ARUP

Thirdi Crows Nest Lot B Pty Ltd

Crows Nest OSD Site B

Reflected Glare Report

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Executive Summary

Arup were engaged to provide a quantitative reflected glare assessment for the proposed Crows Nest OSD Site B, as per the Development Consent conditions.

This document presents an assessment of the potential for reflected sunlight glare from the proposed development. It considers the potential for hazardous glare impacts on the adjacent roads due to the proposed development, with the proposed glazing and other finishes, in response to Development Consent condition B9.

This assessment is based on design documentation issued by Woods Bagot and Apex Façade between July and October 2024.

This study assesses the likelihood of potentially hazardous sunlight reflections and impacts on drivers on nearby roads. The key risk with regard to external sunlight reflections is that of 'disability glare' reflections toward drivers approaching the subject site. On the road, this type of reflection could interfere with drivers' vision of other vehicles, pedestrians and traffic signals.

This study considers sunlight reflection impacts on car drivers with views of the approved development. It comprises of a series of roads with potential view of the development.

The key non-glazed external finish presented on the building elevations and exterior finishes schedule that is visible from nearby roads is CD-01 Terracotta panel, dark green. The specified terracotta panel has a high gloss finish. The key materials with the potential to create specular (mirror-like) reflections are the glazed windows on each façade.

The study assumed 20% external glass reflectance at normal incidence. This is a maximum level of light reflectance discussed with the design team, representing a worst-case scenario regarding reflected sunlight glare risks.

The articulated form of the façades will create sunlight reflections into a range of directions any time the sun is incident on the façade, including toward drivers on surrounding roads. Most of these reflections do not present a risk of creating disability glare.

The following risks of disability glare reflections were identified by the assessment:

- Reflections from the Pacific Highway elevation toward drivers travelling north on the Pacific Hwy. These reflections are expected to be blocked from the drivers' view by either the roof of the vehicle or by sun visors within the vehicle.
- Reflections from the Hume St elevation toward drivers travelling north-east on Hume St. As above, these reflections are expected to be blocked from the drivers' view by either the roof of the vehicle or by sun visors within the vehicle.
- Reflections from a small section of the Hume St elevation over levels G-1 toward drivers travelling south-west on Hume St. This risk is expected to occur for only around 20 mins per day, for only around three weeks in the year.

Sunlight reflections in the terracotta tiles may not be sufficient to create disability glare reflections toward drivers, but are expected to create strong discomfort glare into a range of directions including toward drivers.

Two of the identified risks of disability glare sunlight reflections listed above are considered to be mitigated by drivers operating their sun visors. Regarding the application of sun visors, it is not uncommon to consider this as a suitable risk mitigation measure, as long as it is reasonably determined that the visors would be in use at the time of receiving the sunlight reflections. Further mitigation measures in response to these identified risks are not considered to be required.

The key reflected glare residual risk identified in the assessment summarised above arises from the terracotta tiles with glossy finish. It is recommended to change the specified finish of the terracotta tiles to a more matte finish. This is expected to sufficiently mitigate the identified reflected glare risk. The design team confirmed their agreement to change the finish of the terracotta tiles as recommended.

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1. Introduction

Arup were engaged to provide a quantitative reflected glare assessment for the proposed Crows Nest OSD Site B, as per the Development Consent conditions.

This document presents an assessment of the potential for reflected sunlight glare from the proposed development. It considers the potential for hazardous glare impacts on the adjacent roads due to the proposed development, with the proposed glazing and other finishes.

2. Development Consent conditions

As per Section 4.38 of the Environmental Planning and Assessment Act 1979, the following Development Consent condition relates to reflected glare, Table 2.

Table 1: Applicable Development Consent condition

Clause	Condition
B9	Future development application(s) shall include a Reflectivity Analysis demonstrating that external treatments, materials and finishes of the development do not cause adverse or excessive glare.

3. Development summary

Crows Nest OSD - Site B is a 14-storey tower above the Crows Nest Metro Station.

The site area is 1872 m^2. The concept approval includes a maximum height to the top of the service zone of RL 158 m and includes a maximum residential FSR of 13,000 m^2.

