

Appendix 11.2

Solar Glare Intensity Note



DAYLIGHT & SUNLIGHT

SOLAR GLARE INTENSITY NOTE

**Great Jackson St Plot D &
Crown St Phase 3**

15 March 2023

GIA No: **17759**

PROJECT DATA:

Client **Renaker Build**
Architect **Simpson Haugh**
Project Title **Great Jackson St Plot D & Crown St Phase 3**
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1 INTRODUCTION

GJA have assessed the proposed scheme in order to ascertain whether solar reflections given off the proposed building's facade will be visible from sensitive viewpoints which may affect train drivers.

1.1 GLARE

Glare is a phenomenon occurring in the eye that is caused by the presence of bright light sources within the visual field. It can lead to visual discomfort and, if the glare source is very bright compared to its surrounding, even be disabling in the sense that objects become hard or impossible to see. This is because they are cloaked by the high intensity glare source, whose light gets scattered within the eye.

The CIE 146:2002 Collection on Glare expresses the latter type of glare more formally as:

"Disability glare is glare that impairs vision (CIE, 1987). It is caused by scattering of light inside the eye [...]. The veiling luminance of scattered light will have a significant effect on visibility when intense light sources are present in the peripheral visual field and the contrast of objects to be seen is low."

"Disability glare is most often of importance at night when contrast sensitivity is low and there may well be one or more bright light sources near to the line of sight, such as car headlights, streetlights or floodlights. But even in daylight conditions disability glare may be of practical significance: think of traffic lights when the sun is close to them, or the difficulty viewing paintings hanging next to windows."

Glare is of particular concern if it affects drivers of motor vehicles or trains, since it might impair the visibility of signals and traffic signs, potentially putting the driver, passengers or other parties at risk.

1.2 GLARE FROM REFLECTED SUNLIGHT

Whether or not a sun reflection will cause an instance of glare depends upon a number of factors, these are summarised below:

- The location of the observer and his view direction;
- The sun's position in the sky, which changes not only with the hour of the day, but with the seasons too;
- The location and orientation of the reflective surface, e.g. a glazed facade, in relation to the observer's view direction;
- The specific quality of the reflective surface, e.g. sheen, specularity, etc.;
- The observer's physiology, e.g. age and eye pigmentation; and
- The background brightness defining the state of adaptation in the observer's eye;

This final point is an important one as the same brightness which could cause glare against a dark background may be perfectly acceptable when looked against a light one. A typical example of adaptation is illustrated in Figs. 01 and 02 where the same headlights cause glare at night whereas they do not during daytime hours.

Understanding whether solar glare is likely to occur is based on the observer's position and view direction. Given the transitory nature of the phenomenon, due to the sun's constant movement, any glare assessment should be carried out for a number of representative locations and view directions.

Such studies are often carried out with the help of sun path protractors, as depicted in Fig. 03 below, or with the aid of a full 3 dimensional computer simulation.

When a large number of locations need to be looked at, studies involving solar protractors become rather impractical. Computer software allows multiple view points to be assessed with greater ease so that it has even become feasible to render video sequences showing when and where reflections may become an issue.



Fig. 01: Headlights at night



Fig. 02: Headlights during day

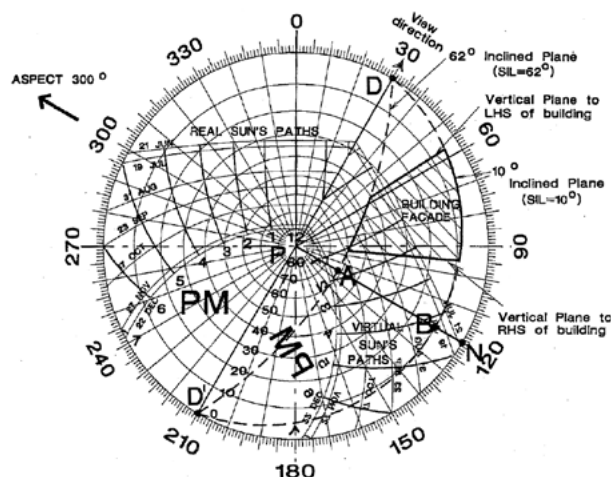


Fig. 03: Hassall's Protractor

1.3 EXISTING GUIDANCE

In the UK, guidance that is relevant to glare assessments is limited to a short section in Littlefair's Site Layout Planning for Daylight and Sunlight published by the BRE in 2011. This document is commonly referred to as BR 209. It suggests that:

"If it is likely that a building may cause solar dazzle the exact scale of the problem should be evaluated. This is done by identifying key locations such as road junctions and windows of nearby buildings, and working out the number of hours of the year that sunlight can be reflected to these points. BRE Information Paper IP 3/87 gives details."

BR IP3/87 provides more detailed instructions on why and how solar dazzle can be calculated:

"Glare or dazzle can occur when sunlight is reflected from a glazed facade. For vertical facades this problem usually occurs only when the sun is low in the sky; but some types of modern design incorporate sloping glazed facades which can, under certain circumstances, reflect unwanted high altitude sunlight into the eyes of motorists, pedestrians and people in nearby buildings."

Both BR 209 and BR IP3/87 only deal with geometrical considerations of glare by identifying when and where reflections occur. However, neither pieces of guidance suggest any threshold values above which reflected sunlight may give rise to an instance of glare. That such a threshold exists in theory becomes clear from the guidance in BR 209:

"... Substituting clear or absorbing glass for reflective glass can also help although sometimes even clear glass may cause reflected glare if, eg, a motorist has the reflected sun close to the centre of their line of sight."

Recommendations on acceptable limits for solar glare is equally sparse in other countries. The only document dealing with the subject is Hassall's Dealing with Rogue Solar Reflections from 1996. Although published in Australia, the theory, methodology and recommendations it introduced are equally applicable in other countries such as the UK.

The severity of glare can be calculated as the equivalent veiling luminance which is caused by the excess light being scattered in the eye thereby

creating a 'veil' through which objects are seen. If the brightness of the veil is sufficiently high compared to that of the actual object, the latter becomes less visible. In very severe cases of disability glare, the object cannot be seen at all.

The veiling luminance can be calculated with a simple empirical formula first proposed by Holladay:

$$L_{\text{seq}} [\text{cd/m}^2] = K \cdot E_{\text{gl}} / \theta^n < \text{threshold}$$

The Holladay glare formula depends on four variables, namely:

- **K**, which is a factor accounting for the observer's sensitivity to glare (eg. age);
- **E_{gl}**, which is the illuminance from the glare source, measured at the eye of the observer;
- **θ**, the angle between the line of sight and the glare source;
- **n**, indicating the power with which θ affects the outcome;

An individual's sensitivity to glare is affected primarily by age. We used a K factor of 17.5 in our calculations, which represents a 65-year old driver.

According to CIE 146:2002, the n power in Holladay's equation has three angular domains:

- **θ³** for angles between 0.1° and 1°;
- **θ²** for angles between 1° and 30°; and
- **θ** for angles beyond 30°;

This angular dependency means that a glare source close to the object being looked at has a much more severe impact upon the visibility of that object than a glare source at the periphery of the observer's visual field.

As stated in CIE 146:2002, occurrences at angles beyond 30° would be of little significance in most situations, but may be relevant in exceptional circumstances. When seated in a driving seat of a typical car, for example, the limits of the windscreen would generally obstruct the driver's view at angles beyond 30° from the line of sight. We have therefore adopted the 1° to 30° domain as a reference for our calculations.

Hassall in his paper proposes a threshold value of 500 cd/m², which we have adopted as a threshold in our assessments.

2 GIA'S APPROACH

Following the guidance documents referenced above, GIA have developed specialised computer software in order to undertake reflected glare assessments.

The preparation of reflected solar glare assessments is based upon the approach described below, which entails:

- The construction of a three-dimensional computer model that includes the proposed building and its relevant setting;
- The physically accurate description of the reflective surface properties;
- Rendering of stills of the solar reflections;
- Masking the images to represent the human field of view; and
- Image analysis;

The individual steps of our work flow are further explained below.



Fig. 04: High-resolution aerial photograph

2.1 3D COMPUTER MODELLING

Detailed geometry of the proposed building, specifically of its facade and glazing configuration is provided by the project architects either in 2d format i.e. plans, sections and elevation drawings, or 3d format as a computer model. The received information is processed by GIA and prepared for assessment with our proprietary software.

A computer model of the proposed building's context is built from high resolution stereoscopic aerial photographs, examples of which are shown in Figs. 04 to 06.



