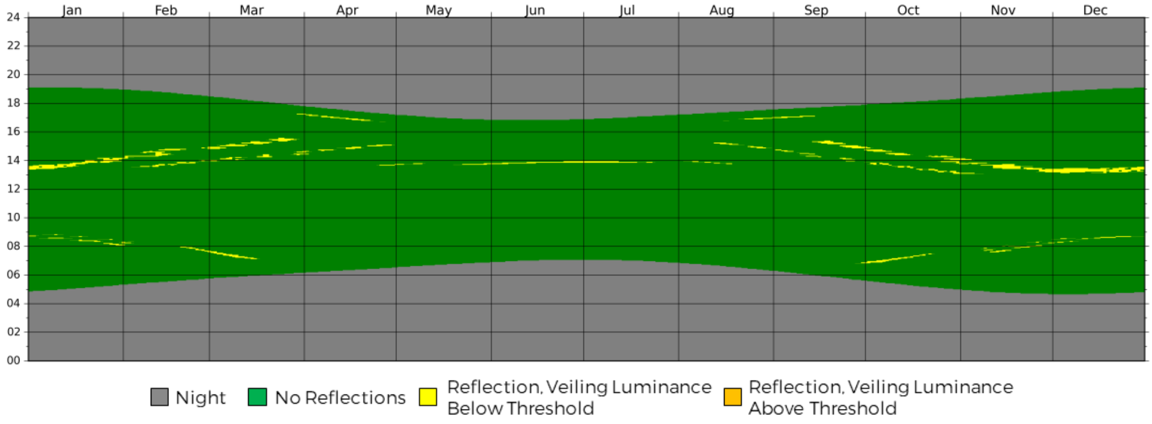

Figure 12 – Annual Reflection Impact Diagram for Driver Receptor D3

8.2.4 Receptor D4

Receptor D4 was chosen to assess the visual impact associated with solar reflections affecting drivers travelling eastbound on Wellington Street at Botany Road.

Intermittent reflections were predicted to reach this area throughout much of the year between 2:00 pm and 5:00 pm AEST. During summer mornings reflections are also possible between 6:00 am and 8:00 am AEST.

None of the reflections were predicted to have a veiling luminance that exceeded 500 cd/m².

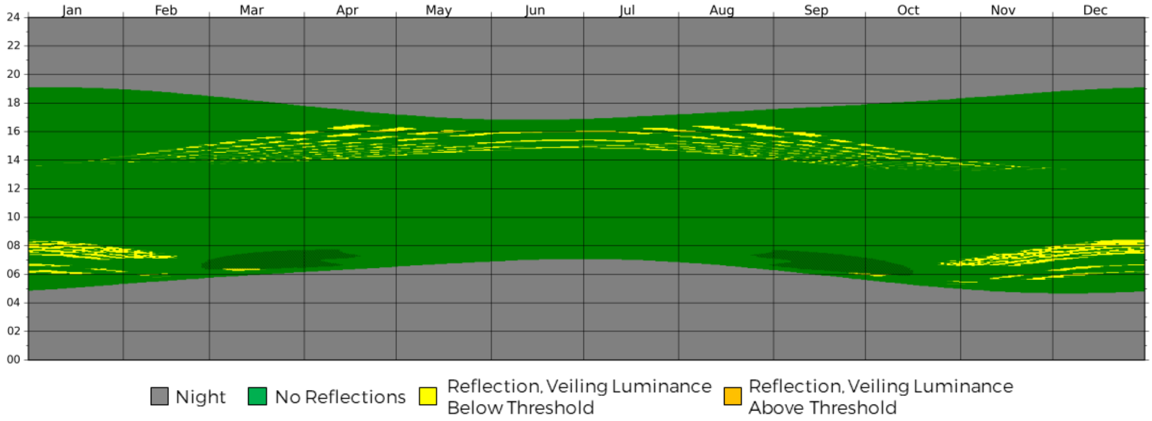

Figure 13 – Annual Reflection Impact Diagram for Driver Receptor D4

8.2.5 Receptor D5

Receptor D5 was chosen to assess the visual impact associated with solar reflections affecting drivers travelling northbound on Cope Street near crosswalk.