The Metro Station is comprised of 3 levels:

- **Ground Level - Hume Street** includes the OSD tower lobby, retail, and back of house spaces.
- **Level 01** includes a retail mezzanine, back of house, and a loading dock which is used for OSD garbage collection and is a future easement for rail authority access.
- **Level 02** contains plant rooms for the metro station.

The OSD car parking levels are located on level 5 and 6. These are naturally ventilated with 27 car spaces on level 5 and 28 car spaces on level 6. There is a total of 55 spaces.

Apartments are located from level 7 to 18. Level 19 and 20 contain penthouses.

A roof terrace on level 21 includes communal gardens and pools, as well as private penthouse terraces.

Level 7-8: 10 apartments per floor

Level 9-18: 11 apartments per floor

Level 19: 8 apartments (5 x two storey)

Level 20: 3 apartments

Total number of apartments: 130

Level 7-16: Winter garden apartments

Level 17-18: Balcony apartments

Level 19-20: Penthouses with balconies

Level 21: Rooftop with pools and outdoor kitchens

Figure 1: Subject site plan

4. Basis of assessment

This assessment is based on the following information:

- SSDA Architectural set, issued by Woods Bagot on 14 August 2024, including site plan (Figure 1) and exterior finishes schedule
- 3D model of the approved development, provided by Woods Bagot on 16 September 2024
- Glazing Performance Specification, provided by Apex Facade, on 24 September 2024
- Physical sample of glazed terracotta cladding sighted on 2 October 2024

5. Methodology

5.1 Sunlight reflections

Sunlight reflects off all surfaces that it hits. Most of these reflections are easily viewed and do not present a risk to vision.

Sunlight reflects off surfaces that are not shiny in a diffuse way. In spreading the reflected sunlight over a wide range of directions, the intensity of the reflected sunlight is significantly reduced. Such reflections are generally bright but not uncomfortable.

Sunlight reflects off smooth, shiny surfaces, such as glass, in a specular (mirror-like) way. The intensity of specular reflections are much stronger than diffuse reflections, and such reflections are generally uncomfortable to view.

When sunlight reflections are strong and close to the observer's direction of view, and the observer is performing detailed visual tasks that require concentration in a given direction of view, this can be hazardous. This causes the observer to be unable to perform a visual task such as driving without taking evasive action. It temporarily degrades the observer's ability to perform the visual task on which they are focused.

Refer to Appendix A.1 for further discussion and illustration of different forms of sunlight reflection.

5.2 Materiality of finishes

A review of the façade elevations and materials intents was completed to identify potential sources of reflected glare or other interference with car drivers.

The review focused on reflective finishes that could create risks of reflected sunlight glare for car drivers.

Where reflective finishes were identified, a reflected glare assessment was performed, as described below.

5.3 Reflected glare

Reflected glare from buildings can cause uncomfortable and potentially hazardous visual impacts in the built environment. This may impact car drivers who require a high degree of concentration. This study assesses the likelihood of potentially hazardous sunlight reflections and impacts on car drivers on the adjacent roads, and assists in mitigating any identified risks.

The key risk with regard to external sunlight reflections is that of 'disability glare' reflections toward drivers approaching the subject site. On the road, this type of reflection could interfere with drivers' vision of other vehicles, pedestrians and traffic signals.

5.4 Hassall methodology

The reflected glare study considered the form, orientation and materiality of the approved development to assess the likelihood of reflected glare issues for observers on adjacent roads. The assessment was based on an industry-standard methodology developed by David Hassall of the University of New South Wales. The methodology is used to estimate veiling luminance, which is a quantitative glare metric used to estimate the potential impact on a person's ability to perform visual tasks. A more detailed description of the methodology and applied criterion is given in Appendix A.

5.5 Identification of glare receptors

This study considers sunlight reflection impacts on car drivers with views of the approved development. These observers are identified as the glare receptors for this study.

Figure 2 below illustrates the locations and paths of travel for the identified glare receptors. It comprises of a series of roads with potential view of the development.

In Figure 2, the subject site is indicated in red and the various roads are indicated in blue.

