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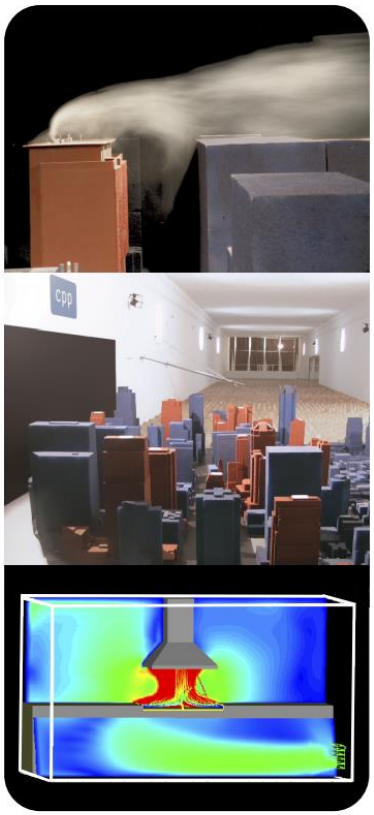
FINAL REPORT



Solar Reflectivity Assessment for:

DARLING SQUARE – SOUTH EAST PLOT

Sydney, Australia

CPP Project 8253

February 2016

Prepared for:

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INTRODUCTION

This report supports a State Significant Development (SSD) Development Application (DA) submitted to the Minister for Planning pursuant to Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

The Application (referred to as SSDA 9) follows the approval of a staged SSD DA (SSDA 2) in December 2013. SSDA 2 sets out a Concept Proposal for a new mixed use residential neighbourhood at Haymarket referred to as "Darling Square", previously known as "The Haymarket". Darling Square forms part of the Sydney International Convention, Exhibition and Entertainment precinct (SICEEP) Project, which will deliver Australia's global city with new world class convention, exhibition and entertainment facilities and support the NSW Government's goal to "make NSW number one again".

More specifically this subsequent DA seeks approval for mixed use development within the South East development plot of Darling Square and associated public domain works. The DA has been prepared and structured to be consistent with the Concept Proposal DA.

Overview of Proposed Development

The proposal relates to a detailed ('Stage 2') DA for a mixed use residential development in the South East Plot of Darling Square together with associated public domain works. The Darling Square Site is to be developed for a mix of residential and non-residential uses, including but not limited to residential buildings, commercial, retail, community and open space. The South East Plot is one of six development plots identified within the approved Concept Proposal.

Under the Concept Proposal, the South East Plot is planned to accommodate a mixed use podium and three residential buildings (SE1, SE2, and SE3) above and within the podium structure. More specifically, this SSD DA seeks approval for the following components of the development:

- Demolition of existing site improvements, including the existing Sydney Entertainment Centre (SEC);
- Associated tree removal and planting;
- Construction and use of a predominantly 5 storey mixed use podium, including:
  - retail floor space, residential lobbies and lobby on Ground Level;
  - above ground parking;
  - residential apartments; and
  - communal facilities.
- Construction and use of three residential buildings above podium;
- Public domain improvements adjacent to the site;
- Provision of vehicle access to the development from Harbour Street;
- Landscaping works to the podium roof level; and
- Extension and augmentation of physical infrastructure / utilities as required.

Background

The NSW Government considers that a precinct-wide renewal and expansion of the existing convention, exhibition and entertainment centre facilities at Darling Harbour is required, and is committed to Sydney reclaiming its position on centre stage for hosting world-class events with the creation of SICEEP.

Following an extensive and rigorous Expressions of Interest and Request for Proposals process, a consortium comprising AEG Ogden, Lend Lease, Capella Capital and Spotless was announced by the NSW Government in December 2012 as the preferred proponent to transform Darling Harbour and create SICEEP.

Key features of the Preferred Master Plan include:

- Delivering world-class convention, exhibition and entertainment facilities, including:
  - Up to 40,000m² exhibition space;
  - Over 8,000m² of meeting rooms space, across 40 rooms;
  - Overall convention space capacity for more than 12,000 people;
  - A ballroom capable of accommodating 2,000 people; and
  - A premium, red-carpet entertainment facility with a capacity of 8,000 persons.
- Providing a hotel complex at the northern end of the precinct.
- A vibrant and authentic new neighbourhood at the southern end of the precinct, now called 'Darling Square', including apartments, student accommodation, shops, cafes and restaurants.
- Renewed and upgraded public domain that has been increased by a hectare, including an outdoor event space for up to 27,000 people at an expanded Tumbalong Park; and
- Improved pedestrian connections linking to the proposed Ultimo Pedestrian Network drawing people between Central, Chinatown and Cockle Bay Wharf as well as east-west between Ultimo/Pyrmont and the City.

