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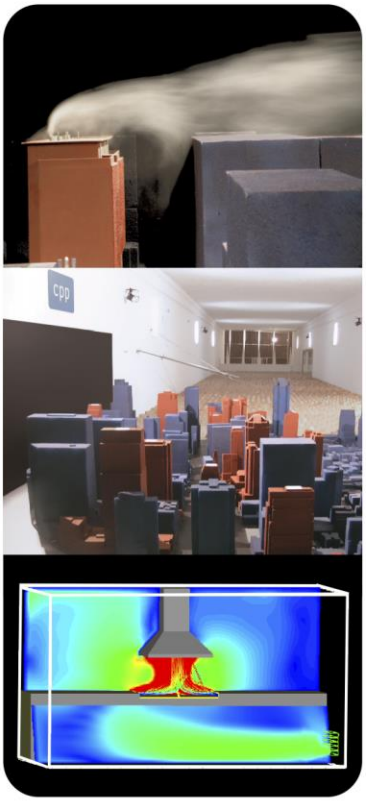
Draft Report



Solar Reflectivity Assessment for:

High Street Penrith

Sydney, Australia

Prepared for:

Toga Group

Level 5, 45 Jones Street,

Ultimo NSW 2007

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CPP Project: 11310

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1 Preamble (Client Provided)

The site is located at 87-91 Union Road / 634-368 High Street in Penrith (Site 1). Toga has another site at 640-652 High Street Penrith (Site 2) which will be progressed in a separate Development Application. Toga's sites are dissected by John Tipping Grove which is a council owned road. This document has been prepared for the Development Application on Site 01, 87-91 Union Road / 634-368 High Street Penrith.

The proposed development comprises of residential buildings, retail and associated parking. Buildings 1 and 2 are joined together by a common ground floor podium, underground basement and podium car parking areas. Thus, both residential buildings are considered to be a united building under a single DA.

The development application subject to these proceedings is amended by way of changes detailed below:

a) Podium - reduction in the scale of the podium from 5 storeys to 4 storeys in the middle section and 2 storeys at the northern and southern ends; decrease in the number of car parking spaces provided within the podium; increased 'sleeving' of car parking provided in the podium with apartments; and enhanced articulation.
b) Basement - increased basement car parking from 1 to 3 levels.
c) Ground level - enhanced activation of the ground floor through relocation of the through site pedestrian link, redistributing and enlarging commercial floorspace, providing stepped sitting edges to the western colonnade facing John Tipping Grove, and increased landscaping.
d) Levels 1 to 3 – increased activation and connection to ground level through additional apartments and enhanced design of communal open space area.
e) Towers - reduction in the height of Tower 2 from 37 to 35 storeys, reduction in height of Tower 1 from 14 storeys to 13 storeys, and redesign to increase building articulation.

The proposed development DA20/0148 seeks consent for a mixed-use development comprising two towers of 35 and 13 storeys located above a part 4 and part 2 storey podium providing 357 residential dwellings with ground level commercial tenancies, 3 levels of basement car parking, a new public road and associated site works on the land at 634-638 High Street and 87-93 Union Road, Penrith NSW.

2 INTRODUCTION

Cermak Peterka Petersen Pty. Ltd. has been engaged by Toga Group to provide an assessment on the potential of the proposed development at Penrith in Sydney, Australia, to produce solar reflectivity impacts on surrounding public roadway locations, Figure 1. The proposed development is bordered by High Street to the north, Union Rd to the south and John Tipping Grove to the west. A temporary new road will also be constructed to the east of the proposed site.

The proposed development consists of two separate towers with height of approximately 49m and 123m above High Street, Figure 2, and is surrounded by mixture of low to medium-rise buildings to the east quadrant.

Figure 1: Aerial view of the proposed development site (Google Earth, 2020).

Figure 2: Structures and massing within the proposed development (perspective view from southwest).

3 CITY OF PENRITH COUNCIL CONSIDERATIONS

CPP have not sighted criteria in the Penrith DCP (2014) quantifying acceptable levels of solar reflectivity for new developments proposed for the Penrith region, with the exception of a general requirement relating to glare under Part C1 Site Planning and Design Principles, 1.2.3 Building Form-Height, Bulk and Scale – f) Building Façade Treatment, item 5:

"design facades to reflect the orientation of the site using elements such as sun shading, light shelves and appropriate glazing as environmental controls."

Many other Australian Council development controls, such as those City of Sydney and Auburn, make a general recommendation for reflectivity limits for building materials to not exceed 20%:

Sydney Development Control Plan 2012, General Provisions, Section 3.2.7 Reflectivity

(2) Generally, light reflectivity from building materials used on facades must not exceed 20%

It is not explicitly defined in Councils' DCP to which component to reflections, specular or diffuse, the prescribed limit is applicable. CPP presumes the reflectivity limit is applicable to the specular component of reflections as they are most associated with traffic disability glare. It is therefore recommended that Toga Group ensure exterior elements on the facades studied in this report will have a specular reflectivity coefficient of 20% or less. This is defined as the percentage of solar reflection when light strikes and reflects normal to the façade plane.

This study does not directly study non-glazing materials/surfaces that produce more diffuse than specular reflections; diffuse reflections are more associated with discomfort glare than disability glare. As CPP are aware, there are no industry accepted criteria guiding design to control discomfort glare from diffuse components of reflections, due to the subjective nature and difficulty of quantifying glare from diffuse components of reflections in terms of amenity. As good practice, it is generally recommended the external surface reflectivity coefficient of chosen materials/surfaces that are more likely to emit diffuse than specular reflections is limited to 20% for the specular component.

4 ASSESSMENT METHODOLOGY

This report assesses the potential for disability glare from solar reflections from the proposed development taking into consideration:

- Seasonal and diurnal solar paths (sun altitude and azimuth) at the project altitude, and the relative angle of the incident and reflected solar rays (reflectivity coefficients of glazing increase with increasing incident angle),
- An assumed specular reflectivity coefficient of 20%, per Council requirements, for the external glazing is used in the calculations, and the incident angle of the solar rays is also accounted for (allowance is made for reflectivity coefficients of glazing to increase with increasing incident angle),
- Receiver locations of interest (the alignment of adjoining public roadways being of particular interest, Figure 3), and
- Architectural drawings provided by Toga Group dated October 21.

Calculations in this report assume the façade surfaces of the proposed development will produce specular type reflections, such as glazing, where the reflected ray angle is equal to the incident solar ray angle, being valid for many smooth surface façade materials. Curved surfaces are not directly quantified in this report; any curved facades of the proposed building were approximated for the assessment by modelling them as multiple vertical flat surfaces to estimate the degree of reflections onto the investigated locations.

CPP use, in part, methodology developed by Hassall (1991), and the concept of veiling glare and contrast when quantifying the potential for hazard rogue specular solar reflections from the proposed development onto selected surrounding receiver locations, Figure 3.

Threshold Increment (TI) is the percentage by which the contrast must be increased relative to the background to make the object just visible due to the addition of glare (generated by the solar reflections) and is the parameter calculated in this study to assess the acceptability of potential glare events. TI is a parameter used in the design of Road Lighting, e.g. AS/NZS 1158.1.1:2005 where a maximum TI value of 20% is used for all roadway lighting categories and is the acceptability criterion adopted in this study for assessing disability glare impact on passing traffic.

Proprietary software was used to calculate TI values at expected maximum impact locations of vehicles travelling in the directions as marked in Figure 3 where potential future changes in traffic conditions have been considered. CPP also utilises the commercially available software suite SGHAT where identified glare impacts approach TI criterion limits and an additional reference is sought. Whilst

the software was developed specifically for the aviation industry, the output provides some additional quantitative guidance.

Certain building materials other than glass, including metallic framing and supports, produce diffuse reflections that are not directly quantified by the methodology adopted in this report. By definition, diffuse reflections have a greater scatter of reflected angles with lower concentration of reflected light in any given direction and are generally less likely to cast hazardous distant disability glare reflections than flat surface glazing. Notwithstanding, these materials and surfaces have potential to produce discomfort glare, and to reduce this impact it is recommended that all non-glazed façade surfaces adopt low lustre, non-glossy, textured or matte finishes.

Figure 3: Investigated impact locations of vehicles travelling in indicated directions.