The simulation indicated that at this location, intermittent reflections are possible between 7:00 am and 11:00 am AEST between February and early-November.

Again, no reflections are expected to exceed the veiling luminance threshold.

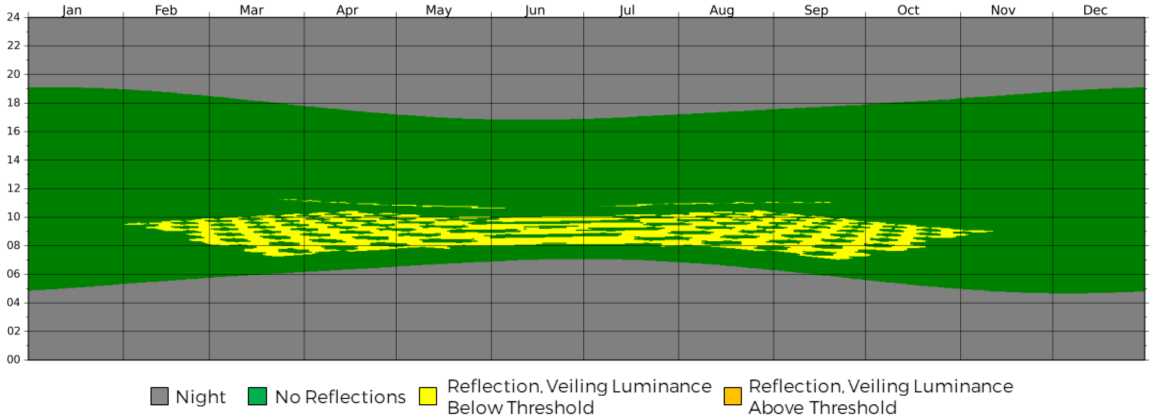

Figure 14 – Annual Reflection Impact Diagram for Driver Receptor D5

9. Conclusion

An assessment has been undertaken to investigate the impact that solar reflections emanating from the development will have on the surrounding urban terrain. Like any contemporary building, the reflective surfaces of the proposed project are naturally causing solar reflections in the surrounding area. The findings of the study are summarised as follows:

- The maximum intensities of the reflected solar energy are predicted to be moderate, with the majority of reflections having a maximum intensity below 650 W/m². Thus, RWDI does not anticipate any significant heat gain issues on people or property, nor do we expect the reflections to create significant additional heat loads in adjacent buildings.
- The screening analysis predicted low potential for glare. Most locations had the potential for glare less than 5% of daylight hours, even with the highly conservative assumption that the viewer would always be looking horizontally towards the source of the reflection.
- The detailed analysis, which accounted for more realistic view directions and operated at one-minute increments, predicted that driver receptor points travelling on roads in the vicinity of the project have the potential to be exposed to reflections. However, assuming that drivers are maintaining forward eye contact, the predicted veiling luminance of all reflections is below the 500 cd/m² limit.
- Given the safety risks associated with glare impacts to drivers, RWDI's analysis is intentionally conservative. It assumed clear skies for all daytime hours and ignored the effects of any landscaping, the use of sunglass, as well as obstructions to reflected light due to the car body.
- Overall this analysis indicates that the proposed project complies with local requirements with respect to solar reflectivity so long as the nominal visible reflectivity of the glazing remains at 20% or lower.

10. Applicability of Results

The drawings and information listed below were received from Woods Bagot, Hassell, and Bates Smart. The findings presented in this report pertain to the proposed design as detailed in the architectural design drawings listed in the table below. Should there be any design changes that deviate from this list of drawings, the predictions presented may change. Therefore, if changes in the design are made, it is recommended that RWDI be contacted.