Fig. 05: High-resolution aerial photograph (close-up)

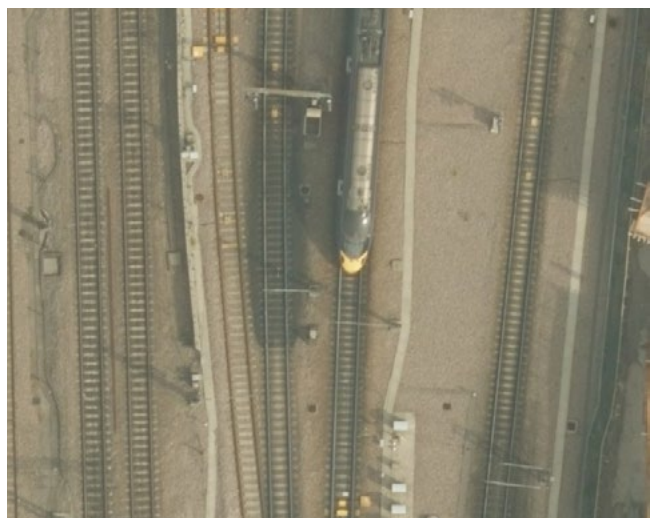


Fig. 06: High-resolution aerial photograph (detail)

2.2 REFLECTIVE SURFACE PROPERTIES

In order to undertake the glare studies it is necessary to acquire physically accurate computer representations of all materials that have the potential of specularly reflecting sunlight, thereby becoming sources of glare. Such materials would include all vertical or sloped glazing, but also certain facade materials such as metal cladding or glazed building tiles.

Diffuse surface reflectance values and object colours can be measured relatively easily however, the same cannot be said of their specular characteristics. These parameters are very hard to estimate yet critical for the study of glare. It is therefore best practice to have samples of the glazing or cladding materials studied in specialised optical laboratories. An example of such a data set is given in Fig. 07. It shows the angular dependency of the reflective properties of a glazed cladding tile.

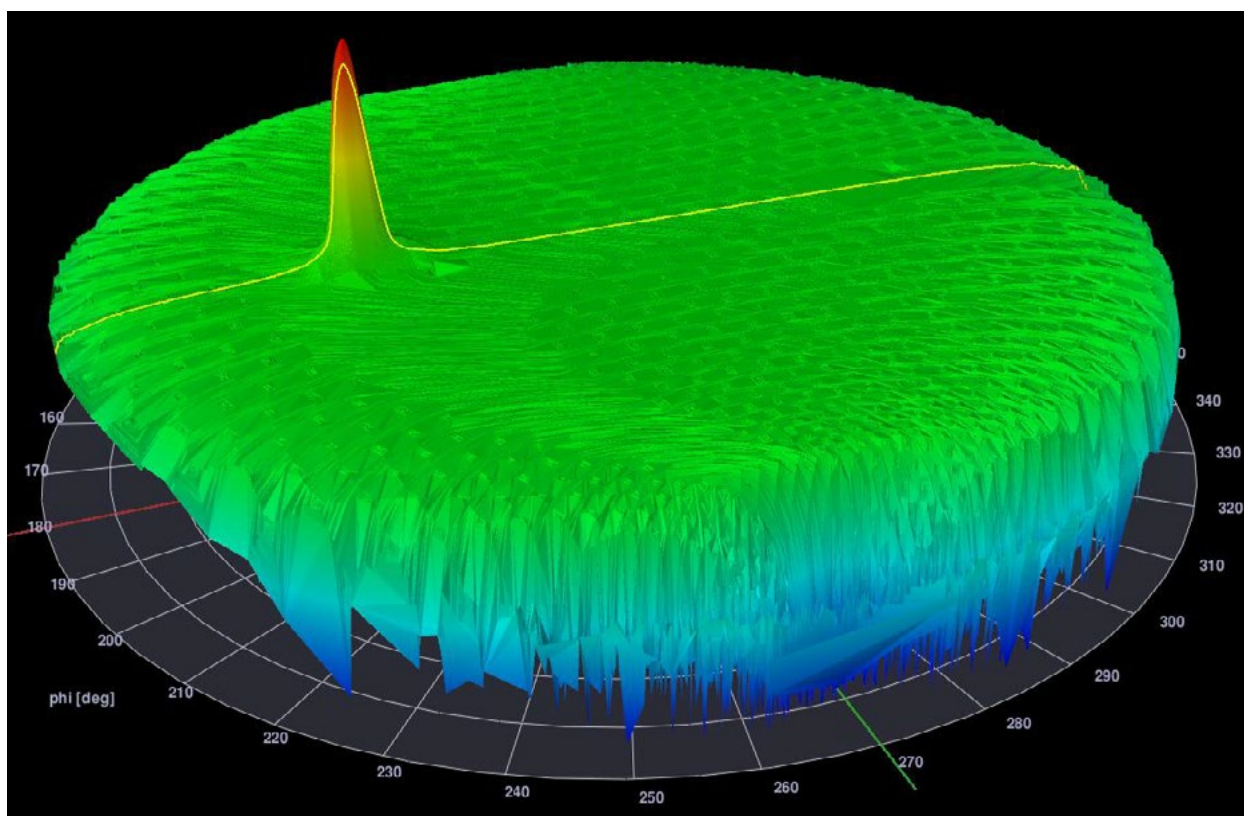


Fig. 07: Reflective properties measurement of a glazed tile

2.3 VIEWPOINTS

The methodology described below is aimed at addressing the intensity of an instance of reflected solar glare, duration throughout the year and the location of this occurrence in respect of a driver’s line of sight.

Potentially sensitive viewpoints around the site are selected. These viewpoints representing locations where reflected solar glare may cause adverse impacts to those travelling towards the development, such as road users or train drivers. The viewpoints are generally located at the minimum stopping distance and at the driver’s eye height. The focal point is a relevant traffic element, such as signals or incoming traffic.

The stopping distance is calculated as the combination of thinking and breaking distances $D_{total} = D_{thinking} + D_{breaking}$
 $= V \cdot T + V^2 / (2 \mu \cdot g)$, where each component is:

V = Relevant vehicle speed, typically the road speed limit.

T = Thinking time (0.67 sec)

μ = Breaking effort (considered 0.65 for cars, 0.5 for buses and 0.031 for trains)

g = Gravity acceleration.

The height of the viewpoint is considered to be 1.5 m for cars, 2.0 m for buses and 2.5 m for trains.

I.e. A viewpoint for car driving at 30 mph would be placed at 23 m (see Figure 08) from a traffic light and at 1.5 m above the ground.

Typical Stopping Distances

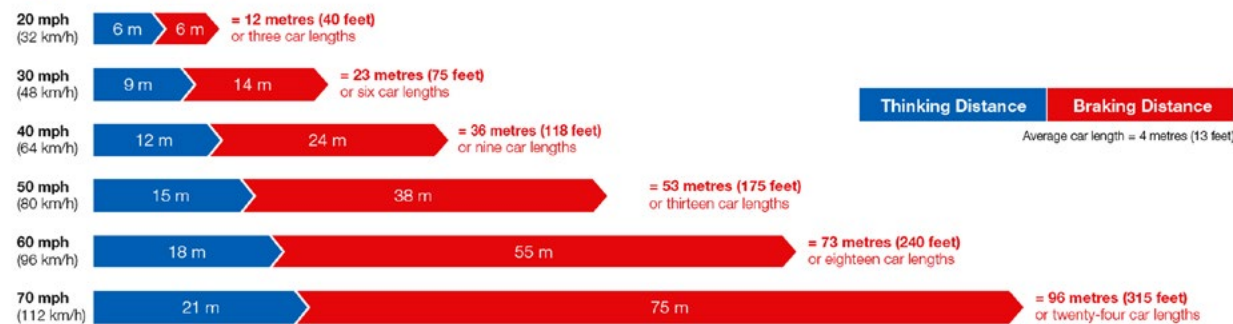


Fig. 08: Typical car stopping distances for various speed limits

2.4 FIELD OF VIEW

"The field of view (also field of vision) is the angular extent of the observable world that is seen at any given moment."

"Different animals have different fields of view, depending on the placement of the eyes. Humans have an almost 180-degree forward-facing field of view[...]."

(http://en.wikipedia.org/wiki/Field_of_view)

"The normal human visual field extends to approximately 60° nasally (toward the nose, or inward) in each eye, to 100° temporally (away from the nose, or outwards), and approximately 60° above and 75° below the horizontal meridian. In the United Kingdom, the minimum field requirement for driving is 60° either side of the vertical meridian, and 20° above and below horizontal. The macula corresponds to the central 13° of the visual field; the fovea to the central 3°."