On 21 March 2013 a critical step in realising the NSW Government's vision for the SICEEP Project was made, with the lodgement of the first two SSD DAs with the (now) Department of Planning and Environment. The key components of these proposals are outlined below.

Public Private Partnership SSD DA (SSD 12_5752)

The Public-Private Partnership (PPP) SSD DA (SSDA 1) includes the core facilities of the SICEEP Project, comprising the new, integrated and world-class convention, exhibition and entertainment facilities along with ancillary commercial premises and public domain upgrades. SSDA1 was approved on 22 August 2013.

Concept Proposal (SSD 13_5878)

The Concept Proposal SSD DA (SSDA 2) establishes the vision and planning and development framework which will be the basis for the consent authority to assess detailed development proposals within the Darling Square Site. SSDA2 was approved on 5 December 2013. The Stage 1 Concept Proposal approved the following key components and development parameters:

- Indicative staging of demolition and development of future development plots;
- Land uses across the site including residential and non-residential uses;
- Street and laneway layouts and pedestrian routes;
- Open spaces and through-site links;
- Six separate development plots, development plot sizes and separation, building envelopes, building separation, building depths, building alignments, and benchmarks for natural ventilation and solar access provisions;
- A maximum total gross floor area (non-residential and residential GFA);
- Above ground car parking including public car parking;
- Residential car parking rates;
- Design Guidelines to guide future development and the public domain; and
- A remediation strategy.

The concept proposed was modified on 26 November 2015 to increase the amount of non-residential GFA. In addition to the approval of SSDA2, the following approvals have been granted for various stages of Darling Square site:

- Darling Drive (part) development plot (SSDA3) for the construction and use of a residential building (student accommodation) and the provision of associated public domain works approved on 7 May 2014;
- North-West development plot (SSDA4) for the construction and use of a mixed use commercial development and public car park building and associated public domain works approved on 7 May 2014; and
- South-West development plot (SSDA5) – construction and use of a mixed use residential development and associated public domain works approved on 21 May 2014.
- North-East development plot (SSDA7) – construction and use of a mixed use residential development and associated public domain works approved on 16 April 2014.

Approval was also granted on 15 June 2014 for SSDA6 which includes the construction and use of the International Convention Centre (ICC) Hotel and provision of public domain works. Approval was also granted for SSDA8 on 16 October 2015 which comprised the ICC Hotel fitout, external lighting and subdivision.

This report has been prepared to support a detailed Stage 2 SSD DA for mixed use development and associated public domain works within Darling Square (SSDA 9), consistent with the Concept Proposal (SSDA 2).

Site Description

The SICEEP Site is located within Darling Harbour. Darling Harbour is a 60 hectare waterfront precinct on the south-western edge of the Sydney Central Business District that provides a mix of functions including recreational, tourist, entertainment and business.

With an area of approximately 20 hectares, the SICEEP Site is generally bound by the light rail Line to the west, Harbourside shopping centre and Cockle Bay to the north, Darling Quarter, the Chinese Garden and Harbour Street to the east, and Hay Street to the south (refer to Figure 1). The Darling Square Site is:

located in the south of the SICEEP Site, within the northern portion of the suburb of Haymarket; bounded by the Powerhouse Museum to the west, the Pier Street overpass and Little Pier Street to the north, Harbour Street to the east, and Hay Street to the south; and irregular in shape and occupies an area of approximately 37,700m2.

