Attachment A4

Environmental Wind Assessment

Mirvac

Green Square Sites 8A & 8B

Environmental Wind Assessment

Wind

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Executive summary

Arup have been commissioned by Mirvac to provide an experienced-based assessment of the impact of the width of the connecting bridge linking Green Square Sites 8A & 8B, located on the north-east corner of Botany Road and Geddes Avenue, Zetland, on the pedestrian level wind conditions for comfort and safety at specific locations within the site.

The purpose of this report is to assess the impact of changing the width of the bridge above the through-site link from 3 m to 20 m wide, on the pedestrian level wind conditions within the through-site link. The remainder of the development is DCP compliant.

Qualitatively, integrating the expected directional wind conditions around the site with the wind climate, it is considered that the width of the bridge would have negligible impact on the wind conditions at all locations remote from the link, as these are governed by the massing of the buildings and surrounds. The wind comfort conditions in the link are expected to be classified as suitable for pedestrian standing/walking with windier locations experienced under the bridge. The difference in wind conditions between the zones in Figure 6 would be expected to be about one classification level. All locations are expected to meet the Lawson safety criterion. These wind conditions would be considered suitable for the intended use of the space.

To quantify the qualitative advice provided in this report, numerical or physical modelling of the development would be required, which is best conducted during detailed design.

Contents

Disclaimer

This assessment of the site environmental wind conditions is presented based on engineering judgement. In addition, experience from more detailed simulations have been used to refine recommendations. No detailed simulation, physical or computational, has been made to develop the recommendations presented in this report.

1 Introduction

This qualitative environmental wind assessment report has been prepared on behalf of Mirvac in support of a Planning Proposal for the Green Square Site 8A and 8B development located to the north-east of the intersection between Botany Road and Geddes Avenue, Zetland.

To accompany the Planning Proposal, two reference schemes have been prepared in accordance with the DCP controls. Both designs feature compliant building envelopes, one with a compliant 3 m wide connecting bridge, and one with a 20 m wide connecting bridge. The bridge is located within the podium above the through-site link between Sties 8A and 8B.

The report outlines the assessment and subsequent recommendations for wind engineering services related to pedestrian wind comfort and safety at ground level within and directly surrounding the through-site link.

2 Site description

Green Square is an area currently experiencing rapid development. The current maximum building height plan is reproduced in Figure 1 showing indicative layout and massing of potential future developments. Discussion in this report covers the existing as well as the implications for future development in the area.

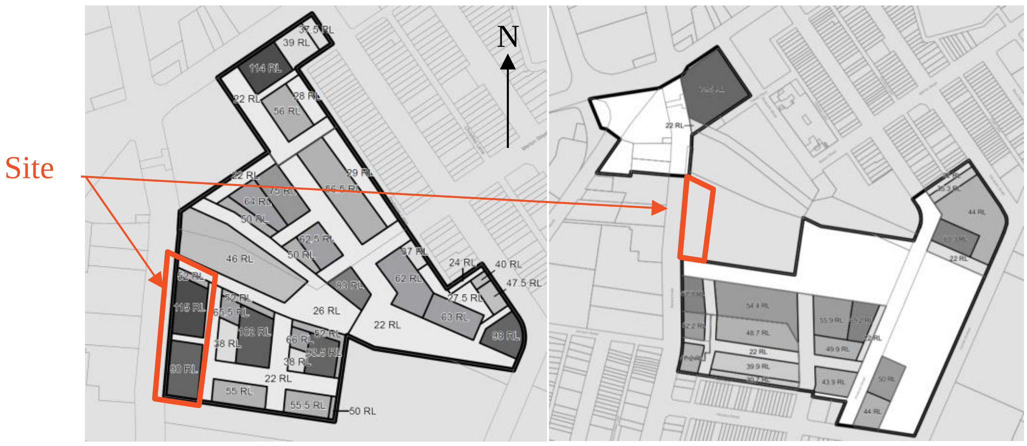

Figure 1: Sydney Local Environmental Plan (Green Square Town Centre) 2013 (L) Stage 2 (R)

The proposed Green Square Sites 8A & 8B site is located on the north-east corner of the intersection of Botany Road and Geddes Avenue, Zetland, Figure 2. Currently, the site is generally surrounded by low-rise buildings in all directions, with nearby isolated medium-rise buildings to the north and south-east. The potential maximum height and orientation of buildings are shown in Figure 1. The surrounding topography is generally flat.