Results of the assessment are visualised using the publicly available SunCalc tool (Hoffmann), which plots the movement of the sun and sunlight-phase at a specific location and time in the year, Figure 4. The solar plot in Figure 4 plots the incoming solar rays (radial yellow line) from the Sun (orange circle) reflecting off the façade of a building (green line) in the southern hemisphere, at 8am inearly- March, onto a receiver location (labelled "a"). The orange radial line, red radial line, and yellow arc mark the Sun's sunrise position, sunset position, and trajectory, respectively, on this particular day. The shaded yellow region shows the variation of the path of the sun throughout the year; the closer the Sun is to the centre, the higher the sun is above the horizon.

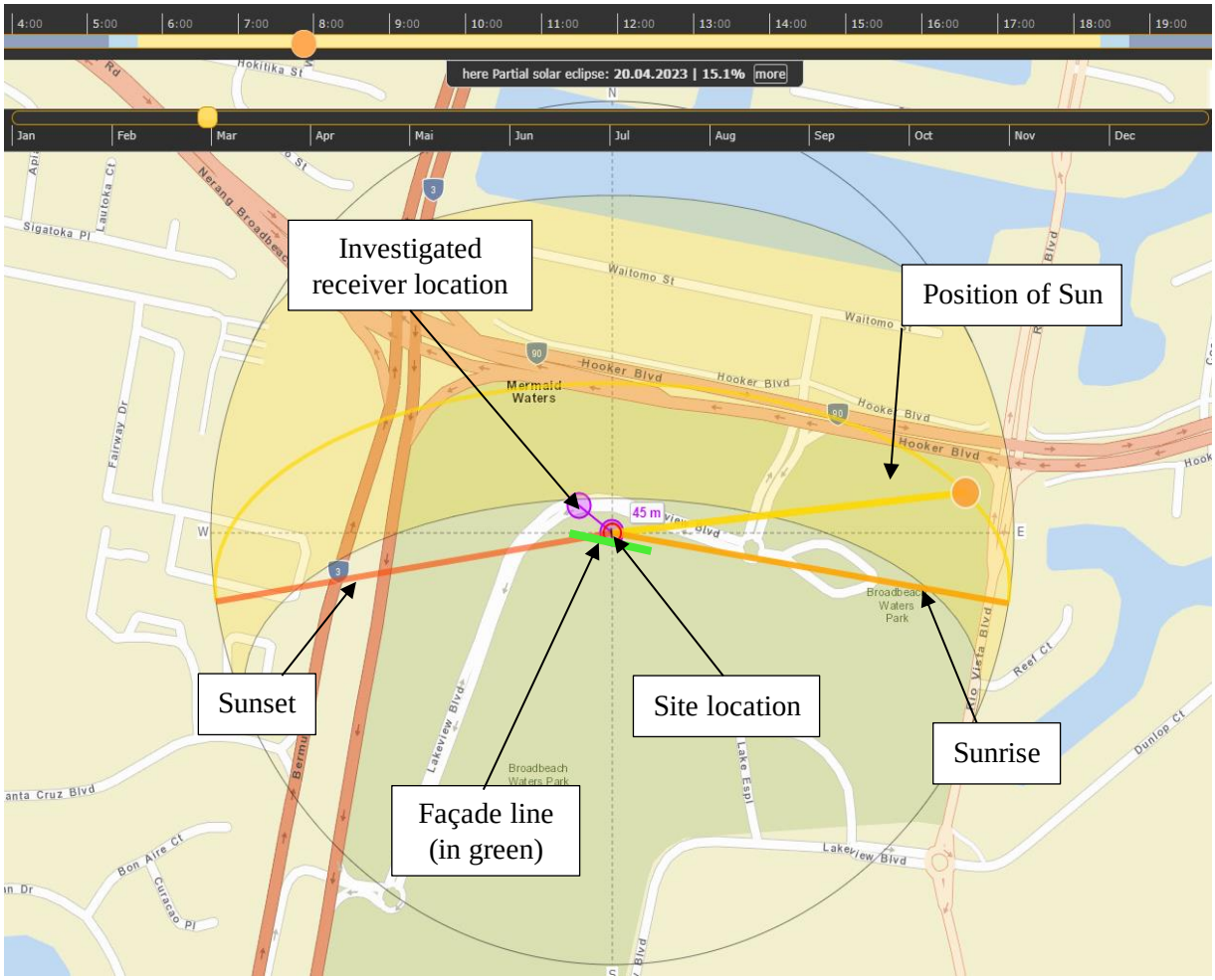

Figure 4: Example usage of the SunCalc tool to visualise solar rays reflecting from a façade.

3 REFLECTIVITY IMPACT RESULTS

3.1 Specular Reflections

Assessment has shown the facades of the proposed High Street Penrith development have the potential to produce specular solar reflections with varying degrees of glare onto surrounding public surrounding roadways. In the first instance as a 'worse' case scenario, the proposed building was modelled as isolated from surrounding buildings and the investigated locations in Figure 3 consider future changes to traffic conditions along the adjacent roadways by assuming traffic can travel in both directions. The façade surfaces that were considered and modelled in this assessment is shown in Figure 5.

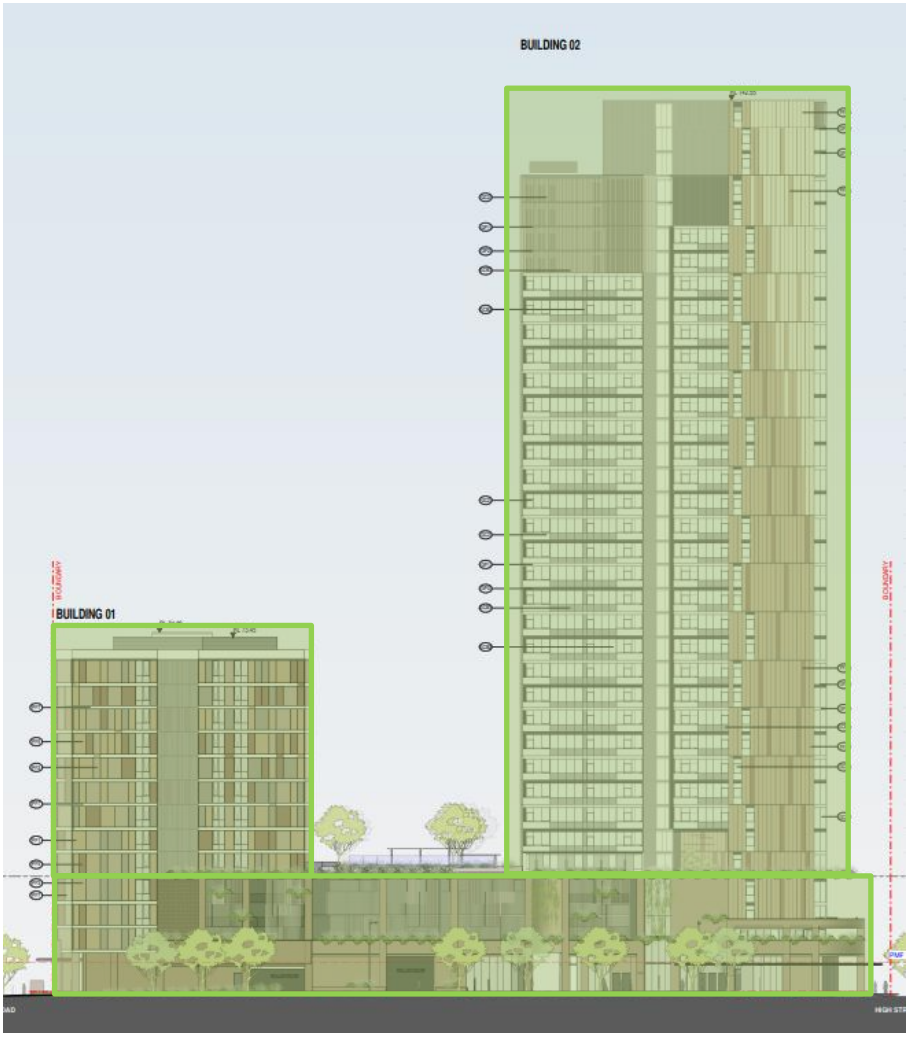

Figure 5: Modelling approximation of facades (green) for the reflectivity assessment.

3.2 Diffuse Reflections

3.2.1 Curved Façade Elements

Diffuse solar reflections that will emanate from convex façade surfaces on the proposed development will diverge into different directions and continually shift throughout the day. The divergent nature of the solar reflections is usually less substantial than specular solar reflections from flat surfaces since divergent solar reflections are not concentrated in one direction, thus producing lower levels of glare than specular reflections.