The glare receptors considered in this study are summarised below:

- North- and south-bound vehicles on Pacific Hwy, Clarke Ln, Clarke St, Nicholson Pl, Nicholson St, Hume Ln, Willoughby Rd
- Northeast- and southwest-bound vehicles on Hume St, Shirley Rd, Lamont St
- West-bound vehicles on Burlington St

Figure 2: Glare receptors with views of the subject site

5.6 Key assumptions

Key assumptions applied to this assessment are summarised below:

- 20% external glass reflectance at normal incidence. This is a maximum level of light reflectance discussed with the design team, representing a worst-case scenario regarding reflected sunlight glare risks.
- Surrounding buildings, except for Crows Nest OSD sites A and C, were considered in their existing form.
- Crows Nest OSD sites A and C were considered in both their current and future completed forms.
- Road users' eyes are located 1.5m above the road
- In general movement, all drivers look horizontally and along their direction of travel.

6. Building materials

A review of the façade elevations (drawings DA-3201, DA-3202) and external finishes schedule was completed to identify potential sources of reflected glare or other interference with driver operations.

6.1 Reflective finishes – cladding

The key non-glazed external finish presented on the building elevations and exterior finishes schedule that is visible from nearby roads is:

- CD-01 Terracotta panel, dark green

The specified terracotta panel has a high gloss finish.

6.2 Reflective finishes – glazing

The key materials with the potential to create specular (mirror-like) reflections are the glazed windows on each façade.

The façade glazing has not yet been selected, but is anticipated to have external specular light reflectance in the range 11-17%.

6.3 Assessment of reflective finishes

The reflected glare assessment presented in this report focuses on the terracotta panels and the glazed windows with specular reflection characteristics, which have the potential to create reflected disability glare.

7. Reflected glare assessment

The assessment of the potential for reflected glare to impact operators in the rail corridor (as identified in Section 5.5) is summarised below, with reference to Figures 3 and 4.

Figure 3: View of the proposed development from the east, showing the Pacific Highway and Hume St elevations

Figure 4: View of the proposed development from the north, showing the Hume St and Clarke Lane elevations

7.1 Pacific Highway elevation

The Pacific Hwy elevation has the potential to reflect sunlight into the view of drivers on the Pacific Hwy as well as various other streets to the west of the site.

One risk of disability glare reflections was identified from this façade: towards drivers travelling north on the Pacific Hwy. These reflections would appear higher in the drivers' view, and many such reflections would be blocked from view by the roof of the vehicle. Those reflections that would not be blocked from view by the roof of the vehicle would be blocked from view if the drivers deployed their sun visor.

For the case of north-bound traffic on the Pacific Hwy, the direct view of the sun at the time of receiving these reflections is expected to be blocked by buildings on the side of the highway and further north in St Leonards. However, earlier in their journey up the highway at these times (further to the south along the highway, on approach to the subject site), direct view of the sun is expected, and visors are likely to be applied to block direct view of the sun. It is therefore reasonable to expect that visors would applied to mitigate the reflected glare risk in this case.

7.2 Hume Street elevation

The Hume St elevation has the potential to reflect sunlight into the view of drivers on Hume St, Clarke Lane, the Pacific Hwy and various other streets to the north of the site.

Two risks of disability glare reflections were identified from this façade: towards drivers travelling south-west and north-east on Hume St.

Drivers travelling south-west on Hume St could receive disability glare reflections from a small section of this façade over levels G-1. While there is shading / overhang included in this section of the façade, the reflections would be low enough to get around the overhang. This risk is expected to occur for only around 20 mins per day, for only around three weeks in the year.

Drivers travelling north-east on Hume St could receive disability glare reflections from higher up on the tower façade. These would appear higher in the drivers' view, such that they would also be blocked if the drivers deployed their sun visor.

For the case of north-east bound traffic on Hume St, the direct sun would be in view at the same time as the reflections, until the adjacent Site A is developed. If the direct sun is in view at the same time as the reflections, the impact of the reflections would be much less than that of the direct sun view. Also, visors would be expected to be deployed to block view of the direct sun, and these would effectively block view of the reflections. Following completion of Site A, it would block the direct sun view at the time of receiving these reflections. As above, earlier in the drivers' journey up Hume St (further to the south-west along Hume St, on approach to the subject site), direct sun is likely to be in view, and visors are likely to have been deployed to block this view.

7.3 Clarke Lane elevation

The Clarke Ln elevation has the potential to reflect sunlight into the view of drivers on Clarke Lane, Hume St and various other streets to the east of the site.