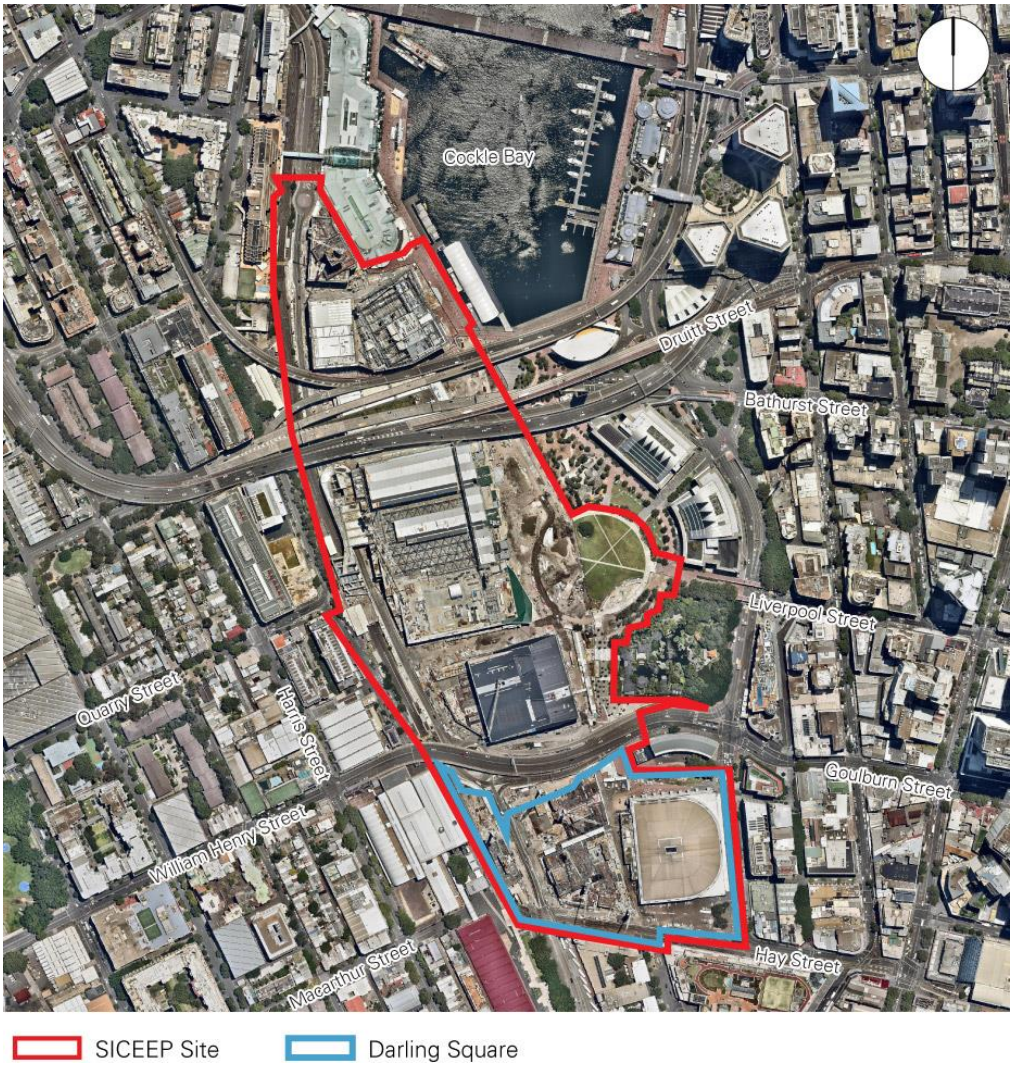

Figure 1 – Aerial Photograph of the SICEEP Site

The Concept Proposal DA provides for six (6) separate development plots across the Darling Square Site (refer to Figure 2):

1. North Plot;
2. North East Plot;
3. South East Plot;
4. South West Plot;
5. North West Plot; and
6. Western Plot (Darling Drive).

The Application Site area relates to the South East Plot and surrounds as detailed within the architectural and landscape plans submitted in support of the DA.