From a thermal perspective, concave façade curvature is known to potentially concentrate reflections to hazardous levels at focal points a distance from the development site. This report does not evaluate thermal properties or visual glare impacts of solar reflections from concave facades of the proposed building.

3.2.2 Non-glazed Façade Elements

Non-glazed façade elements such as metallic framing and supports have the potential to generate localised glare of both a diffuse and specular nature that can produce a discomfort glare and affect the amenity of the site. It is recommended these elements have an external specular reflectivity coefficient of less than 20% to comply with the recommendations of the various Australian DCPs that have adopted the limit.

3.3 Summary

The summary table below lists the investigated locations that were found to potentially experience solar glare from the proposed building. The following sections of the report will discuss the assessment results in detail, including recommendations for mitigating glare issues.

Table 1: Summary of reflectivity assessment results along surrounding roadways.

Building	Façade	Investigated Location	Street Name	Level of Glare (TI)	Approximate Time Period (GMT +10)	Season	Discussion
Podium	NE	2	High Street	<20%	2.30pm to 3.30pm	Mid autumn to early spring	Low altitude, incident solar rays are emanating near parallel to the facade. Façade predominantly made of masonry and presence of verticsl opaque façade element is expected to reduce the impact of glare onto investigated locations.
		7	High Street	<20%	5am to 6am	Early summer to mid summer	
	NW	5	High Street	<20%	4pm to 5.30pm	Late summer to mid autumn, spring	
		28	Union Road	<20%	2pm	Early winter and mid winter	
	SW	32	Union Road	~27%	4pm to 5pm	Mid autumn to late autumn, late winter to early spring	Low altitude, incident solar rays likely blocked by upstream buildings during this time period. Façade predominantly made of masonry and presence of verticsl opaque façade element is expected to reduce the impact of glare onto investigated locations.
	SE1	32	Union Road	<20%	5am to 7.30am	Late spring to late summer	
		39	Temporary New Road	<20%	7am to 9am	Autumn, mid winter to early spring	
	SE2	32	Union Road	<20%	6am to 7am	Late spring and late summer	
		38	Union Lane	~65%	5am to 8am	Mid spring to early autumn	Low altitude, incident solar rays likely blocked by upstream existing and future buildings, and topography during this time period.
		39	Temporary New Road	<20%	7am to 10am	Early autumn to mid spring	

Stage 1 Tower 1	NE	37	Union Lane	<20%	2.30pm to 3.30pm	Mid autumn to early spring	Low altitude, incident solar rays likely blocked by upstream buildings during this time period. Façade treatment (ratio 1:10, e.g. 100m deep vertical mullion for every 1000mm width of glass)recommended to reduce the impact of glare onto investigated locations.
		40	Temporary New Road	<20%	10am to 11am	Mid autumn to early spring	
	NW	21	John Tipping Grove	<20%	10am	Late autumn and late winter	
		28	Union Road	<20%	12.30pm to 2pm	Mid autumn to early spring	
	SW	32	Union Road	~30%	3pm to 5pm	Autumn, mid winter to early spring	Low altitude, incident solar rays likely blocked by upstream buildings during this time period. Façade predominantly made of masonry and presence of verticsl opaque façade element is expected to reduce the impact of glare onto investigated locations.
	SE	32	Union Road	~20%	5am to 7.30am	Late spring to late summer	Low altitude, incident solar rays likely blocked by upstream buildings during this time period. Façade predominantly made of masonry and presence of verticsl opaque façade element is expected to reduce the impact of glare onto investigated locations.
Stage 2 Tower 2	NE	2	High Street	<20%	2pm to 3pm	Early autumn to mid spring	Low altitude, incident solar rays likely blocked by upstream buildings during this time period. Façade treatment (ratio 1:10, e.g. 100m deep vertical mullion for every 1000mm width of glass)recommended to reduce the impact of glare onto investigated locations.
		7	High Street	<20%	5am to 6am	Early summer to mid summer	
	NW	5	High Street	<20%	3pm to 5pm	Late summer to mid autumn, spring	
		21	John Tipping Grove	<20%	10am to 10.30am	Mid autumn to late autumn, late winter to early spring	
	SW	30	Union Road	<20%	4pm to 4.30pm	Mid autumn and early spring	
		38	Union Lane	~50%	2pm to 5pm	Early autumn to mid spring	Low altitude, incident solar rays likely blocked by upstream buildings during this time period. Façade treatment (ratio 1:10, e.g. 100m deep vertical mullion for every 1000mm width of glass)recommended to reduce the impact of glare onto investigated locations.
		39	Temporary New Road	<20%	5pm to 7pm	Early summer to mid summer	
	SE	38	Union Lane	~25%	5.00am to 7.30am	Late spring to late summer	Low altitude, incident solar rays likely blocked by upstream buildings during this time period. Façade treatment (ratio 1:10, e.g. 100m deep vertical mullion for every 1000mm width of glass)recommended to reduce the impact of glare onto investigated locations.
		39	Temporary New Road	<20%	7am to 9.30am	Early autumn to mid spring	

4 SOLAR REFLECTIVITY ASSESSMENT

4.1 Podium- North-East Facade

4.1.1 High Street

Assessment showed there is potential for drivers at Location 2, Figure 3, travelling northwest along High Street toward the development site, to experience low levels of glare from the Podium's North-East façade in the late afternoons during mid-autumn to early spring.

Analysis showed that between approximately 2.30pm to 3.30pm, drivers travelling northwest at Location 2, Figure 6, experienced solar glare with TI values of approximately 16%, which is approaching but lower than the prescribed public roadway limit of 20% (AS/NZS 1158.1.1:2005).

Similar levels of moderate exceedance were found at other locations analysed along High Street travelling northwest toward the development site were found for shorter periods of time from the Podium's South-West façade. It is noted this analysis conservatively assumes a fully glazed podium façade at this location. The reflections generating the high levels of glare will occur when the sun's altitude is low, and its solar rays are emanating near parallel to the facade. As currently planned, the North- East façade at podium level is predominantly made of masonry and the presence of vertical opaque façade elements shown in current architectural drawings will largely block glancing reflections.

Furthermore, shopfront glazing is well recessed within the façade line and will receive shading from all but the lowest altitude incident solar rays.

Hence it is expected solar reflections from the Podium's North-East façade will not negatively impact the vision of drivers' who are travelling northwest along High Street.

Figure 6: Representation of incident and reflection of solar rays from the Podium's North-East façade onto High Street.

Drivers at the remaining investigated locations on the other surrounding streets were found to not experience solar reflections from the Podium's North-East façade.

4.1.2 High Street (Opposite direction)

Assessment showed there is potential for drivers at Location 7, Figure 3, travelling southeast along High Street toward the development site, to experience low levels of glare from the Podium's North-East façade in the morning during early summer to mid-summer.

Analysis showed that between approximately 5am to 6am, drivers travelling southeast at Location 7, Figure 7, experienced solar glare with TI values of approximately 9%, which is lower than the prescribed public roadway limit of 20% (AS/NZS 1158.1.1:2005).

Drivers at other locations analysed along High Street travelling toward the development site were found to experience lower levels of TI values for shorter periods of time from the Podium's North-East façade. Thus, it is expected solar reflections from the Podium's North-East façade will not negatively impact the vision of drivers' who are travelling southeast along High Street.

Figure 7: Representation of incident and reflection of solar rays from the Podium's North-East façade onto High Street.

Drivers at the remaining investigated locations on the other surrounding streets were found to not experience solar reflections from the Podium's North-East façade.

4.2 Podium- North- West Facade

4.2.1 High Street

Assessment showed there is potential for drivers at Location 5, Figure 3, travelling southeast along High Street toward the development site, to experience low levels of glare from the Podium's North-West façade in the late afternoon during late summer to mid-autumn and spring.

Analysis showed that between approximately 4pm till 5.30pm, drivers travelling southeast at Location 5, Figure 8, experienced solar glare with TI values of approximately 18%, which is lower than the prescribed public roadway limit of 20% (AS/NZS 1158.1.1:2005).

Drivers at other locations analysed along High Street travelling southeast toward the development site were found to experience lower levels of TI values for shorter periods of time from the Podium's North-West façade. Thus, it is expected solar reflections from the Podium's North-West façade will not negatively impact the vision of drivers' who are travelling southeast along High Street.

Figure 8: Representation of incident and reflection of solar rays from the Podium's North-West façade onto High Street.