(http://en.wikipedia.org/wiki/Visual_field)

"The fovea centralis, also generally known as the fovea, is a part of the eye, located in the centre of the macula region of the retina. The fovea is responsible for sharp central vision (also called foveal vision), which is necessary in humans for reading, watching television or movies, driving, and any activity where visual detail is of primary importance."

(http://en.wikipedia.org/wiki/Fovea_centralis_in_macula)

2.5 IMAGE ANALYSIS

Glare assessments are carried out following a three-stage approach. In **Stage 1**, stills are generated with which the potential for the occurrence of reflected sunlight is evaluated with regards to the times of the year and hours of the day when this may happen, as well as its relative location to the observer's line of sight.

In order to achieve this, the yearly sun path is mapped onto the sky and colour-coded so that the hours of the day and the period of the year can be distinguished. This sun path is picked up by the reflective elements of the proposed buildings in our rendered stills.

Fig. 10 shows the colour coded sunpaths projected onto the sky dome to visualise the time of day and season during which solar reflections occur.

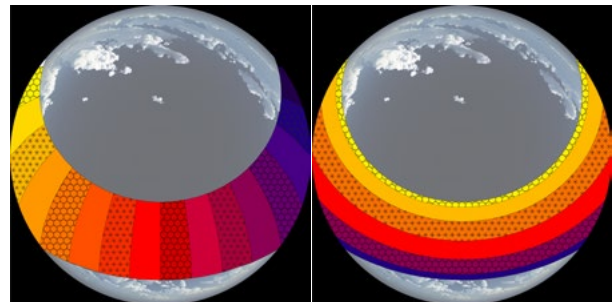


Fig. 10: Stage 2 - Colour coded sunpath for time of day and seasons

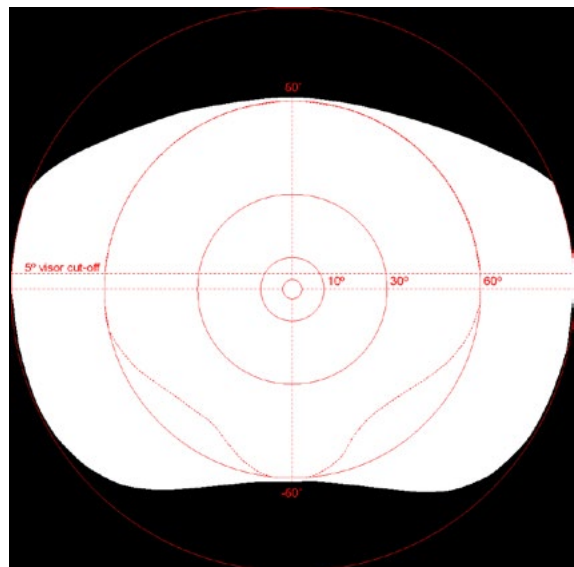


Fig. 09: Typical human field of view

Two identical viewpoints are rendered, shown in Figs. 11 and 12, one focussing on the times of the day when the reflection would be visible, and the second looking at the months throughout the year.

The following guidance is used to determine whether an intensity study is necessary:

- Solar reflections are visible within 30° to 10° of the driver's line of sight for a long period of time (large reflective surface) or between 10° to 5° for a short period of time;
- Solar reflections are visible within 10° and 5° of the driver's line of sight occurring for a long period of time;
- Solar reflections are visible within 5° of a driver's line of sight;

Stage 2 predicts the intensity of the reflected sunlight, using the Holladay formula presented in Section 1.3 of this report. An example is provided in Fig. 13. Only one view is necessary to portray the equivalent veiling luminance.

Any value exceeding 500 cd/m² is further looked into and discussed within the conclusions of our report.

A limitation of this Stage 2 methodology is that it can flag false positives when the reflector, i.e. a window, is too small to actually reflect the full extent of the solar disc. As a result of this, even a single bright pixel in the

computer image is capable of producing a peak veiling luminance equivalent to that of the full solar disc.

In our 60° animations, which are rendered out at a resolution of 1,000 x 1,000 pixels, the sun's disc has a diameter of 8 pixels.

To account for such situations, an additional **Stage 3** solar glare methodology was developed. Stage 3 was primarily developed to provide a visual assessment of the solar reflections. This is done by rendering out computer images which are then post-processed to mimic how a human observer might perceive the scene. In addition to the visual appraisal, our Stage 3 methodology can also provide veiling luminance values without potentially highlighting false positives from very bright, but individual pixels within the image. Unlike a Stage 2 analysis, however, which looks at the entire year, a Stage 3 analysis is limited to a specific time of day, and day of the years, as informed by the Stage 2 results.

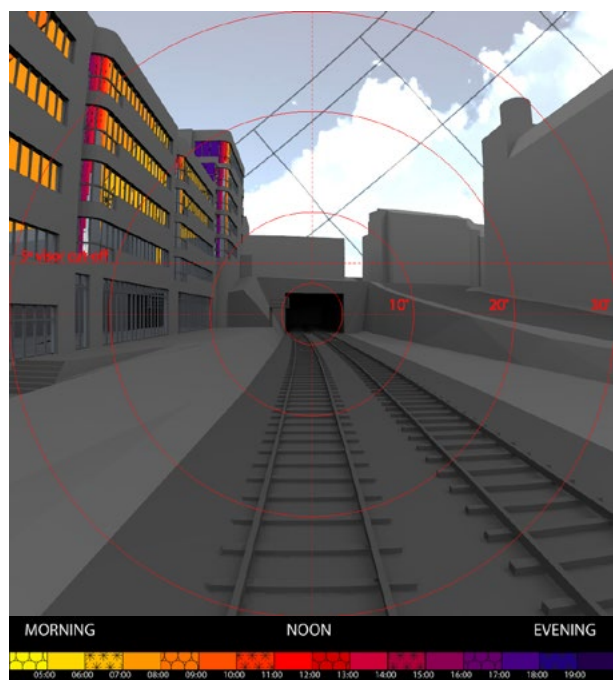


Fig. 11: Stage 1 Example - Hours

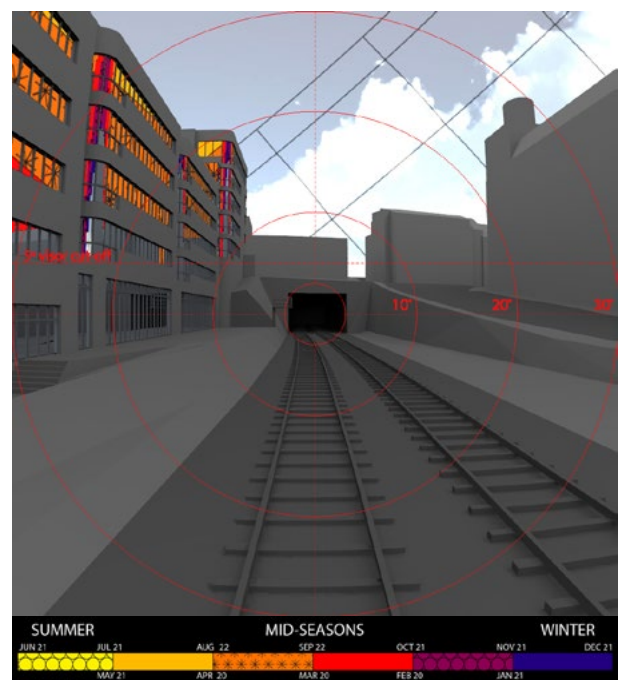


Fig. 12: Stage 1 Example - Months

2.6 LIMITATIONS

Great care is taken in identifying typical viewpoints around a new development. However, this does not guarantee that all sensitive locations where reflected solar glare could present a particular risk are covered, especially where these are farther away from the site.

IMPORTANT: The hours shown in the diagrams and described in the text reflect solar time and therefore do not take British Summer Time into account.