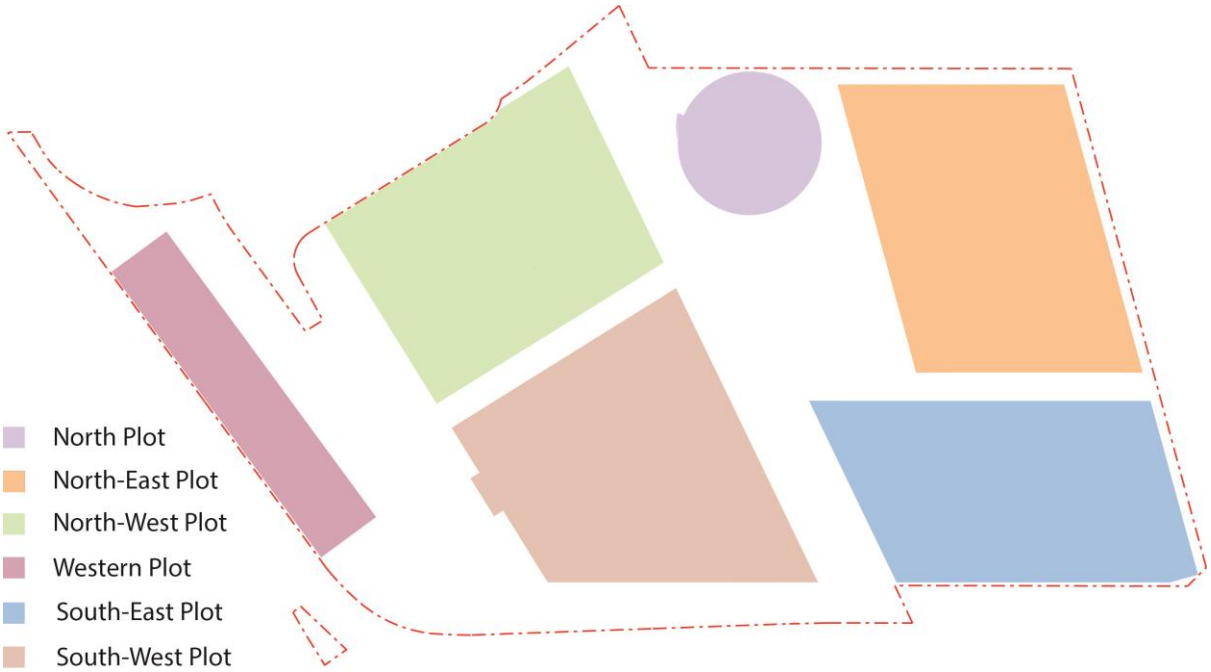

Figure 2 – Concept Proposal Development Plots

Planning Approvals Strategy

The SICEEP Project has resulted in the lodgement of numerous SSD DAs for the various components of the redevelopment project. Future applications will continue to be lodged in accordance with the Concept Proposal SSD DA for the remaining development plots of Darling Square Site.

PURPOSE

Cermak Peterka Petersen Pty. Ltd. has been engaged by Lend Lease to assess the proposed South East Plot (SEP) Precinct within the Sydney International Convention, Exhibition and Entertainment Precinct (SICEEP) Project at Darling Harbour in terms of solar reflectivity impact, Figure 3.

Figure 3: Architectural impression of the proposed SICEEP Project site viewed from the east.

The South East Plot Precinct, within the Darling Square SICEEP development, will consist of 391 residential apartments, in a mix of Studio, 1, 2, 3 bedroom apartments, with a retail area on the ground floor with frontages to Little Hay Street to the north, Hay Street to the south, Harbour Street to the east, and the Boulevard to the west. Tower SE1 will be 29 storeys, SE2 8 storeys and SE3 8 storeys.

This report makes reference to the Sydney Development Control Plan 2012, Section 3 General Provisions – Section 3.2.7 Reflectivity. Specifically, Section 3.2.7 states that "A Reflectivity Report that analyses potential for solar glare from the proposed building design may be required for tall buildings".

REFLECTIVITY IMPACT CONSIDERATIONS

To assess the impacts of the proposal, this report considers the Sydney Development Control Plan 2012, Section 3 General Provisions – Section 3.2.7 Reflectivity, specifically:

Provisions

- A Reflectivity Report that analyses potential for solar glare from the proposed building design may be required for tall buildings.
- Generally, light reflectivity from building materials used on facades must not exceed 20%.
- For buildings in the vicinity of arterial roads/major roads and Sydney Airport, proof of light reflectivity is required and is to demonstrate that light reflectivity does not exceed 20%.

Lend Lease will ensure all exterior façade elements used throughout the South East Plot development will limit light reflectivity to 20% or less. For glazing producing specular type reflections this is defined as the percentage solar reflection when light strikes and reflects normal to the façade plane. When incident solar rays strike near parallel to the façade plane (large incident angle of typically greater than 70° also referred to as glancing reflections), it is known that the reflectivity of all glazing types increases dramatically towards the properties of a mirror, Figure 4.