Drivers at the remaining investigated locations on the other surrounding streets were found to not experience solar reflections from the Podium's North-West façade.

4.2.2 Union Road

Assessment showed there is potential for drivers at Location 28, Figure 3, travelling west along Union Road toward the development site, to experience low levels of glare from the Podium's North-West façade in the afternoon during early winter and mid-winter.

Analysis showed that between approximately 2pm, drivers travelling west at Location 28, Figure 9, experienced solar glare with TI values of approximately 6.5%, which is lower than the prescribed public roadway limit of 20% (AS/NZS 1158.1.1:2005).

Drivers at other locations analysed along Union Road travelling west toward the development site were found to experience lower levels of TI values for shorter periods of time from the Podium's North-West façade. Thus, it is expected solar reflections from the Podium's North-West façade will not negatively impact the vision of drivers' who are travelling west along Union Road.

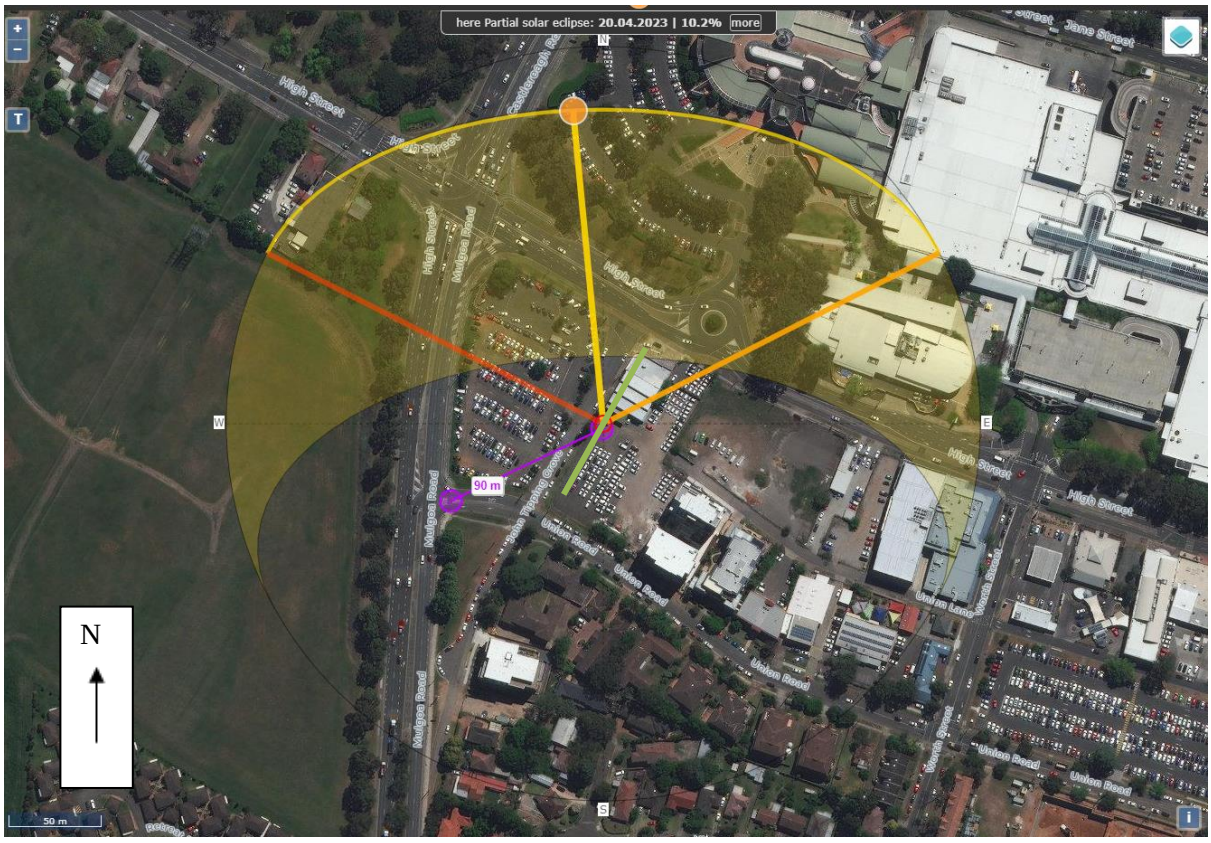

Figure 9: Representation of incident and reflection of solar rays from the Podium's North-West façade onto Union Road.

Drivers at the remaining investigated locations on the other surrounding streets were found to not experience solar reflections from the Podium's North-West façade.

4.3 Podium- South-West Facade

4.3.1 Union Road

Assessment showed there is potential for drivers at Location 32, Figure 3, travelling northwest along Union Road toward the development site, to experience high levels of glare from the Podium's South-West façade in the afternoon during mid-autumn to late autumn, late winter to early spring.

Analysis showed that between approximately 4pm till 5pm, drivers travelling northwest at Location 32, Figure 10, experienced solar glare with TI values of approximately 27%, which is higher than the prescribed public roadway limit of 20% (AS/NZS 1158.1.1:2005).

Similar levels of moderate exceedance were found at other locations analysed along Union Road travelling northwest toward the development site were found for shorter periods of time from the Podium's South-West façade. It is noted this analysis conservatively assumes a fully glazed podium façade at this location. As currently planned, the South- West façade at podium level is predominantly made of masonry and the presence of vertical opaque façade elements shown in current architectural drawings will largely block glancing reflections.

Furthermore, the low altitude incident solar rays will be largely blocked by upstream building and topography before reaching the development site. Furthermore, shopfront glazing is well recessed within the façade line and will receive shading from all but the lowest altitude incident solar rays.

Hence it is expected solar reflections from the Podium's South-West façade will not negatively impact the vision of drivers' who are travelling northwest along Union Road.

Figure 10: Representation of incident and reflection of solar rays from the Podium's South-West façade onto Union Road.

Drivers at the remaining investigated locations on the other surrounding streets were found to not experience solar reflections from the Podium's South-West façade.

4.4 Podium- South- East Façade 1

4.4.1 Union Road

Assessment showed there is potential for drivers at Location 32, Figure 3, travelling northwest along Union Road toward the development site, to experience low levels of glare from the Podium's South-East façade 1 in the morning during the late spring to late summer.

Analysis showed that between approximately 5am till 7.30am, drivers travelling northwest at Location 32, Figure 11, experienced solar glare with TI values of approximately 15%, which is lower than the prescribed public roadway limit of 20% (AS/NZS 1158.1.1:2005).

Drivers at other locations analysed along Union Road travelling northwest toward the development site were found to experience lower levels of TI values for shorter periods of time from the Podium's South-East façade 1. Thus, it is expected solar reflections from the Podium's South-East façade 1 will not negatively impact the vision of drivers' who are travelling northwest along Union Road.

Figure 11: Representation of incident and reflection of solar rays from the Podium's South-East façade 1 onto Union Road.

Drivers at the remaining investigated locations on the other surrounding streets were found to not experience solar reflections from the Podium's South-East façade 1.

4.4.2 Temporary New Road

Assessment showed there is potential for drivers at Location 39, Figure 3, travelling northeast along Temporary New Road toward the development site, to experience low levels of glare from the Podium's South-East façade 1 in the morning during the autumn, mid-winter to early spring.

Analysis showed that between approximately 7am till 9am, drivers travelling northeast at Location 39, Figure 12, experienced solar glare with TI values of approximately 6%, which is lower than the prescribed public roadway limit of 20% (AS/NZS 1158.1.1:2005).

Drivers at other locations analysed along Temporary New Road travelling northeast toward the development site were found to experience lower levels of TI values for shorter periods of time from the Podium's South-East façade 1. Thus, it is expected solar reflections from the Podium's South-East façade 1 will not negatively impact the vision of drivers' who are travelling northeast along Temporary New Road.

Figure 12: Representation of incident and reflection of solar rays from the Podium's South-East façade 1 onto Temporary New Road.

Drivers at the remaining investigated locations on the other surrounding streets were found to not experience solar reflections from the Podium's South-East façade 1.

4.5 Podium- South- East Façade 2

4.5.1 Union Road

Assessment showed there is potential for drivers at Location 32, Figure 3, travelling northwest along Union Road toward the development site, to experience low levels of glare from the Podium's South-East façade 2 in the morning during late spring and late summer.

Analysis showed that between approximately 6am till 7am, drivers travelling northwest at Location 32, Figure 13, experienced solar glare with TI values of approximately 5.5%, which is lower than the prescribed public roadway limit of 20% (AS/NZS 1158.1.1:2005).