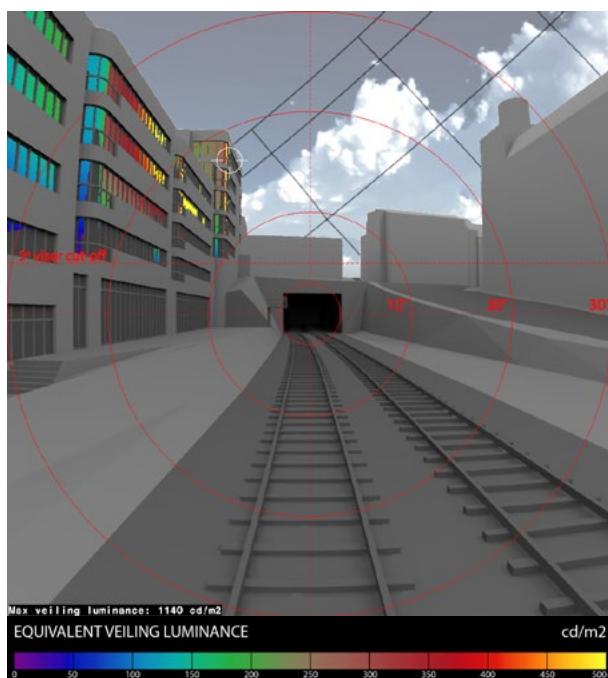


Fig. 13: Stage 2 Example - Veiling Glare Luminance

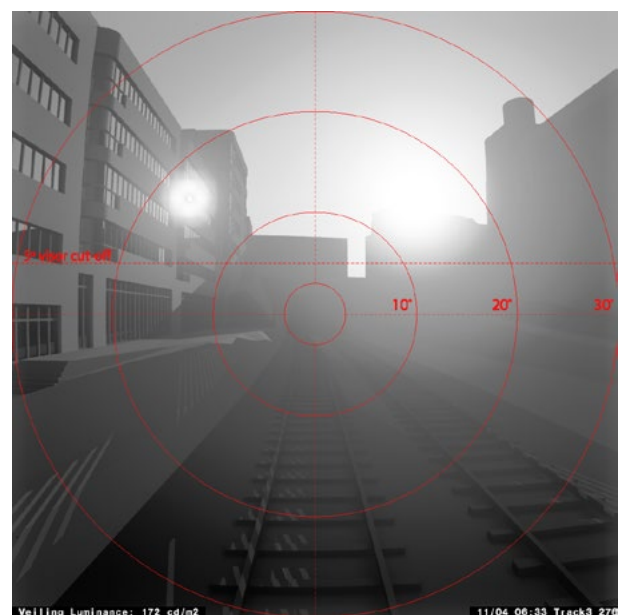


Fig. 14: Stage 3 Example - Veiling Glare Luminance

3 STAGE GLARE INTENSITY ASSESSMENT

Melbourne Street Northbound Junction (with Great Jackson Street)

STAGE 1: 60° FIELD OF VIEW: TIME OF DAY
VIEWPOINT MS1 - MELBOURNE STREET
LOOKING FORWARD

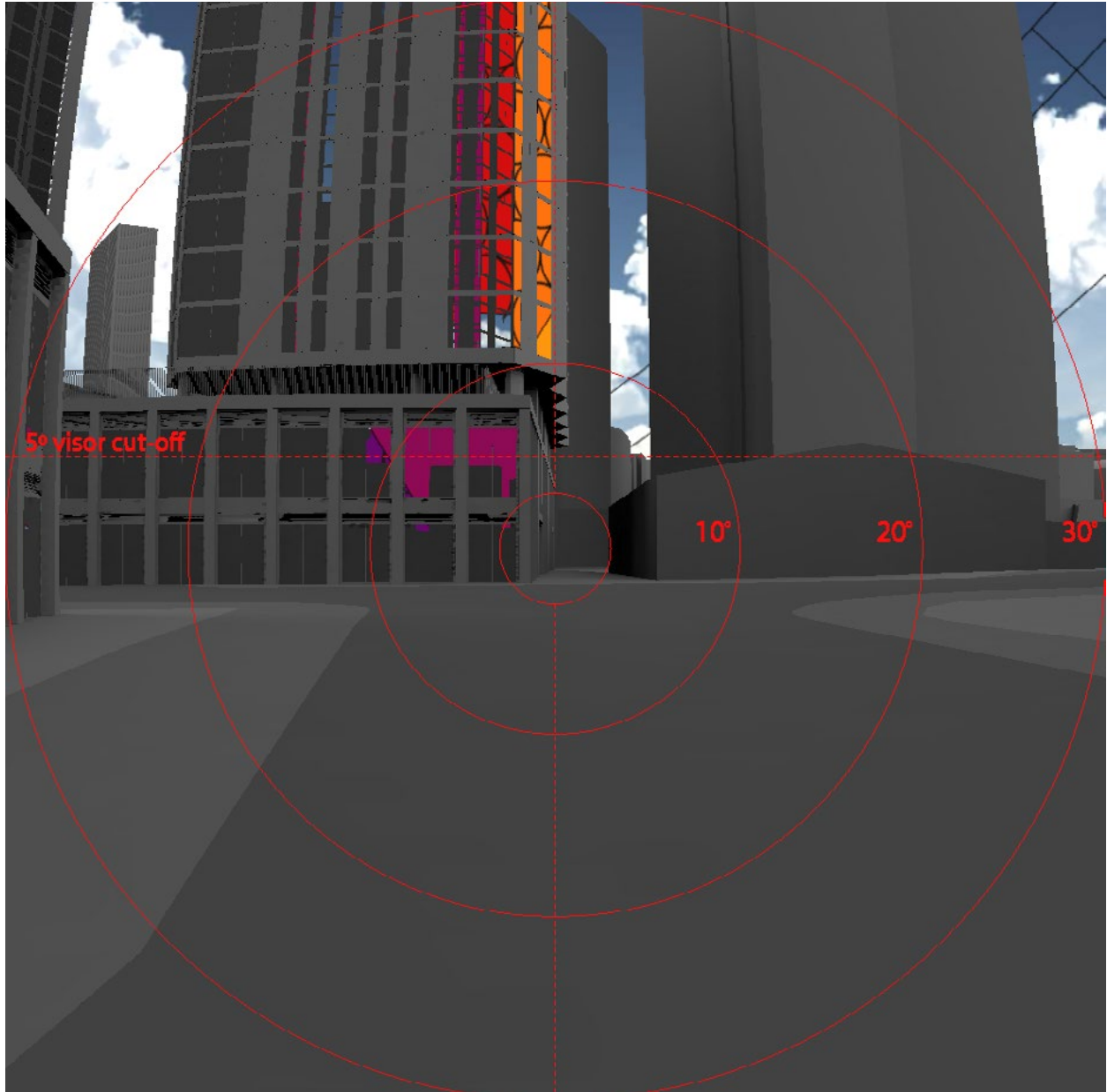
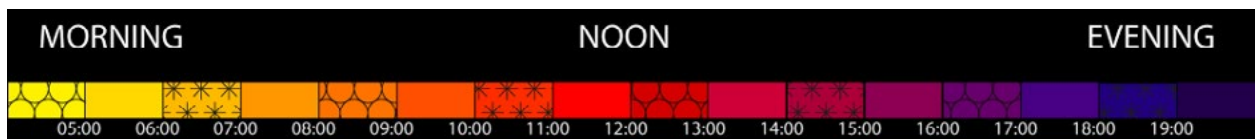