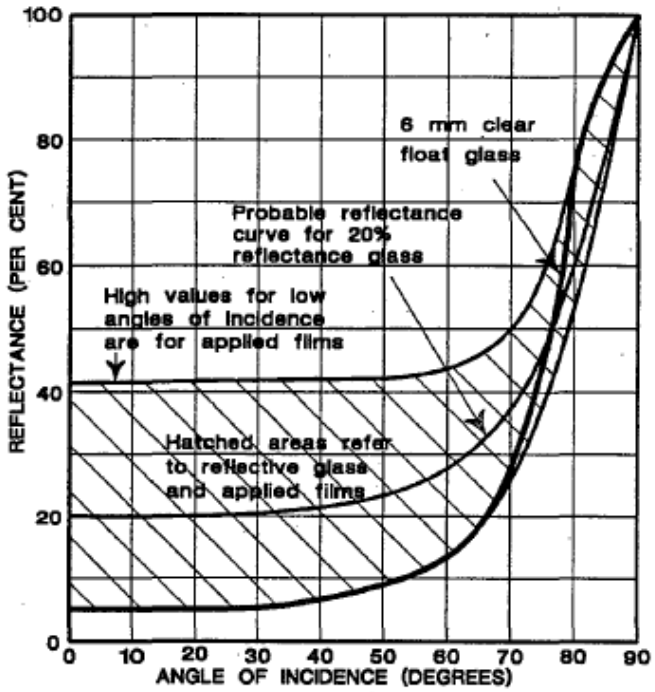

Figure 4: Façade Reflectivity versus angle of incidence (Hassall, 1991)

Thus, even for glazing with low reflectivity coefficients, the potential for glare increases significantly when incoming solar rays can impact on a building close to parallel to the plane of the glazing, i.e. a glancing reflection. The following report quantifies potential for solar reflections of all incident angles on glazing to impact upon the surrounds taking into consideration:

- Seasonal and diurnal solar paths (sun altitude and azimuth) at the SE Plot latitude and longitude and the relative angle between incident solar rays and façade orientation.
- Reflectivity coefficients of the external glazing being used.
- Roadway receiver locations of interest; the alignment of adjoining public roads.

Where the combination of these factors suggests there is potential for hazardous rogue reflections to impact on surrounding areas, the potential magnitude of reflections can be quantified and compared with acceptability criterion described below. This report quantifies the potential for solar reflectivity glare impact upon motorists using roadways intersecting and surrounding the SE Plot. CPP use in part methodology developed by Hassall (1991) and the concept of veiling glare and contrast when quantifying the potential for hazard rogue reflections onto surrounding receiver locations. In many instances the potential for a façade to generate rogue reflections can be eliminated without the need for calculation by taking into account the above factors as well as shading offered by surrounding building massing.

Pedestrian impacts are less likely to be of safety concern and are assessed more broadly in this report in terms of general amenity and usability of the site. A pedestrian can more readily divert their viewing angle away from the glare source or halt walking momentarily. It must be appreciated it is impractical to mitigate potential solar reflections at all potential pedestrian receiver locations across and surrounding the precinct.

Similarly, this report does not assess the impact of reflected solar glare onto surrounding building windows. Notwithstanding, designers have no glass sloping toward the sky in order to minimise solar reflections back onto surrounding multi-storey buildings, i.e. all glass is aligned vertically or sloping downward toward the ground.

GLARE ACCEPTABILITY CRITERIA

Consider an object that is just visible in the absence of glare. The object will no longer be visible when glare is introduced and it will be necessary to increase the contrast to make the object visible again. Threshold Increment (TI) is the percentage by which the contrast must be increased to make the object just visible and is the parameter calculated in this study to assess the acceptability or otherwise of potential reflectivity 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 TI acceptability criterion adopted in this study for assessing solar glare impact on passing traffic.

Where high TI values are identified it is useful to investigate the angular limits of façade reflections relative to the motorist observer using a glare protractor (Hassall 1991). The glare protractor comprises a series of loops indicating whether a glare source will be above a predetermined veiling glare limit for the resultant % level of cladding reflectivity.