Drivers at other locations analysed along Union Road travelling northwest toward the development site were found to experience lower levels of TI values for shorter periods of time from the Podium's South-East façade 2. Thus, it is expected solar reflections from the Podium's South-East façade 2 will not negatively impact the vision of drivers' who are travelling northwest along Union Road.

Figure 13: Representation of incident and reflection of solar rays from the Podium's South-East façade 2 onto Union Road.

Drivers at the remaining investigated locations on the other surrounding streets were found to not experience solar reflections from the Podium's South-East façade 2.

4.5.2 Union Lane

Assessment showed there is potential for drivers at Location 38, Figure 3, travelling northwest along Union Lane toward the development site, to experience high levels of glare from the Podium's South-East façade 2 in the morning during mid spring to early autumn.

Analysis showed that between approximately 5am till 8am, drivers travelling northwest at Location 38, Figure 14, experienced solar glare with TI values of approximately 65%, which is higher than the prescribed public roadway limit of 20% (AS/NZS 1158.1.1:2005).

The reflections generating the high levels of glare will occur when the sun's altitude is low, and its solar rays are emanating near parallel to the horizon. Thus, it is likely the incident solar rays will be largely blocked by upstream building and topography before reaching the development site.

Furthermore, the South-East façade at podium level is heavily articulated and largely masonry which will largely reduce these near perpendicular reflections.

Hence it is expected solar reflections from the Podium's South-East façade 2 will not negatively impact the vision of drivers' who are travelling northwest along Union Lane.

Figure 14: Representation of incident and reflection of solar rays from the Podium's South-East façade 2 onto Union Lane.

Drivers at the remaining investigated locations on the other surrounding streets were found to not experience solar reflections from the Podium's South-East façade 2.

4.5.3 Temporary New Road

Assessment showed there is potential for drivers at Location 39, Figure 3, travelling northeast along Temporary New Road toward the development site, to experience low levels of glare from the Podium's South-East façade 2 in the morning during early autumn to mid spring.

Analysis showed that between approximately 7am till 10am, drivers travelling northeast at Location 39, Figure 15, experienced solar glare with TI values of approximately 14%, which is lower than the prescribed public roadway limit of 20% (AS/NZS 1158.1.1:2005).

Drivers at other locations analysed along Temporary New Road travelling northeast toward the development site were found to experience higher levels of TI values for shorter periods of time from the Podium's South-East façade 2. Thus, it is expected solar reflections from the Podium's South-East façade 2 will not negatively impact the vision of drivers' who are travelling northeast along Temporary New Road.

Figure 15: Representation of incident and reflection of solar rays from the Podium's South-East façade 2 onto Temporary New Road.

Drivers at the remaining investigated locations on the other surrounding streets were found to not experience solar reflections from the Podium's South-East façade 2.

4.6 Stage 1 Tower 1 (S1T1)- North- East

4.6.1 Union Lane

Assessment showed there is potential for drivers at Location 37, Figure 3, travelling northwest along Union Lane toward the development site, to experience low levels of glare from the S1T1's North-East façade in the afternoons during the mid-autumn to early spring.

Analysis showed that between approximately 2.30 pm till 3.30 pm, drivers travelling northwest at Location 37, Figure 16, experienced solar glare with TI values of approximately 19%, which is lower than the prescribed public roadway limit of 20% (AS/NZS 1158.1.1:2005).

Similar levels of moderate exceedance were found at other locations analysed along Union Lane travelling northwest toward the development site were found for shorter periods of time from the S1T1's North-East façade. It is noted this analysis conservatively assumes a fully glazed tower façade at this location. The reflections generating the high levels of glare will occur when the sun's altitude is low, and its solar rays are emanating near parallel to the horizon. Thus, solar rays are likely blocked by podium which is predominantly made of masonry and vertical opaque façade elements.

To improve glare result, it is recommended each glazing unit be vertically recessed behind adjacent non-glazed and non-reflective façade elements in a ration of 1:10, e.g. 100mm deep vertical mullion for every 1000mm width of glass.

With this measure in place, it is expected solar reflections from the S1T1's North-East façade will not negatively impact the vision of drivers' who are travelling northwest along Union Lane.

Figure 16: Representation of incident and reflection of solar rays from the S1T1's North-East façade onto Union Lane.

Drivers at the remaining investigated locations on the other surrounding streets were found to not experience solar reflections from the S1T1's North-East façade.

4.6.2 Temporary New Road

Assessment showed there is potential for drivers at Location 40, Figure 3, travelling southwest along Temporary New Road toward the development site, to experience low levels of glare from the S1T1's North-East façade in the mornings during the mid-autumn to early spring.

Analysis showed that between approximately 10am till 11am, drivers travelling southwest at Location 40, Figure 17, experienced solar glare with TI values of approximately 5%, which is lower than the prescribed public roadway limit of 20% (AS/NZS 1158.1.1:2005).

Drivers at other locations analysed along Temporary New Road travelling southwest toward the development site were found to experience lower levels of TI values for shorter periods of time from the S1T1's North-East façade. Thus, it is expected solar reflections from the S1T1's North-East façade will not negatively impact the vision of drivers' who are travelling southwest along Temporary New Road.

Figure 17: Representation of incident and reflection of solar rays from the S1T1's North-East façade onto Temporary New Road.

Drivers at the remaining investigated locations on the other surrounding streets were found to not experience solar reflections from the S1T1's North-East façade.

4.7 Stage 1 Tower 1 (S1T1)- North- West

4.7.1 John Tipping Grove

Assessment showed there is potential for drivers at Location 21, Figure 3, travelling northwest along John Tipping Grove toward the development site, to experience low levels of glare from the S1T1's North-West façade in the morning during the late autumn and late winter.

Analysis showed that between approximately 10am, drivers travelling northwest at Location 21, Figure 18, experienced solar glare with TI values of approximately 8.5%, which is lower than the prescribed public roadway limit of 20% (AS/NZS 1158.1.1:2005).

Drivers at other locations analysed along John Tipping Grove travelling northwest toward the development site were found to experience lower levels of TI values for shorter periods of time from the S1T1's North-West façade. Thus, it is expected solar reflections from the S1T1's North-West façade will not negatively impact the vision of drivers' who are travelling northwest along John Tipping Grove.

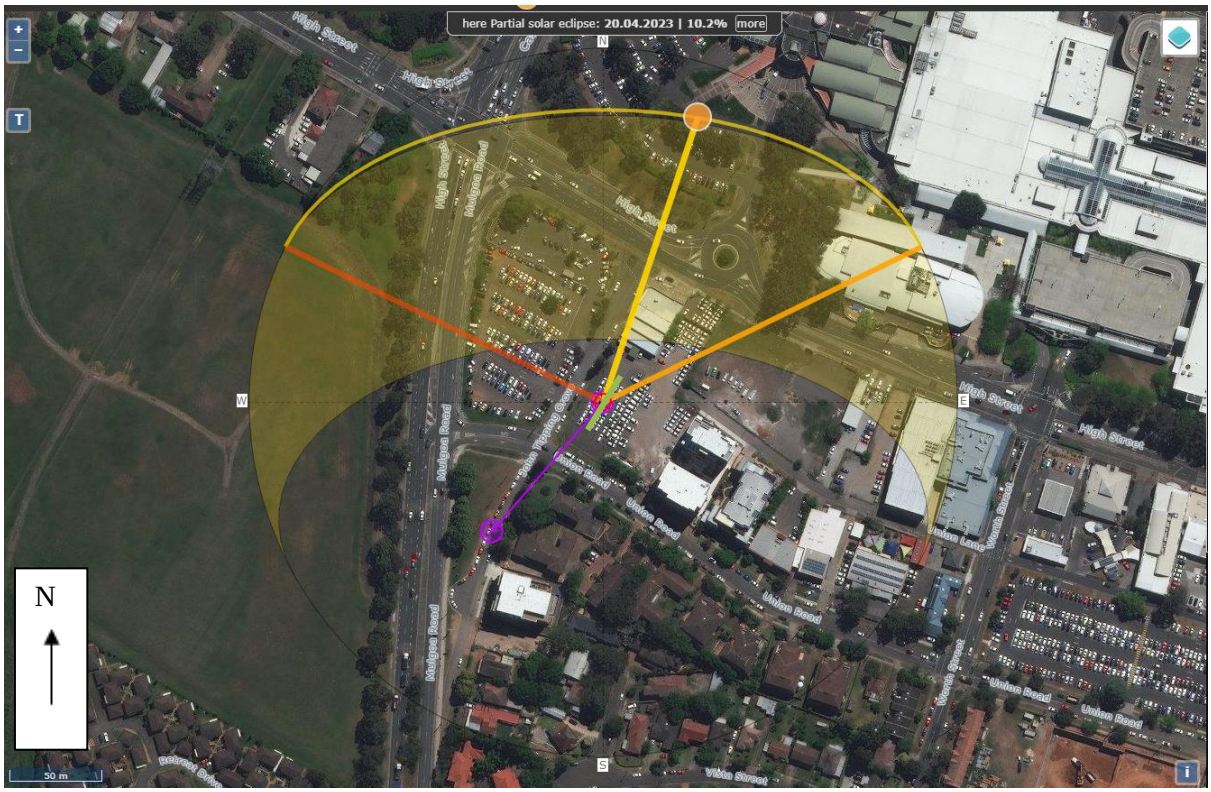

Figure 18: Representation of incident and reflection of solar rays from the S1T1's North-West façade onto John Tipping Grove.