File Name	File Type	Date Received (dd/mm/yyyy)
Building 1 (Woods Bagot)		
WMQ-SITE-HAS-UD-MDL-0005	DWG	12/06/2020
WMQ-BLD1-WBG-AR-DRG-DA001-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA002-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA003-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA091-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA092-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA100-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA100M-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA101-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA102-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA103-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA104-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA105-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA108-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA109-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA110-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA113-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA114-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA115-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA116-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA117-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA121-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA122-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA123-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA124-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA131-dwg[B]	DWG	28/07/2020

File Name	File Type	Date Received (dd/mm/yyyy)
WMQ-BLD1-WBG-AR-DRG-DA132-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA133-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA134-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA141-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA142-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA143-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA144-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA145-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA146-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA147-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA148-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA149-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA190-dwg[B] WMQ-BLD1-WBG-AR-DRG-DA191-dwg[B]		
Building 2 (Hassell)		
WMQ-SITE-HAS-UD-MDL-0005	DWG	12/06/2020
WMQ-BLD2-HAS-AR-DRG-DA001 WMQ-BLD2-HAS-AR-DRG-DA002 WMQ-BLD2-HAS-AR-DRG-DA010 WMQ-BLD2-HAS-AR-DRG-DA011 WMQ-BLD2-HAS-AR-DRG-DA012 WMQ-BLD2-HAS-AR-DRG-DA013 WMQ-BLD2-HAS-AR-DRG-DA014 WMQ-BLD2-HAS-AR-DRG-DA015 WMQ-BLD2-HAS-AR-DRG-DA016 WMQ-BLD2-HAS-AR-DRG-DA017 WMQ-BLD2-HAS-AR-DRG-DA018 WMQ-BLD2-HAS-AR-DRG-DA019 WMQ-BLD2-HAS-AR-DRG-DA020 WMQ-BLD2-HAS-AR-DRG-DA021 WMQ-BLD2-HAS-AR-DRG-DA022 WMQ-BLD2-HAS-AR-DRG-DA023	DWG	29/07/2020

File Name	File Type	Date Received (dd/mm/yyyy)
WMQ-BLD2-HAS-AR-DRG-DA024 WMQ-BLD2-HAS-AR-DRG-DA025 WMQ-BLD2-HAS-AR-DRG-DA026 WMQ-BLD2-HAS-AR-DRG-DA027 WMQ-BLD2-HAS-AR-DRG-DA028 WMQ-BLD2-HAS-AR-DRG-DA029 WMQ-BLD2-HAS-AR-DRG-DA030 WMQ-BLD2-HAS-AR-DRG-DA031 WMQ-BLD2-HAS-AR-DRG-DA032 WMQ-BLD2-HAS-AR-DRG-DA033 WMQ-BLD2-HAS-AR-DRG-DA034 WMQ-BLD2-HAS-AR-DRG-DA035 WMQ-BLD2-HAS-AR-DRG-DA101 WMQ-BLD2-HAS-AR-DRG-DA102 WMQ-BLD2-HAS-AR-DRG-DA103 WMQ-BLD2-HAS-AR-DRG-DA201 WMQ-BLD2-HAS-AR-DRG-DA202 WMQ-BLD2-HAS-AR-DRG-DA301 WMQ-BLD2-HAS-AR-DRG-DA302 WMQ-BLD2-HAS-AR-DRG-DA303 WMQ-BLD2-HAS-AR-DRG-DA304 WMQ-BLD2-HAS-AR-DRG-DA401 WMQ-BLD2-HAS-AR-DRG-DA402 WMQ-BLD2-HAS-AR-DRG-DA501 WMQ-BLD2-HAS-AR-DRG-DA502 WMQ-BLD2-HAS-AR-DRG-DA503 WMQ-BLD2-HAS-AR-DRG-DA601 WMQ-BLD2-HAS-AR-DRG-DA701 WMQ-BLD2-HAS-AR-DRG-DA801 WMQ-BLD2-HAS-AR-DRG-DA901 WMQ-BLD2-HAS-AR-DRG-DA902		
Building 3 (Bates Smart)		
WMQ-SITE-HAS-UD-MDL-0005	DWG	12/06/2020