No disability glare sunlight reflections are expected in this elevation.

This façade is largely obstructed from the view of drivers by existing surrounding developments. By the time this section of façade becomes visible, any sunlight reflections that would be visible in this façade would appear high enough from the drivers' direction of view that they would be blocked from view by the roof of the vehicle.

7.4 South elevation

The south elevation has the potential to reflect sunlight into the view of drivers on the Pacific Hwy and various other streets to the south of the site.

No disability glare sunlight reflections are expected in this elevation.

This section of façade would reflect parts of the southern sky through which the sun does not travel.

7.5 Terracotta panels

A sample of the proposed terracotta cladding was reviewed in sunny conditions. The specified finish is glossy, and when exposed to sunlight is expected to create strongly glary sunlight reflections.

Sunlight reflections in the terracotta tiles would appear most strongly in the mirror direction, but the texture in the terracotta would create some scattering of these reflections into a broader range of directions. This may not be sufficient to create disability glare reflections toward drivers, but it is expected to create strong discomfort glare into a range of directions including toward drivers.

7.6 Other sunlight reflections

The articulated form of the façades will create sunlight reflections into a range of directions any time the sun is incident on the façade.

While the façade will create sunlight reflections into many directions, including toward drivers on surrounding roads, these other sunlight reflections are not expected to create hazardous (disability glare) reflections to drivers.

While these other reflections are expected to create some discomfort glare (sunlight glints), they are not expected to create disability glare (interference with visual acuity). This is a common occurrence, and is consistent with sunlight reflections off all other buildings in and around the city.

8. Mitigation measures

Two of the identified risks of disability glare sunlight reflections are considered to be mitigated by drivers operating their sun visors (refer to Sections 7.1 and 7.2). Regarding the application of sun visors, it is not uncommon to consider this as a suitable risk mitigation measure, as long as it is reasonably determined that the visors would be in use at the time of receiving the sunlight reflections. This was determined for each identified risk, as discussed above. Further mitigation measures in response to these identified risks are not considered to be required.

The key reflected glare residual risk identified in the assessment summarised above arises from the terracotta tiles with glossy finish.

A mitigation measure in response to this finding was recommended to the design team – to change the specified finish of the terracotta tiles to a more matte finish. This is expected to sufficiently mitigate the identified reflected glare risk.

The design team confirmed their agreement to change the finish of the terracotta tiles as recommended.

9. Declaration

I, Phillip Greenup, confirm that all available information relevant to the assessment of the proposed development is contained in this report and that the information contained in this report is neither false nor misleading.

Senior Lighting Designer, PhD

Appendix A

A.1 Reflected glare

Sunlight reflects off all surfaces that it hits. Most of these reflections are easily viewed and do not present a risk to vision.

Sunlight reflects off surfaces that are not shiny in a diffuse way. These surfaces reflect sunlight into a wide range of reflected directions. In spreading the reflected sunlight over a wide range of directions, the intensity of the reflected sunlight is significantly reduced. Such reflections can be considered similar to sunlight patches on grass or carpet – they are generally bright but not uncomfortable.

Sunlight reflects off smooth, shiny surfaces, such as glass, in a specular (mirror-like) way. The intensity of specular reflections are much stronger than diffuse reflections, and such reflections are generally uncomfortable to view. Most often, this type of visual discomfort is known as 'discomfort glare'. Discomfort glare causes psychological annoyance, but is not considered to present a risk to vision as it does not require the observer to immediately turn away from the glare source.