Calculations in this report assume specular type reflective façade surfaces, where the reflected ray angle is equal to the incident solar ray angle; being valid for most smooth surface glazing materials. Other building materials including surface fritted glazing, masonry, brickwork, tiles, and metal deck roofing produce diffuse components of reflection 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 glare reflections than glazing.

REFLECTIVITY IMPACT RESULTS

The South East Plot buildings are tall relative to surrounding roadways, so reflections from the facades are able to extend significant distances; especially early morning and late afternoon events when the solar altitude angle is low. Also important is the solar shading available from surrounding and proposed developments and the massing of the Sydney CBD.

The Boulevard, Hay Street and Harbour Street were considered most at risk to solar glare from the development and were primarily assessed for reflectivity impact in this report. With reference to the Holladay formula (Hassall, 1991); the greatest potential for glare impact upon drivers is when the angle between the centre of the glare source and line of sight is small. Therefore, the greatest potential for glare impacts is for motorists travelling *toward* the SE Plot site.

<u>Hay Street SE Plot travelling west toward the site</u>

The greatest potential for the proposed SICEEP Haymarket SE Plot developments to generate reflections onto westbound motorists on Hay Street is solar interaction with the southern facades of SE1, including Hay street locations west and east of George Street.

The highest TI values calculated for this facade were caused by late afternoon reflection conditions. Evening (around 6pm daylight savings time) low altitude solar rays during the mid-season months strike the southern facade of SE1 from the west with reflections towards the east along Hay Street.

An example of this reflection condition is on April 1st, which is illustrated in Figure 5 showing reflections off the south façade of SE1 between the roadway and roof levels. The impact point is on Hay Street near the intersection of Dixon Street.

Reflections start	6:15 pm	TI = 40
Reflections cease	6:30 pm	TI = 15

The highest TI levels are in excess of the criterion. It is noted the altitude angle of the incident solar rays is low being about 10 degrees and in the line of sight of a driver travelling westward, contributing to the high TI value (refer Holladay formula).