Drivers at the remaining investigated locations on the other surrounding streets were found to not experience solar reflections from the S1T1's North-West façade.

4.7.2 Union Road

Assessment showed there is potential for drivers at Location 28, Figure 3, travelling west along Union Road toward the development site, to experience low levels of glare from the S1T1's North-West façade in the afternoon during the mid- autumn to early spring.

Analysis showed that between approximately 12.30pm till 2pm, drivers travelling west at Location 28, Figure 19, experienced solar glare with TI values of approximately 8%, which is lower than the prescribed public roadway limit of 20% (AS/NZS 1158.1.1:2005).

Drivers at other locations analysed along Union Road travelling west toward the development site were found to experience lower levels of TI values for shorter periods of time from the S1T1's North-West façade. Thus, it is expected solar reflections from the S1T1's North-West façade will not negatively impact the vision of drivers' who are travelling west along Union Road.

Figure 19: Representation of incident and reflection of solar rays from the S1T1's North-West façade onto Union Road.

Drivers at the remaining investigated locations on the other surrounding streets were found to not experience solar reflections from the S1T1's North-West façade.

4.8 Stage 1 Tower 1 (S1T1)- South- West

4.8.1 Union Road

Assessment showed there is potential for drivers at Location 32, Figure 3, travelling northwest along Union Road toward the development site, to experience high levels of glare from the S1T1's South-West façade in the afternoon during the autumn, mid-winter to early spring.

Analysis showed that between approximately 3pm till 5pm, drivers travelling northwest at Location 32, Figure 20, experienced solar glare with TI values of approximately 30%, which is higher than the prescribed public roadway limit of 20% (AS/NZS 1158.1.1:2005).

Similar levels of moderate exceedance were found at other locations analysed along Union Road travelling northwest toward the development site were found for shorter periods of time from the S1T1's South-West façade. It is noted this analysis conservatively assumes a fully glazed tower façade at this location. As currently planned, the S1T1's South-West tower façade is predominantly made of masonry and the presence of vertical opaque façade elements shown in current architectural drawings will largely block glancing reflections.

Hence it is expected solar reflections from the S1T1's South-West façade will not negatively impact the vision of drivers' who are travelling northwest along Union Road.

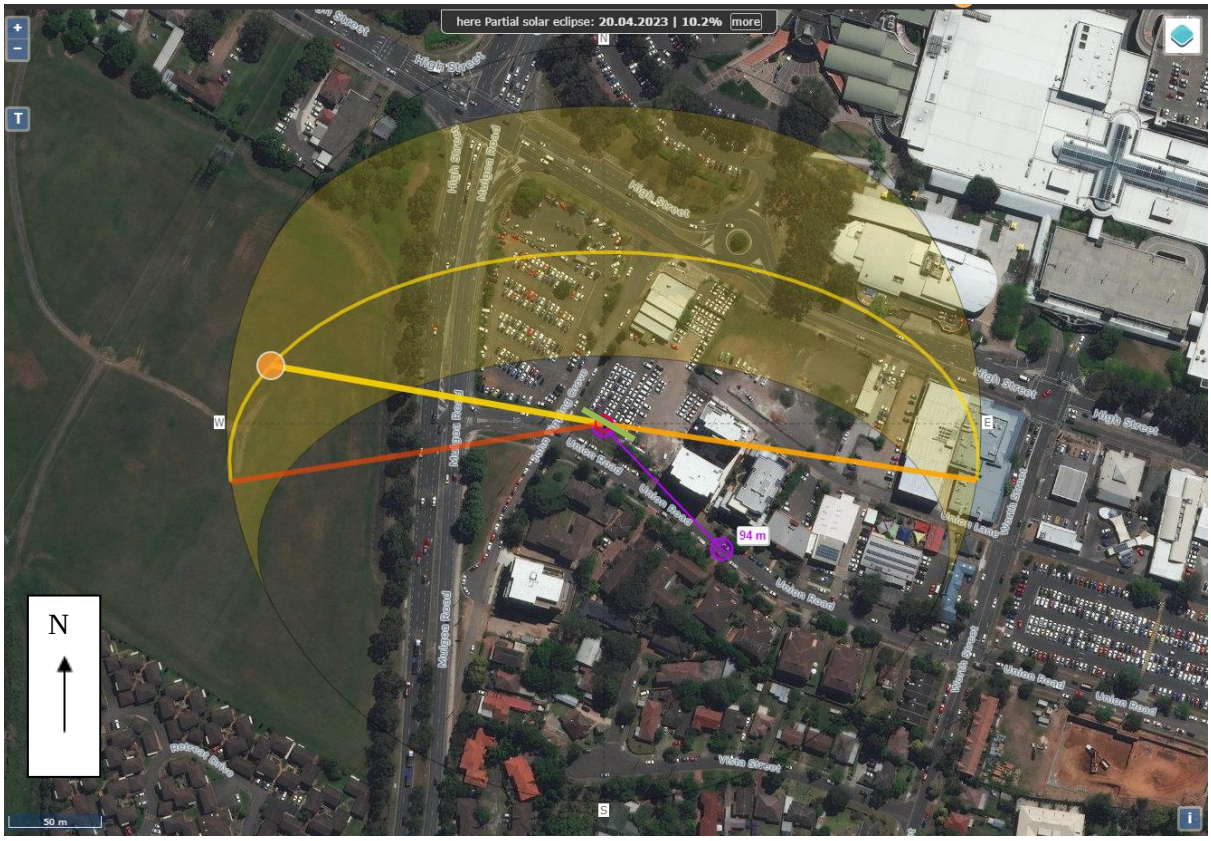

Figure 20: Representation of incident and reflection of solar rays from the S1T1's South-West façade onto Union Road.

4.9 Stage 1 Tower 1 (S1T1)- South- East

4.9.1 Union Road

Assessment showed there is potential for drivers at Location 32, Figure 3, travelling northwest along Union Road toward the development site, to experience medium levels of glare from the S1T1's South-East façade in the morning during the late spring to late summer.

Analysis showed that between approximately 5am till 7am, drivers travelling northwest at Location 32, Figure 21, experienced solar glare with TI values of approximately 20%, which is equal to the prescribed public roadway limit of 20% (AS/NZS 1158.1.1:2005).

Similar levels of moderate exceedance were found at other locations analysed along Union Road travelling northwest toward the development site were found for shorter periods of time from the S1T1's South-East façade. It is noted this analysis conservatively assumes a fully glazed tower façade at this location. As currently planned, the S1T1's South-East façade is predominantly made of masonry and the presence of vertical opaque façade elements shown in current architectural drawings will largely block glancing reflections.

Hence it is expected solar reflections from the S1T1's South-East façade will not negatively impact the vision of drivers' who are travelling northwest along Union Road.

Figure 21: Representation of incident and reflection of solar rays from the S1T1's South-East façade onto Union Road.

Drivers at the remaining investigated locations on the other surrounding streets were found to not experience solar reflections from the S1T1's South-East façade.

4.10 Stage 2 Tower 2 (S2T2)- North- East

4.10.1 High Street

Assessment showed there is potential for drivers at Location 2, Figure 3, travelling northwest along High Street toward the development site, to experience low levels of glare from the S2T2's North-East façade in the afternoon during the early autumn to mid spring.