Fig. 15: Solar reflections



STAGE 1: 60° FIELD OF VIEW: SEASON
VIEWPOINT MS1 - MELBOURNE STREET
LOOKING FORWARD

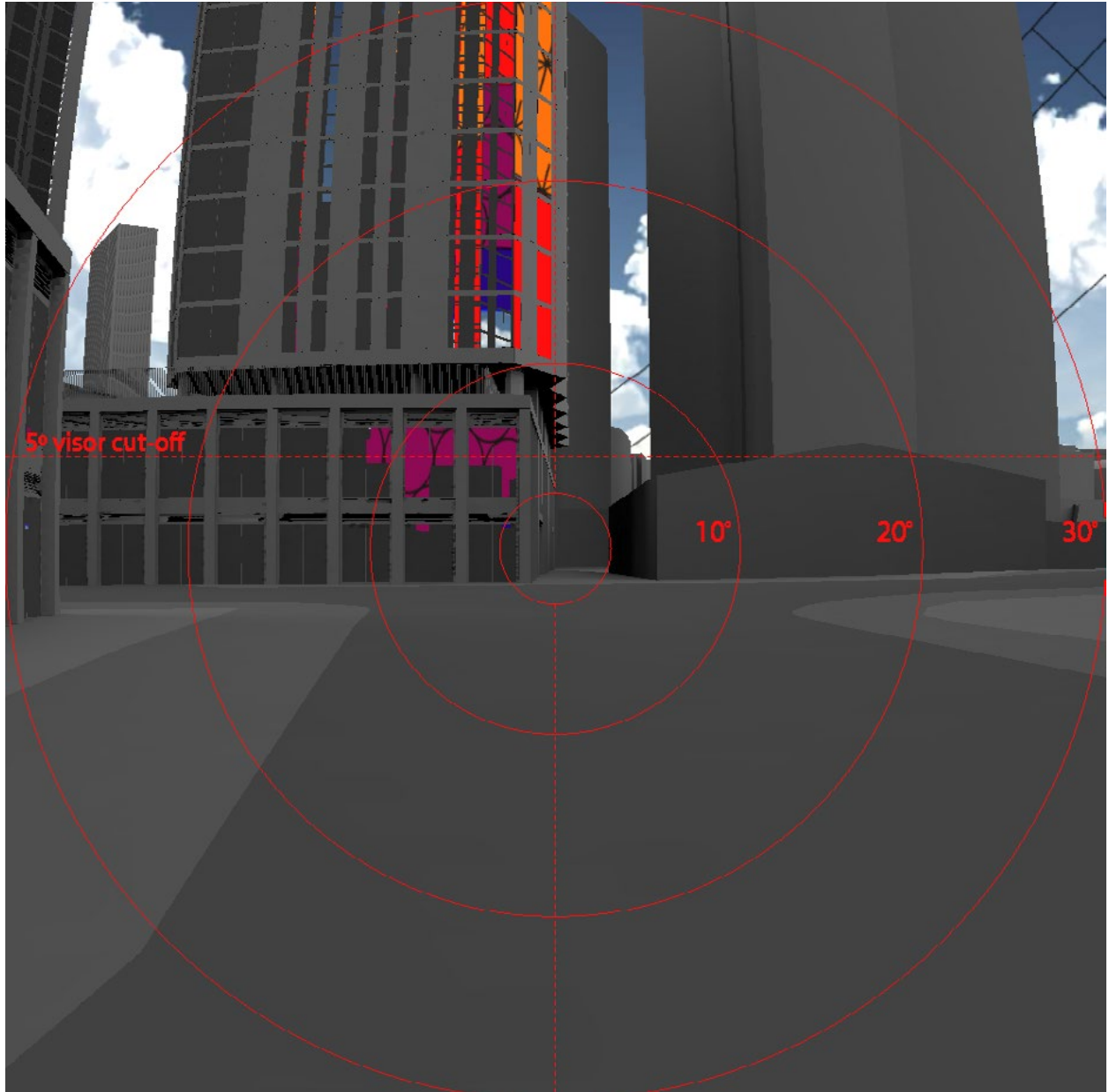


Fig. 16: Solar reflections



STAGE 2: PEAK INTENSITY ASSESSMENT
VIEWPOINT MS1 - MELBOURNE STREET
LOOKING FORWARD

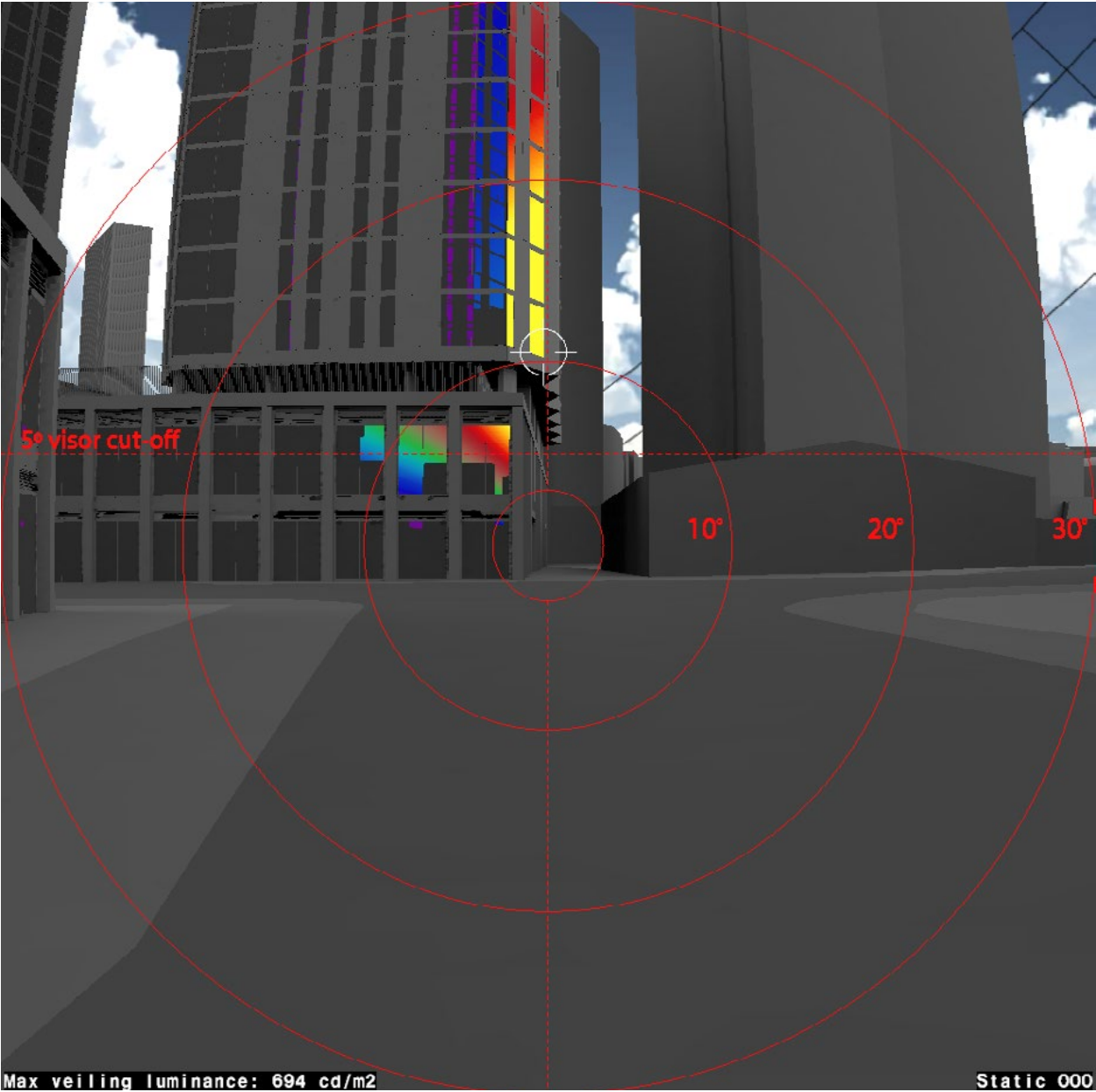
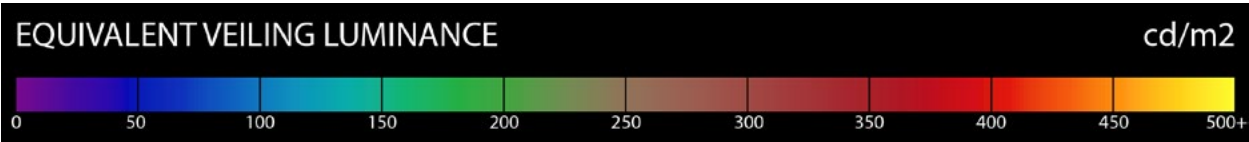


Fig. 17: Peak intensity



One viewpoint has been assessed at this junction, MS1. There is just one lane of traffic, and this is not a controlled junction, therefore the viewpoint assessed (MS1) shows the view of drivers looking forward as they approach the junction.

Stage 1

Potential reflections occur within 10° of a drivers direct line of sight at this viewpoint from the Great Jackson Street elevation of the Crown Street Phase 3 Plot E2 podium. Potential reflections occur in the afternoon from 15:00 to just after 16:00 GMT during the late-autumn and winter months (early-January to mid-February and mid-October to late-November). Reflections are visible from 3° of a drivers direct line of sight.

At this junction, for the viewpoint assessed:

- There are no signals where visibility can be affected by reflections from the Proposed Development.
- The majority of potential reflections occur above the driver's visor line, which would mitigate the majority of effects when deployed.
- Reflections occur from a small area, with just three glazed panels capable of generating reflections towards a driver at this junction.
- The probability of the sun shining at the times of day and year when reflections occur within 10° of a driver's line of sight is less than 30%.

The overall effect in terms of solar glare to drivers at the junction of Melbourne Street with Great Jackson Street is considered to be permanent, Moderate Adverse and significant, and so a Stage 2 assessment has been undertaken.

Stage 2

Figure 17 shows the peak intensity of reflections from the proposed development at this viewpoint. This assessment is based on podium glazing having a Visible Light Reflectance (VLR) of 16%, whilst residential glazing has a VLR of 14%.