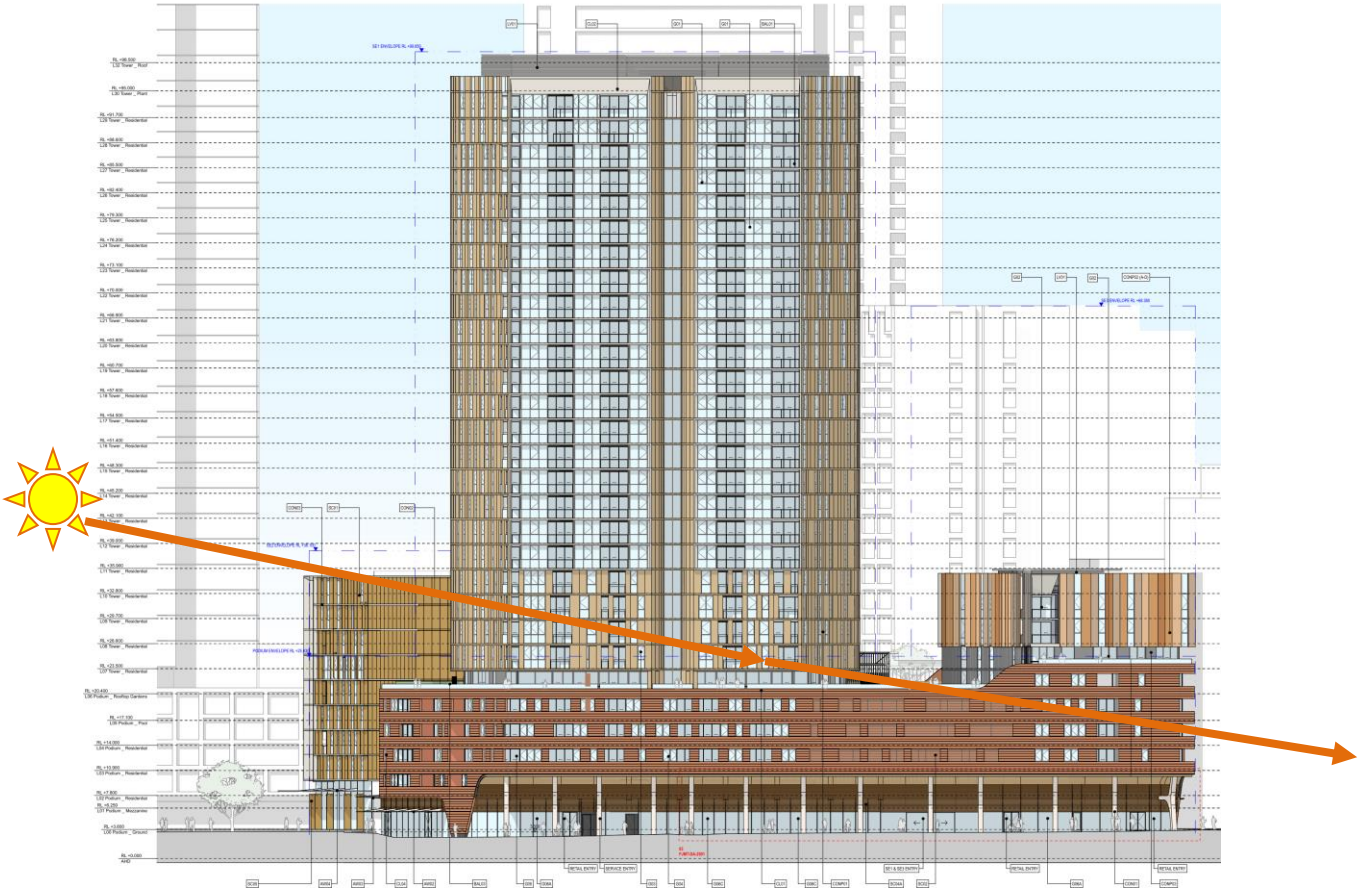

Figure 5: Afternoon reflection condition off SE1

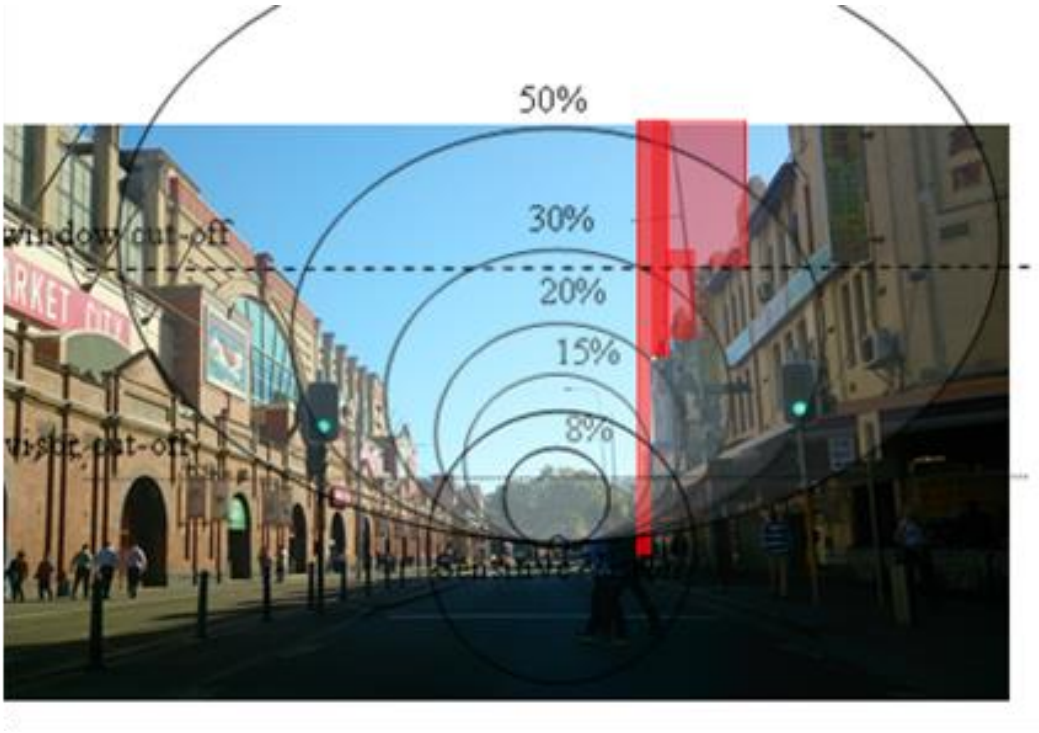

Figure 6: Glare protractor on Hay Street at Dixon Street intersection, westward view

A Hassall glare protractor is used to investigate potential solar glare impacts on the westbound motorist. With reference to Figure 6, it is evident that reflections from the southern facade of SE1 fall within the sensitive vision zone.