Analysis showed that between approximately 2pm till 3pm, drivers travelling northwest at Location 2, Figure 22, experienced solar glare with TI values of approximately 13%, which is lower than the prescribed public roadway limit of 20% (AS/NZS 1158.1.1:2005).

Given the proximity of the tower façade to High Street and the volume of traffic expected, further assessment was also conducted using the commercial software SGHAT. Whilst the software was developed specifically for the aviation industry, the output provides an additional quantitative assessment tool.

Output from SGHAT analysis demonstrated some potential for glare impacts along High Street.

Hence, it is recommended that each glazing unit on the North-East façade be vertically recessed behind adjacent non-glazed and non-reflective façade elements in a ration of 1:10, e.g. 100mm deep vertical mullion for every 1000mm width of glass to minimize impact of glare produced by S2T2's North-East façade on the vision of driver's who are travelling northwest along High Street.

Figure 22: Representation of incident and reflection of solar rays from the S2T2's North-East façade onto High Street.

Drivers at the remaining investigated locations on the other surrounding streets were found to not experience solar reflections from the S2T2's North-East façade.

4.10.2 High Street (Opposite)

Assessment showed there is potential for drivers at Location 7, Figure 3, travelling southeast along High Street toward the development site, to experience low levels of glare from the S2T2's North-East façade in the morning during the early summer to mid- summer.

Analysis showed that between approximately 5am till 6am, drivers travelling southeast at Location 7, Figure 23, experienced solar glare with TI values of approximately 9%, which is lower than the prescribed public roadway limit of 20% (AS/NZS 1158.1.1:2005).

Drivers at other locations analysed along High Street travelling southeast toward the development site were found to experience lower levels of TI values for shorter periods of time from the S2T2's North-East façade. Thus, it is expected solar reflections from the S2T2's North-East façade will not negatively impact the vision of drivers' who are travelling southeast along High Street.

Figure 23: Representation of incident and reflection of solar rays from the S2T2's North-East façade onto High Street.

Drivers at the remaining investigated locations on the other surrounding streets were found to not experience solar reflections from the S2T2's North-East façade.

4.11 Stage 2 Tower 2 (S2T2)- North- West

4.11.1 High Street

Assessment showed there is potential for drivers at Location 5, Figure 3, travelling southeast along High Street toward the development site, to experience low levels of glare from the S2T2's North-West façade in the late afternoon during the late summer to mid-autumn and spring.

Analysis showed that between approximately 3pm till 5pm, drivers travelling southeast at Location 5, Figure 24, experienced solar glare with TI values of approximately 15%, which is lower than the prescribed public roadway limit of 20% (AS/NZS 1158.1.1:2005).

Drivers at other locations analysed along High Street travelling southeast toward the development site were found to experience lower levels of TI values for shorter periods of time from the S2T2's North-West façade. Thus, it is expected solar reflections from the S2T2's North-West façade will not negatively impact the vision of drivers' who are travelling southeast along High Street.

Figure 24: Representation of incident and reflection of solar rays from the S2T2's North-West façade onto High Street.

Drivers at the remaining investigated locations on the other surrounding streets were found to not experience solar reflections from the S2T2's North-West façade.

4.11.2 John Tipping Grove

Assessment showed there is potential for drivers at Location 21, Figure 3, travelling northeast along John Tipping Grove toward the development site, to experience low levels of glare from the S2T2's North-West façade in the morning during the mid-autumn to late autumn, late winter to early spring .

Analysis showed that between approximately 10am till 10.30am, drivers travelling northeast at Location 21, Figure 25, experienced solar glare with TI values of approximately 10%, which is lower than the prescribed public roadway limit of 20% (AS/NZS 1158.1.1:2005).

Drivers at other locations analysed along John Tipping Grove travelling northeast toward the development site were found to experience lower levels of TI values for shorter periods of time from the S2T2's North-West façade. Thus, it is expected solar reflections from the S2T2's North-West façade will not negatively impact the vision of drivers' who are travelling northeast along John Tipping Grove.

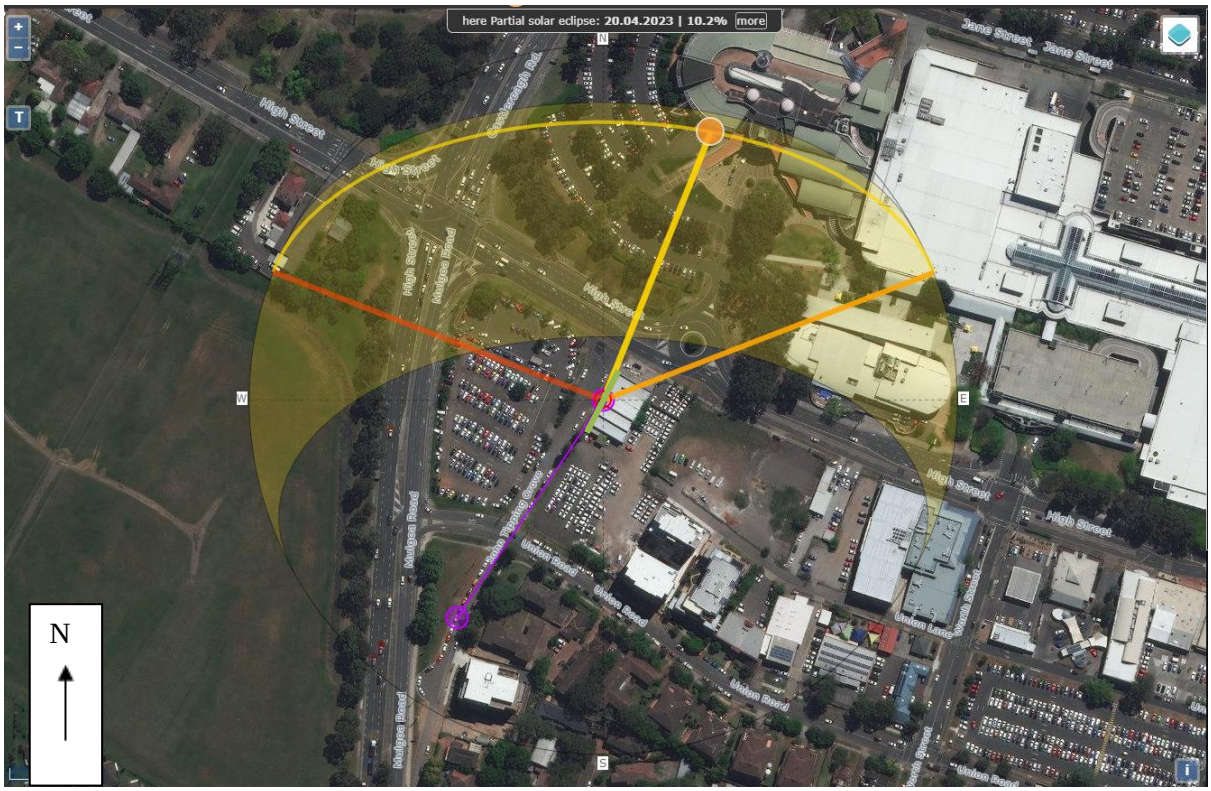

Figure 25: Representation of incident and reflection of solar rays from the S2T2's North-West façade onto John Tipping Grove.

Drivers at the remaining investigated locations on the other surrounding streets were found to not experience solar reflections from the S2T2's North-West façade.

4.12 Stage 2 Tower 2 (S2T2)- South- West

4.12.1 Union Road

Assessment showed there is potential for drivers at Location 30, Figure 3, travelling northwest along Union Road toward the development site, to experience low levels of glare from the S2T2's South-West façade in the late afternoon during the early to mid-autumn and early spring.

Analysis showed that between approximately 4pm till 4.30pm, drivers travelling northwest at Location 30, Figure 26, experienced solar glare with TI values of approximately 3%, which is lower than the prescribed public roadway limit of 20% (AS/NZS 1158.1.1:2005).

Drivers at other locations analysed along Union Road travelling northwest toward the development site were found to experience lower levels of TI values for shorter periods of time from the S2T2's South-West façade. Thus, it is expected solar reflections from the S2T2's South-West façade will not negatively impact the vision of drivers' who are travelling northwest along Union Road.

Figure 26: Representation of incident and reflection of solar rays from the S2T2's South-West façade onto Union Road.

Drivers at the remaining investigated locations on the other surrounding streets were found to not experience solar reflections from the S2T2's South-West façade.