As evidenced in Figure 17, the reflections occurring within 10° are all below the threshold for glare of 500cd/m², as such, they are not considered to be an instance of glare and would not significantly impact driver visibility at this location.

The peak intensity at this location of 694 cd/m² occurs from residential glazing outside 10° of a drivers direct line of sight. These reflections are only slightly above the threshold for glare, in addition, they are well above the drivers visor cut-off line and occur from only a small area of glazing so would only occur for a very short duration. In combination with the above and the factor that this is an uncontrolled junction where drivers do not need to sight signals, these reflections are not considered to be a concern from a glare perspective.

No further mitigation is considered necessary at this location provided the three panels identified in Figure 21 of the Great Jackson Street elevation of the Crown Street Phase 3 Plot E2 have a VLR of 16% or less.

Mancunian Way (MW1) – Westbound over Medlock Street junction

STAGE 1: 60° FIELD OF VIEW: TIME OF DAY
VIEWPOINT MW1 - MANCUNIAN WAY 1
RIGHT LANE, LOOKING FORWARD

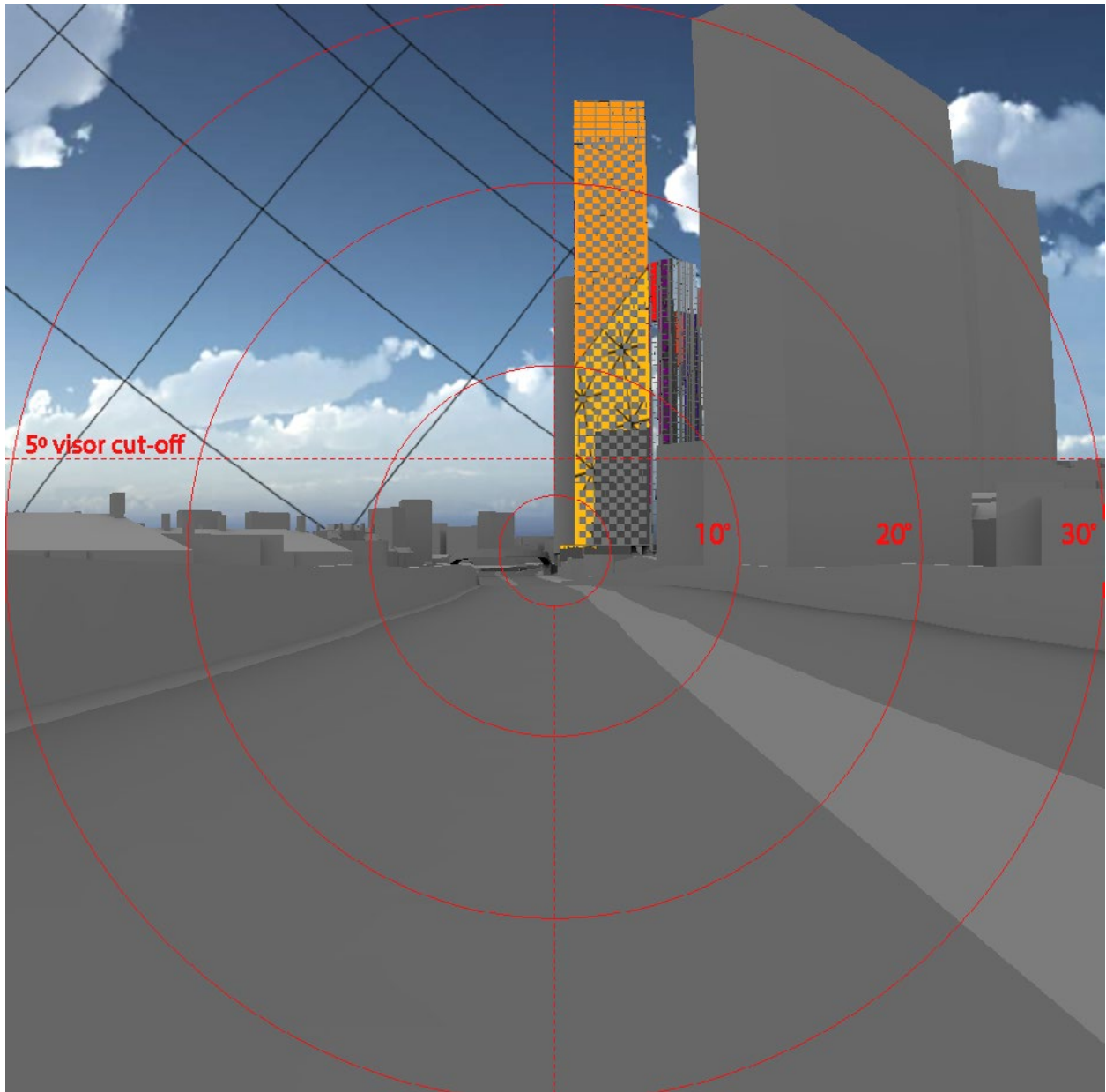
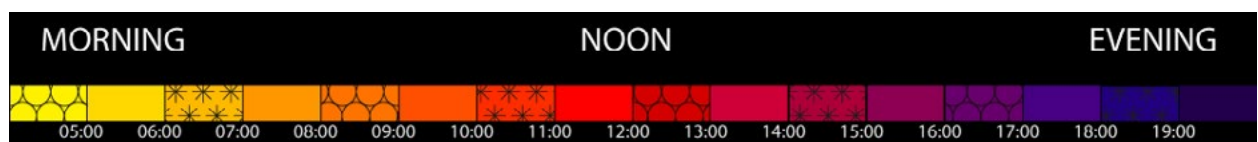