File Name	File Type	Date Received (dd/mm/yyyy)
WMQ-BLD3-BSA-AR-DRG-DA100-dwg_G WMQ-BLD3-BSA-AR-DRG-DA100M-dwg_F WMQ-BLD3-BSA-AR-DRG-DA101-dwg_F WMQ-BLD3-BSA-AR-DRG-DA102-dwg_F WMQ-BLD3-BSA-AR-DRG-DA103-dwg_F WMQ-BLD3-BSA-AR-DRG-DA106-dwg_F WMQ-BLD3-BSA-AR-DRG-DA116-dwg_D WMQ-BLD3-BSA-AR-DRG-DA123-dwg_F WMQ-BLD3-BSA-AR-DRG-DA124-dwg_F WMQ-BLD3-BSA-AR-DRG-DA125-dwg_F	DWG	28/07/2020
WMQ-BLD3-BSA-AR-DRG-DA140-dwg_C WMQ-BLD3-BSA-AR-DRG-DA141-dwg_C WMQ-BLD3-BSA-AR-DRG-DA142-dwg_C WMQ-BLD3-BSA-AR-DRG-DA143-dwg_C WMQ-BLD3-BSA-AR-DRG-DA150-dwg_E WMQ-BLD3-BSA-AR-DRG-DA151-dwg_F	DWG	29/07/2020
Building 4 (Bates Smart)		
WMQ-SITE-HAS-UD-MDL-0005	DWG	12/06/2020
WMQ-BLD4-BSA-AR-DRG-DA101-dwg_I WMQ-BLD4-BSA-AR-DRG-DA102-dwg_D WMQ-BLD4-BSA-AR-DRG-DA103-dwg_I WMQ-BLD4-BSA-AR-DRG-DA108-dwg_H WMQ-BLD4-BSA-AR-DRG-DA109-dwg_H WMQ-BLD4-BSA-AR-DRG-DA110-dwg_G	DWG	28/07/2020
WMQ-BLD4-BSA-AR-DRG-DA140-dwg_D WMQ-BLD4-BSA-AR-DRG-DA141-dwg_D WMQ-BLD4-BSA-AR-DRG-DA142-dwg_D WMQ-BLD4-BSA-AR-DRG-DA143-dwg_D WMQ-BLD4-BSA-AR-DRG-DA150-dwg_H WMQ-BLD4-BSA-AR-DRG-DA151-dwg_B WMQ-BLD4-BSA-AR-DRG-DA160-dwg_E	DWG	29/07/2020

File Name	File Type	Date Received (dd/mm/yyyy)
WMQ-BLD4-BSA-AR-DRG-DA161-dwg_E WMQ-BLD4-BSA-AR-DRG-DA162-dwg_E WMQ-BLD4-BSA-AR-DRG-DA163-dwg_E		

11. Appendices

11.1 Appendix 1 – RWDI Reflection Criteria

The following sections describe the criteria applied. References are listed in Appendix 2.

Visual Glare
RWDI has extensive experience in the analysis and assessment of the impacts of sunlight and solar energy reflected from buildings[1].

In the work described herein, we have adopted the typical Australian criteria put forth by Hassall[2], which defines glare as occurring when the veiling luminance of a reflection exceeds 500 cd/m².

Veiling luminance was computed using the CIE General Disability Glare Equation[3]. This equation is a more robust formulation of the classical Stiles-Holladay glare equation that accounts for the effects of age and eye colour when predicting veiling luminance. This formulation remains valid for light sources between 0.1° and 100° away from the direction of view.

RWDI conservatively assumed a light-blue eye colour (pigmentation factor of 1.2) and an observer age of 60 years old for this work. Based on the most recent Australian Census, this age represents approximately the 80th percentile age for the residents of New South Wales. This means that in reality, veiling luminance would be lower than these predictions for 80% of the population.

It should be noted that the 500 cd/m² limit assumes an adaptation luminance corresponding to a dawn or dusk time frame and may be overly conservative during brighter parts of the day.

Thermal Impact (Heat Gain) on People
The primary sources for exposure limits to thermal radiation come from fire protection literature. However, there is currently inconsistency between different bodies regarding what level of exposure can be reasonably tolerated by people.