4.12.2 Union Lane

Assessment showed there is potential for drivers at Location 38, Figure 3, travelling northwest along Union Lane toward the development site, to experience high levels of glare from the S2T2's South-West façade in the afternoons during the early autumn to mid spring.

Analysis showed that between approximately 2pm till 5pm, drivers travelling northwest at Location 38, Figure 27, experienced solar glare with TI values of approximately 50%, which is higher than the prescribed public roadway limit of 20% (AS/NZS 1158.1.1:2005).

Similar levels of moderate exceedance were found at other locations analysed along Union Lane travelling northwest toward the development site were found for shorter periods of time from the S2T2's South-West façade. It is noted this analysis conservatively assumes a fully glazed tower façade at this location. The reflections generating the high levels of glare will occur when the sun's altitude is low, and its solar rays are emanating near parallel to the horizon. As currently planned, the S2T2's South-West façade at lower level consists of a podium which is predominantly made of masonry and the presence of vertical opaque façade elements shown in current architectural drawings will largely block glancing reflections.

To improve glare result, it is recommended that each glazing unit on the South-West façade be vertically recessed behind adjacent non-glazed and non-reflective façade elements in a ration of 1:10, e.g. 100mm deep vertical mullion for every 1000mm width of glass to minimize impact of glare produced by S2T2's South-West façade on the vision of driver's who are travelling northwest along Union Lane.

Hence it is expected solar reflections from the S2T2's South-West façade will not negatively impact the vision of drivers' who are travelling northwest along Union Lane.

Figure 27: Representation of incident and reflection of solar rays from the S2T2's South-West façade onto Union Lane.

Drivers at the remaining investigated locations on the other surrounding streets were found to not experience solar reflections from the S2T2's South-West façade.

4.12.3 Temporary New Road

Assessment showed there is potential for drivers at Location 39, Figure 3, travelling northeast along Temporary New Road toward the development site, to experience low levels of glare from the S2T2's South-West façade in the late afternoon during the early summer to mid-summer.

Analysis showed that between approximately 5pm till 7pm, drivers travelling northeast at Location 39, Figure 28, experienced solar glare with TI values of approximately 5.5%, which is lower than the prescribed public roadway limit of 20% (AS/NZS 1158.1.1:2005).

Drivers at other locations analysed along Temporary New Road travelling northeast toward the development site were found to experience lower levels of TI values for shorter periods of time from the S2T2's South-West façade. Thus, it is expected solar reflections from the S2T2's South-West façade will not negatively impact the vision of drivers' who are travelling northeast along Temporary New Road.

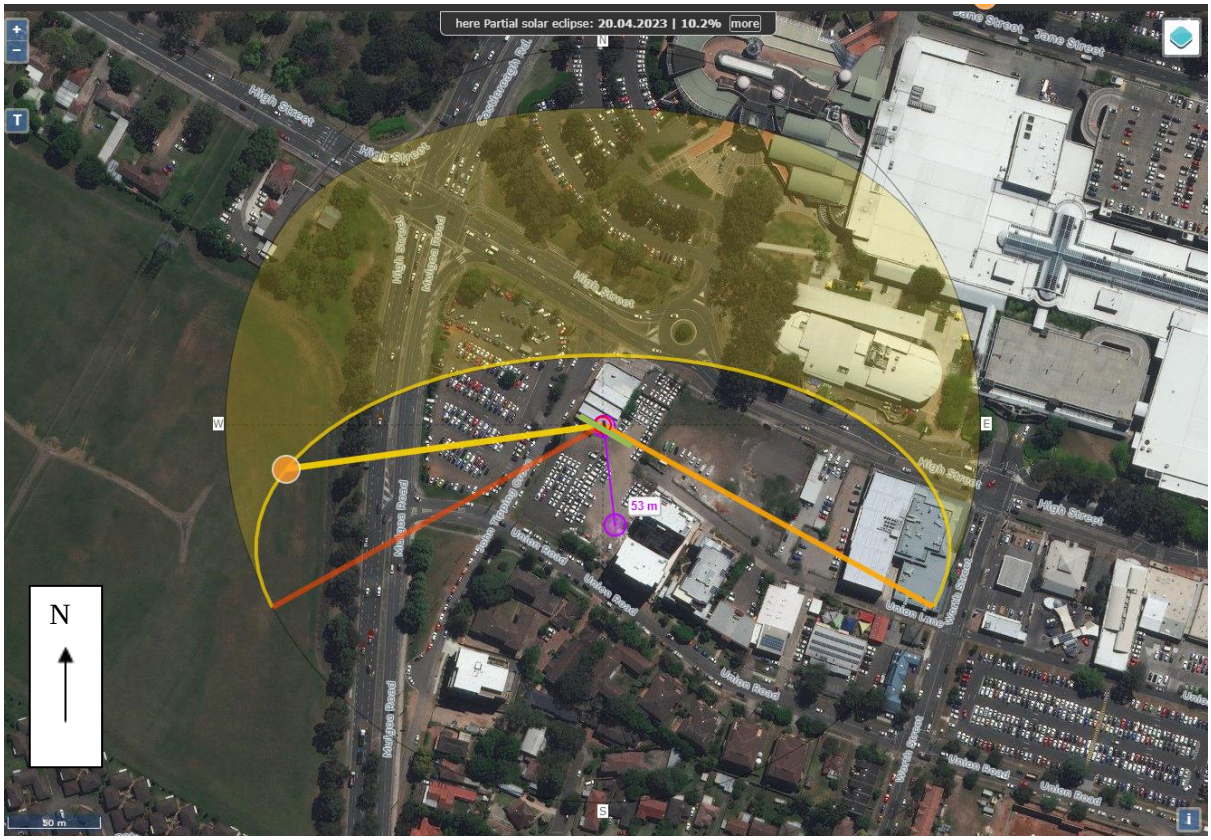

Figure 28: Representation of incident and reflection of solar rays from the S2T2's South-West façade onto Temporary New Road.

Drivers at the remaining investigated locations on the other surrounding streets were found to not experience solar reflections from the S2T2's South-West façade.

4.13 Stage 2 Tower 2 (S2T2)- South- East

4.13.1 Union Lane

Assessment showed there is potential for drivers at Location 38, Figure 3, travelling northwest along Union Lane toward the development site, to experience medium levels of glare from the S2T2's South-East façade in the mornings during the late spring to late summer.

Analysis showed that between approximately 5am till 7.30am, drivers travelling northwest at Location 38, Figure 29, experienced solar glare with TI values of approximately 25%, which is slightly higher than the prescribed public roadway limit of 20% (AS/NZS 1158.1.1:2005). Given the marginal exceedance and the lower volume of traffic at this location, it is expected solar reflections from the S2T2's South-East façade will not negatively impact the vision of drivers' who are travelling northwest along Union Lane.

Figure 29: Representation of incident and reflection of solar rays from the S2T2's South-East façade onto Union Lane.

Drivers at the remaining investigated locations on the other surrounding streets were found to not experience solar reflections from the S2T2's South-East façade.

4.13.2 Temporary New Road

Assessment showed there is potential for drivers at Location 39, Figure 3, travelling northeast along Temporary New Road toward the development site, to experience low levels of glare from the S2T2's South-East façade in the morning during the early autumn to mid spring.

Analysis showed that between approximately 7am till 9.30am, drivers travelling northeast at Location 39, Figure 30, experienced solar glare with TI values of approximately 14%, which is lower than the prescribed public roadway limit of 20% (AS/NZS 1158.1.1:2005).

Drivers at other locations analysed along Temporary New Road travelling northeast toward the development site were found to experience lower levels of TI values for shorter periods of time from the S2T2's South-East façade. Thus, it is expected solar reflections from the S2T2's South-East façade will not negatively impact the vision of drivers' who are travelling northeast along Temporary New Road.

Figure 30: Representation of incident and reflection of solar rays from the S2T2's South-East façade onto Temporary New Road.

Drivers at the remaining investigated locations on the other surrounding streets were found to not experience solar reflections from the S2T2's South-East façade.

5 CONCLUSION

The proposed High Street Penrith development in Sydney, Australia was assessed to ascertain any potential its facades will produce traffic disability solar reflectivity glare events onto surrounding roadway locations.

At many investigated locations along the adjacent roadways, it is expected the proposed development as currently configured will not produce significant disability glare onto vehicles travelling toward the development, and solar glare detected were within recommended limits. Where higher glare levels were found, recommendations have been provided to mitigate the reflections.

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