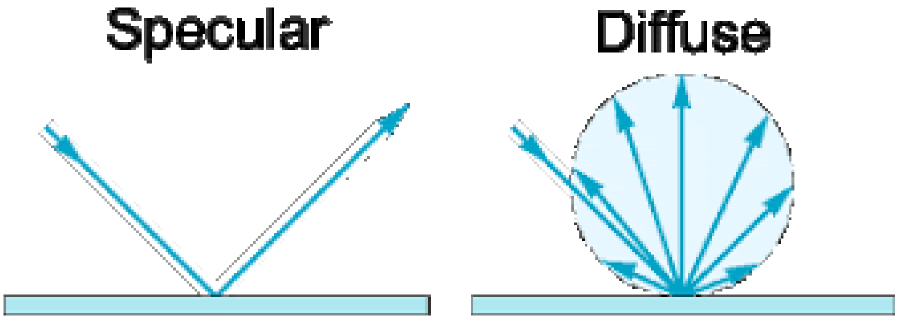

Figure 5: Specular and diffuse light reflection

When sunlight reflections are strong and close to the observer's direction of view, and the observer is performing detailed visual tasks that require concentration in a given direction of view, this can be hazardous. This form of visual impact, known as 'disability glare', causes the observer to be unable to perform a visual task such as driving without taking evasive action (such as turning away or raising a hand to shield the eyes). It temporarily degrades the observer's ability to perform the visual task on which they are focused. Disability glare does not imply long-term disability in any form.

This assessment of reflected glare risks is focused on identifying the risk of hazardous (disability) glare for relevant observers (glare receptors).

A.2 Hassall methodology

The risk of disability glare can be estimated using the Hassall methodology.

The Hassall methodology predicts disability glare by estimating 'veiling luminance' in the eye due to reflected sunlight glare. Veiling luminance is described further below.

The Hassall methodology predicts veiling luminance by considering many factors including the direction of view, the variation in surface reflectance with angle of incidence, and the variation in sun brightness with solar altitude.

For each combination of observer bearing (direction of view) and façade aspect (orientation of the façade), our assessment estimates veiling luminance due to reflected sunlight for every day of the year. This is used to predict the frequency and intensity of occurrence of reflected glare.

A.3 Veiling luminance

The physical manifestation of disability glare is the scattering of light from a glare source within the eye's ocular media (the near-transparent material within the eyeball). This creates a glow within the eye which interferes with vision in the direction of focus, as if a veil has been dropped in front of the eye. If this veiling glow is as bright as or brighter than the object on which the observer is focusing (the focal object), vision of the focal object can be significantly reduced.

The Hassall methodology predicts veiling luminance – the brightness of the glow created within the eye due to a glare source within the observer's field of view. Veiling luminance is a function of the brightness of the glare source and its proximity to line of sight. The function used is shown below.

$$Lv = 10\,E / \theta^2$$

Where,

Lv	=	Equivalent Veiling Luminance [cd/m²]
E	=	Illuminance at the eye produced by the glare source [lux]
θ	=	Angle between the light source and the line of sight [°]

The above formula, known as the Holladay formula, has been widely accepted as a calculation of disability glare since the 1930s.

The risk of disability glare, as estimated by veiling luminance, increases with the brightness of the reflection, and increases more strongly with the proximity of the glare source to the observer's direction of view.

A.4 The Hassall criterion

The Hassall methodology sets a criterion of Lv = 500 cd/m² for prediction of disability glare. Calculated veiling luminance levels below 500 cd/m² are not considered to indicate disability glare, and calculated veiling luminance levels above 500 cd/m² are considered to indicate disability glare.

The Hassall methodology does not set out the basis of setting the 500 cd/m² criterion. It is, therefore, informative to understand what this level of luminance represents. A few reference luminance levels are described below for comparison:

- Luminance reflected off a typical exterior surface of 20% reflectance, exposed to a median sky brightness (20,000 lux): 1,270 cd/m²
- Luminance reflected off a typical exterior surface of 20% reflectance, in a shaded position receiving 5,000 lux: 320 cd/m²
- Indicative luminance of a rail signal, in the direction of its orientation: 11,300-70,800 cd/m² (minimum brightness red to maximum brightness yellow)
- Indicative luminance of a rail signal, 6° away from the direction of its orientation: 5,650-35,400 cd/m² (minimum brightness red to maximum brightness yellow)

The above comparisons show that the Hassall criterion of 500 cd/m² is significantly lower than the luminance reflected off typical exterior surfaces under all but the most shaded conditions. It is also significantly lower than the expected luminance of rail signals.

The Hassall criterion can then be considered as reasonably reliable for view of the direction of travel and any obstructions under typical daytime conditions, and considerably conservative for assessment of impacts on rail signals.

The Hassall methodology and criterion are widely accepted by industry for this application. Both have been applied to assessments of similar risks from several previous developments around Australia and internationally.