The U.S. National Fire Protection Association (NFPA) defines 1,700 W/m² as an upper limit for a tenable egress environment[4]; i.e. an individual could escape through such an environment successfully, though they would not necessarily emerge unscathed. The British Standards Institution[5] sets their limit at 2,000 W/m², which "…is tolerable for ~ 5 min[utes]…". Other researchers[6] have found that higher irradiance levels (3,500 – 5,000 W/m²) can be tolerated in outdoor environments for several minutes without issue.

The only current quantitative guideline specific to reflections comes from the City of London's Planning Note on 'Solar Convergence'[7]. Produced in conjunction with the UK Building Research Establishment (BRE), this document indicates that no areas should receive 10,000 W/m² or more for any duration, exposures above 2,500 W/m² should be limited to less than 30 seconds; and that "…areas with reflected irradiances above 1,500 W/m², and preferably those above 1000 W/m², should be minimized."

It should be noted that all these thresholds are guideline values only, and that in reality many factors (skin colour, age, clothing choice, etc.) influence how a person reacts to thermal radiation.

Clearly, there are currently no definitive guidelines or criteria with respect to the issue of thresholds for exposure to thermal irradiance in an urban setting. We know this criterion should be lower than the thresholds set in the context of an individual escaping from a fire and greater than typical peak solar noon levels of 1,000 W/m² which people commonly experience.

Therefore, RWDI's opinion at this time, is that reasonable criteria is to establish 2,500 W/m² as a ceiling exposure limit, which reflection intensity should not exceed for any length of time; and 1,500 W/m² as a short term (10 minutes or less) exposure limit.

Thermal Impact (Heat Gain) on Property

The impact of solar irradiance on different materials is primarily based on the temperature gains to the material which can cause softening, deformation, melting, or in extreme cases, combustion. These temperature gains are difficult to predict as they are highly dependent on the convective heat transfer from air movement around the object and long-wave radiative heat transfer to the surroundings.

Generally, irradiance levels at or above 10,000 W/m² for more than 10 minutes are required to ignite common building and automotive materials in the presence of a pilot flame. That value increases to 25,000 W/m² when no pilot flame is present[8,9,10]. However, some materials like plastics and even some asphalts may begin to soften and deform at lower temperatures. For example, some plastics can deform at a temperature of 140°F (60°C), or lower if force is applied. The applied force typically comes from the thermal expansion of the material, the force of gravity acting on the material or an external mechanical force (i.e. someone or something pushing or pulling on it).

Aside from the risk of damage to the material itself, a hot surface poses a safety risk to any person who may come into contact with it. This is particularly important in an urban context as the individual may not expect the object to be heated. NASA[11] defines an upper limit of 111°F (44°C) for surfaces that require extended contact time with bare skin. Surface temperatures below this limit can be handled for any length of time without causing pain.

That said, surfaces within the urban realm are routinely exposed to reflections from windows, metal panels and bodies of water without causing material damage or excessive heating.

Therefore, as this time, RWDI takes a conservative approach and uses a value of 1,000 W/m², consistent with a single (i.e. non-focused) reflection of the sun's peak intensity, as a baseline threshold for reflected irradiance on stationary objects.

However, this is simply a starting point. As noted, depending on the environmental conditions and material properties of the object/assembly other values may be used instead.

11.2 Appendix 2 – References

1. Danks, R., Good, J., & Sinclair, R., "Assessing reflected sunlight from building facades: A literature review and proposed criteria." Building and Environment, 103, 193-202, 2016.

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6. Raj, P.K., “Field tests on human tolerance to (LNG) fire radiant heat exposure, and attenuation effects of clothing and other objects”, Journal of Hazardous Materials, vol. 157 no. 2-3, 2008.
7. Department of the Built Environment. (2017). Solar Convergence Planning Advice Note. City of London Corporation.
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9. SFPE Handbook of Fire Protection Engineering 4th Edition NFPA/SPFE 2008 USA
10. V. Babrauskas ‘Ignition Handbook’ Fire Science Publishers + SFP, 2003
11. E Ungar, K Stroud ‘A New Approach to Defining Human Touch Temperature Standards’ National Aeronautics and Space Agency, 2010