Fig. 18: Solar reflections



STAGE 1: 60° FIELD OF VIEW: SEASON
VIEWPOINT MW1 - MANCUNIAN WAY 1
RIGHT LANE, LOOKING FORWARD

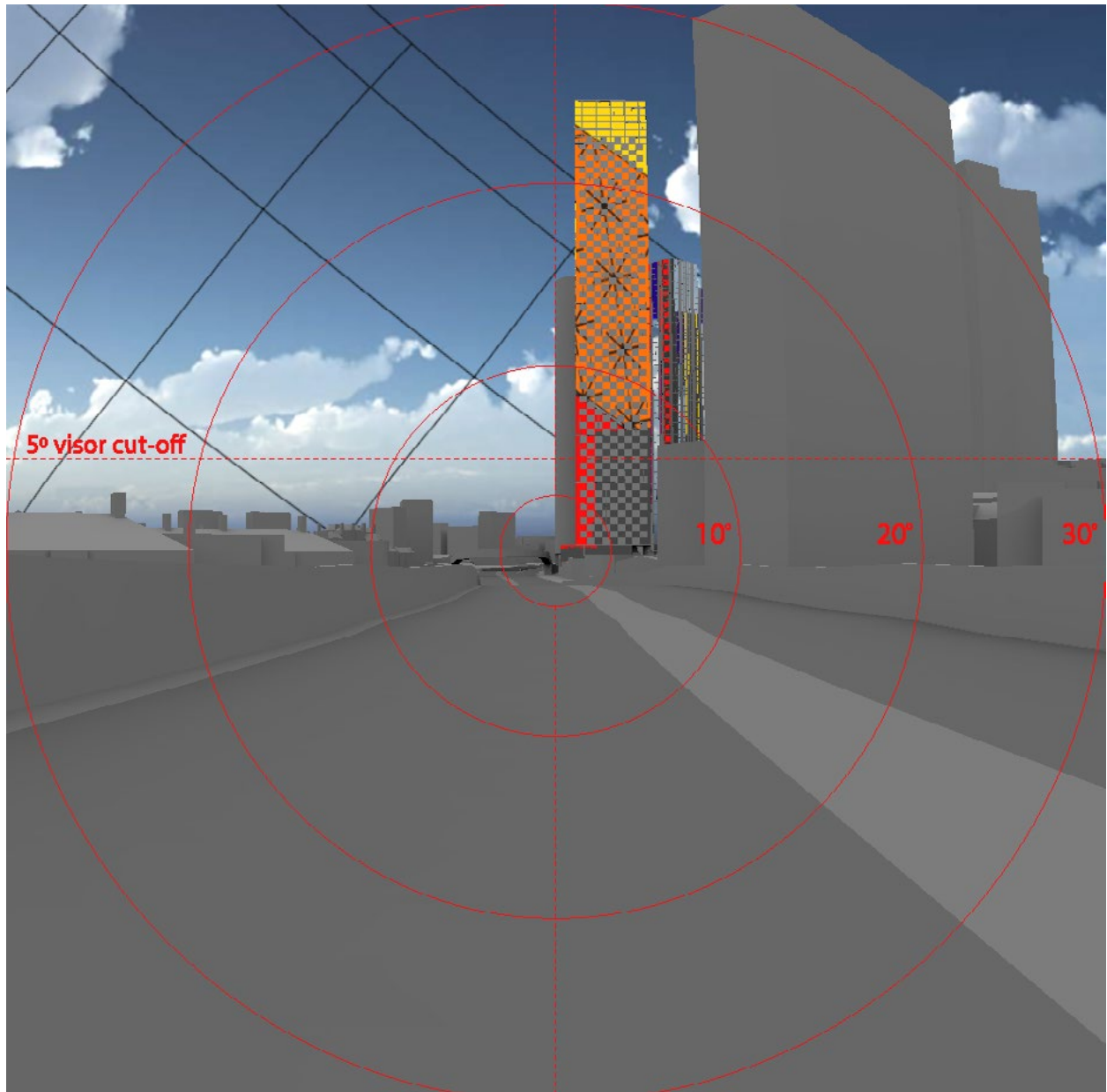


Fig. 19: Solar reflections



STAGE 2: PEAK INTENSITY ASSESSMENT
VIEWPOINT MW1 - MANCUNIAN WAY 1
RIGHT LANE, LOOKING FORWARD

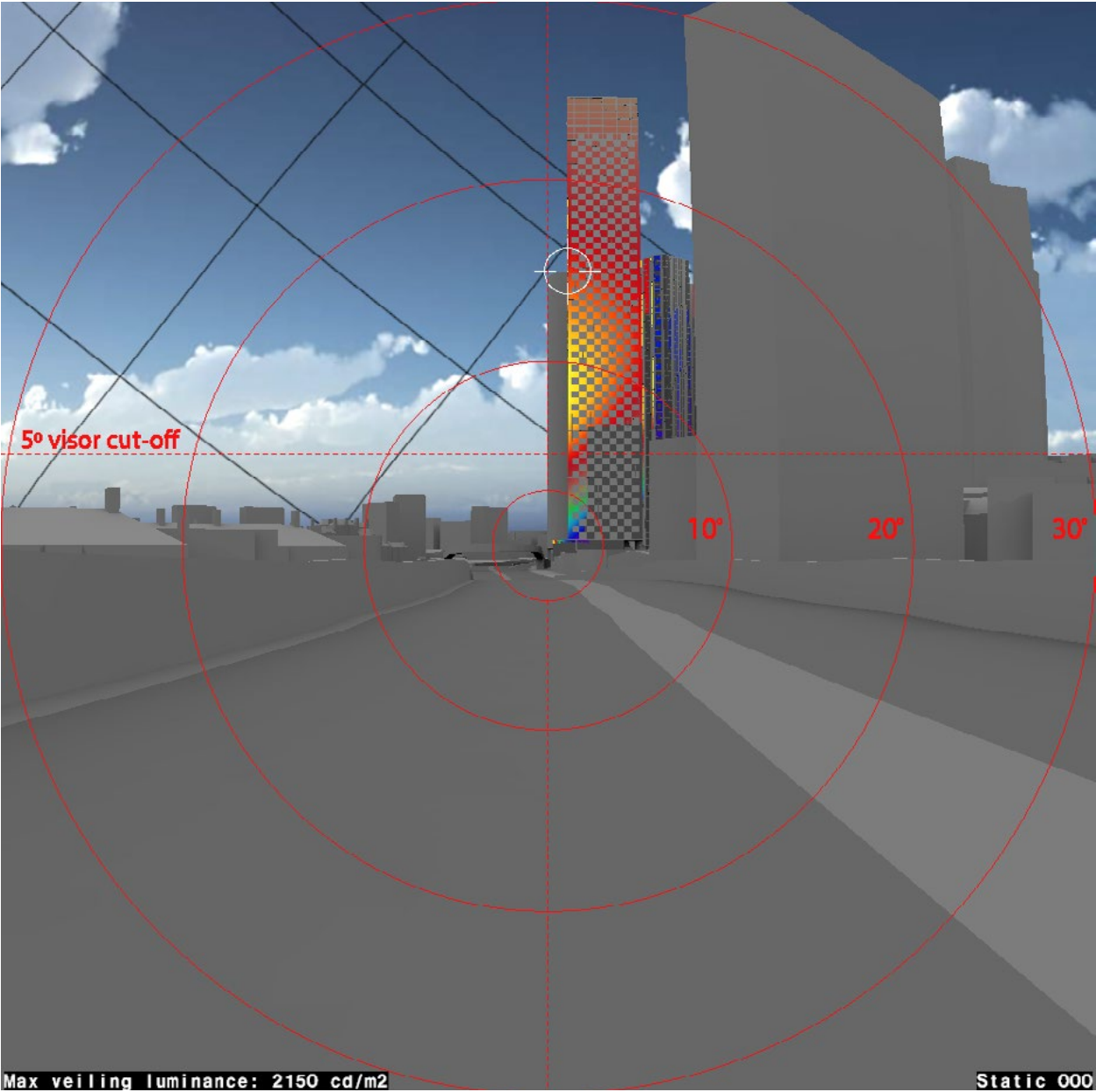
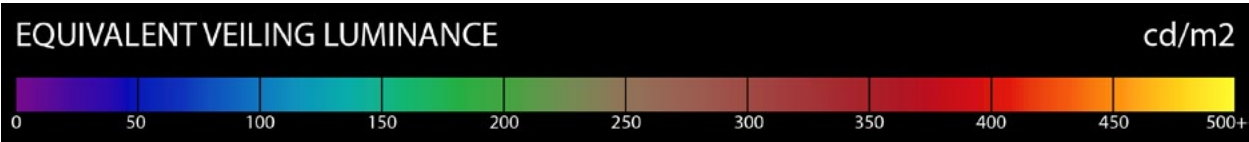


Fig. 20: Peak intensity



There are two lanes of traffic travelling westbound on Mancunian Way, the viewpoint assessed is not a junction but has been assessed due to the sensitive nature of this motorway and its proximity to the Site. Viewpoint MW1 shows the view of drivers in the right lane, looking forward as they travel along this road. This viewpoint shows the view of drivers as they pass over the Medlock Street junction.

Stage 1

Potential reflections occur within 10° of a drivers direct line of sight at this viewpoint from the eastern elevation of the Great Jackson Street Plot D tower, the eastern elevation of the top floor of the Great Jackson Street Plot D office and the south-eastern elevation of Crown Street Phase 3 Plot C7. Potential reflections occur for Great Jackson Street Plot D tower and office in the early-morning from 06:00 to 07:00 GMT during the mid-seasons (mid-February to late-March and early-September to mid-October). Reflections from the GJS Plot D office are from a very small area from 0° of drivers direct line of sight and reflections from the GJS Plot D tower are from 1°. Whilst potential reflections occur for Crown Street Phase 3 Plot C7 tower in the afternoon from 15:00 to 17:00 GMT during the autumn and winter months (mid-January to mid-March and mid-September to mid-November). Reflection occur from very thin strips visible from 7° of a drivers direct line of sight.

At this location, for the viewpoint assessed:

- There are no signals where visibility can be affected by reflections from the Proposed Development.
- The majority of potential reflections occur above the driver's visor line, which would mitigate the majority of effects when deployed.
- Reflections from GJS Plot D office are from a very small area so would only occur for a very short period of time.
- Anodised aluminium screens have been distributed across the GJS Plot D tower elevations to break up reflections and lower the intensity of any reflections that do occur.
- The sun path sits within the field of view of a driver at this junction, once implemented the Proposed Development will partially obscure the direct view of the sun. Any reflections visible from the Proposed Development would be significantly less intense than a view of the direct sun as is currently experienced at this viewpoint. A large portion of the sun's path would remain visible at this junction with a greater intensity than the reflections

that would be generated from the Proposed Development.

- The probability of the sun shining at the times of day and year when reflections occur within 10° of a driver's line of sight is less than 40%.

The overall effect in terms of solar glare to drivers on Mancunian Way above the Medlock Street junction is considered to be permanent, Moderate Adverse and significant, and so a Stage 2 assessment has been undertaken.

Stage 2

Figure 20 shows the peak intensity of reflections from the proposed development at this viewpoint. This assessment is based on office glazing having a VLR of 16%, whilst residential glazing has a VLR of 14%.

As evidenced in Figure 20, the reflections occurring within 10° are all below the threshold for glare of 500cd/m², as such, they are not considered to be an instance of glare and would not significantly impact driver visibility at this location.