Living rooms and balconies protruding from the southern façade of SE1 contain glazing elements including windows and balustrades, Figure 5. The potential for glare to be generated from these glazing elements increases significantly when incoming solar rays can impact on a building close to parallel to the plane of the glazing, i.e. a glancing reflection. Designers have therefore incorporated vertically aligned opaque fin type elements against the facade to block high incident angle solar reflections able to impact on the sensitive vision zone of approaching motorists. The vertical elements will need to run perpendicular to the façade line over the height of the tower and be spaced horizontally.

A depth ratio of 1:6 was calculated to provide sufficient solar blockage and is being adopted whereby the element needs a depth of 1 unit for every 6 units of glazing width being protected; for example, a mullion extending 100 mm proud of the glazing line will need to be placed at 600 mm horizontal centres. The final dimensions will be chosen during detailed design but will comply with this ratio.

Harbour Street travelling north toward the site

The greatest potential for the proposed SE Plot developments to generate reflections onto Harbour Street is solar interaction with the eastern podium facades of SE3.

The highest TI values calculated for this facade were caused by midday reflection conditions. Higher altitude solar rays during the winter months strike the eastern façade of SE3 from the north with reflections towards the south along Harbour Street. TI values were found to be below

criterion levels of 20 due largely to the relatively high altitude of the sun (refer Holladay formula). Further, at midday the altitude angle of incident solar rays is high enough to be cut off by the windscreen roof of most vehicles.

The Boulevard

The greatest potential for the proposed SE Plot developments to generate reflections onto The Boulevard is solar interaction with the western podium facades and west tower facades of SE1 and SE2.

The highest TI values calculated for this facade were caused by early afternoon reflection conditions. Higher altitude solar rays during the winter months strike the western façades from the north with reflections towards the south along The Boulevard. Again, TI values were found to be below criterion levels of 20 due largely to the relatively high altitude of the sun (refer Holladay formula). Further, at midday the altitude angle of incident solar rays is high enough to be cut off by the windscreen roof of most vehicles.

Other Surrounding Locations

Given the height of the SE1 tower, there is potential for facades to cast solar reflections beyond the roadways listed above, but TI values will be low. For example, southbound traffic on Harbour Street approaching Pier Street for the north; some mid-morning winter events were identified but below the TI criterion level.

Lend Lease will ensure all exterior façade elements used throughout the development will limit light reflectivity to 20% or less as required under the Sydney Development Control Plan 2012. Low glazing reflectivity coefficient on these facades will also be of benefit to pedestrian users of the precinct in areas such as the Chinese Gardens.

Diffuse Reflections

Other façade and roof ancillaries to be developed during detailed design should each be assessed for potential to generate nuisance reflections. Elements such as external louvers, metallic awnings, photovoltaic arrays, signage, blade walls, and masonry walls have potential to generate localised glare of both a diffuse and specular nature. Assessment of these is not made in the current study but will be assessed during detailed design.

CONCLUSIONS

Lend Lease will ensure all exterior façade elements used throughout the development will limit light reflectivity to 20% or less as outlined under the Sydney Development Control Plan 2012.

To meet the qualitative requirements of the Sydney Development Control Plan 2012, this reflectivity analysis has assessed the potential for the proposed developments to cause adverse glare events at surrounding motorway locations.

In summary, with the measures adopted by the designers as described in this report regarding choice of façade materials and façade articulation, the proposed SICEEP Haymarket South East Plot development does not present a driver hazard in terms of solar glare and will meet the Sydney Development Control Plan 2012 controls for reflectivity.

REFERENCES

Australia/New Zealand Standard AS/NZS 1158.1.1:2005 "Lighting for Roads and Public Spaces" Part 1.1: Vehicular Traffic (Category V) lighting – Performance and design requirements".

Hassall (1991) "Reflectivity, Dealing with Rogue Solar Reflections" Faculty of Architecture, University of NSW.