The peak intensity at this location of 2,150 cd/m² occurs from the southern elevation of the GJS Plot D tower which is a false positive as discussed in section 2.5, where the reflector is too small to actually reflect the full extent of the solar disc. As a result of this, even a single bright pixel in the computer image is capable of producing a peak veiling luminance equivalent to that of the full solar disc. Similarly reflections from Crown Street Phase 3 Plot C7 are also not capable of reflecting more than a pixel width so are not a concern in terms of solar glare.

No further mitigation is considered necessary at this location provided the lowest 26 floors of the eastern elevation of the GJS tower, as identified in Figure 22, have a VLR of 14% or less, and the eastern elevation of the top floor of the GJS office has a VLR of 16% or less.

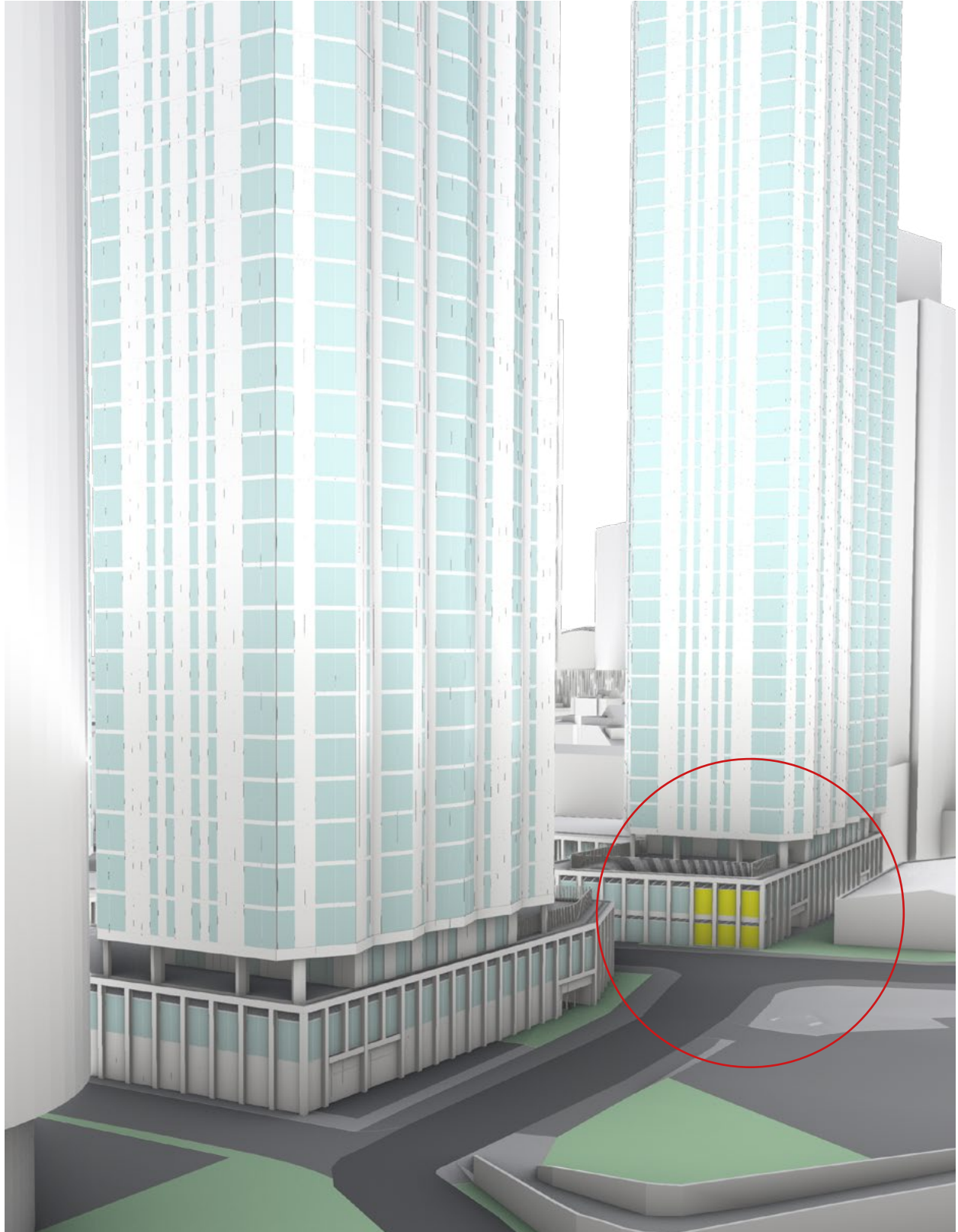


Fig. 21: MS1 Area of low VLR glazing required (yellow)

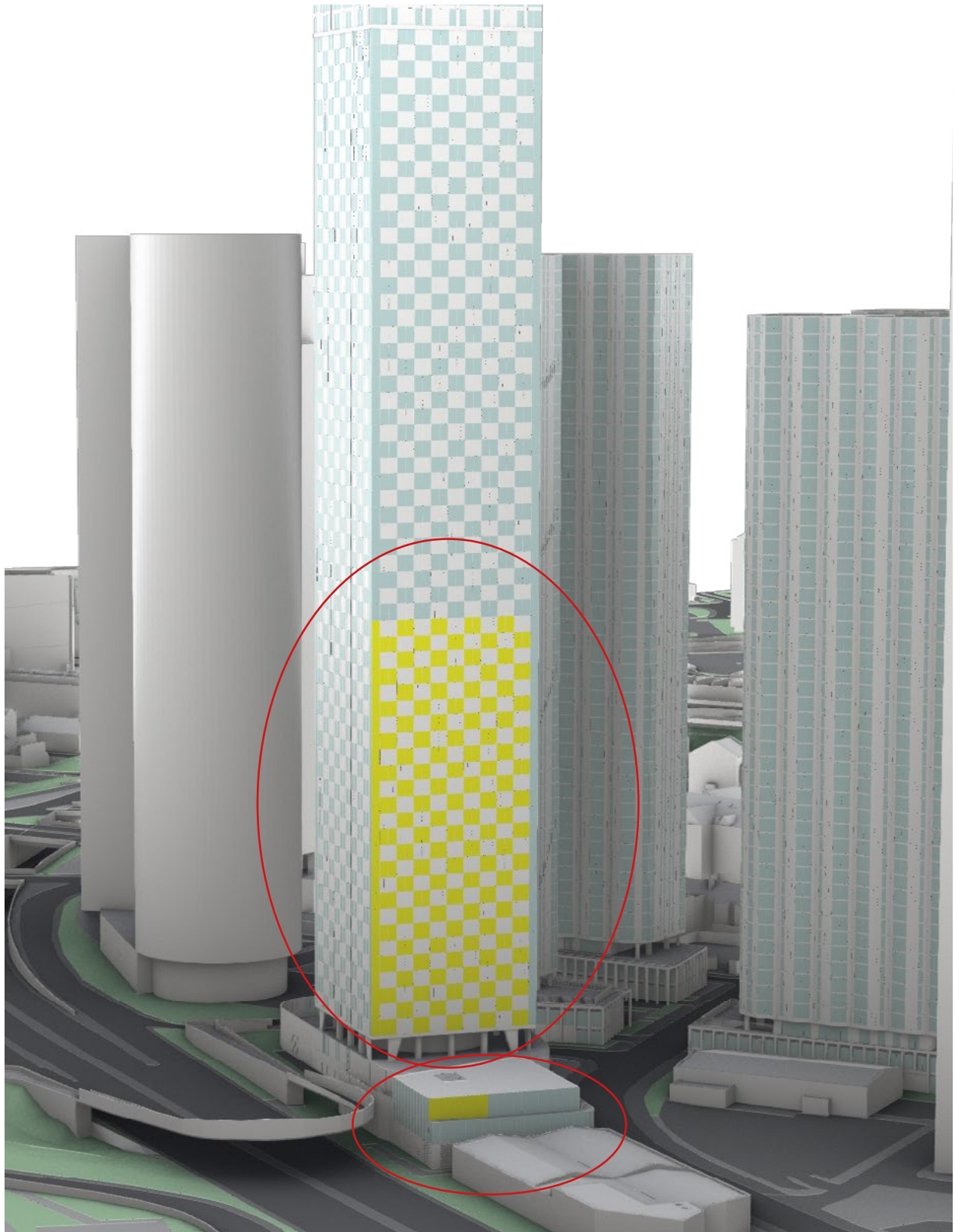


Fig. 22: MW1 Area of low VLR glazing required (yellow)



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