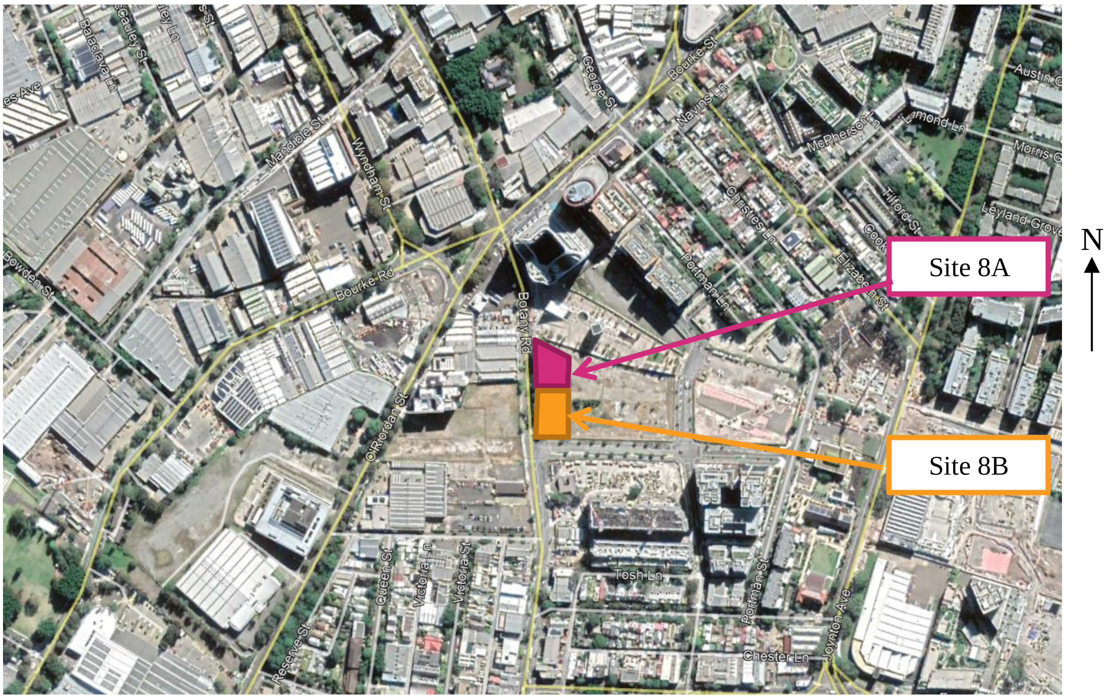

Figure 2: Site location (source: Google Maps 2020)

In both configurations, the proposed development consists of two commercial buildings, Figure 3 and Figure 4,, with an interconnecting sky bridge on Levels 2-17 between the 6 m building separation. The primary difference between the designs is the width of the bridge above the through-site link.

Site 8A, located to the north, is 24 storeys, which includes an 8-storey podium and 16-storey tower. There is a 2-level high and 6 m wide colonnade to the north, and 1.4 m overhang to the west. The tower is setback from the podium edge by 6 m to the north at Level 8.

Site 8B, located to the south, is 18 storeys and a 1.4 m colonnade to the west. In the Reference Design there are outdoor terraces proposed to the north of Level 8 of Site 8A, and at roof level of Site 8B (Level 17), with access to all sides of the roof, Figure 4.

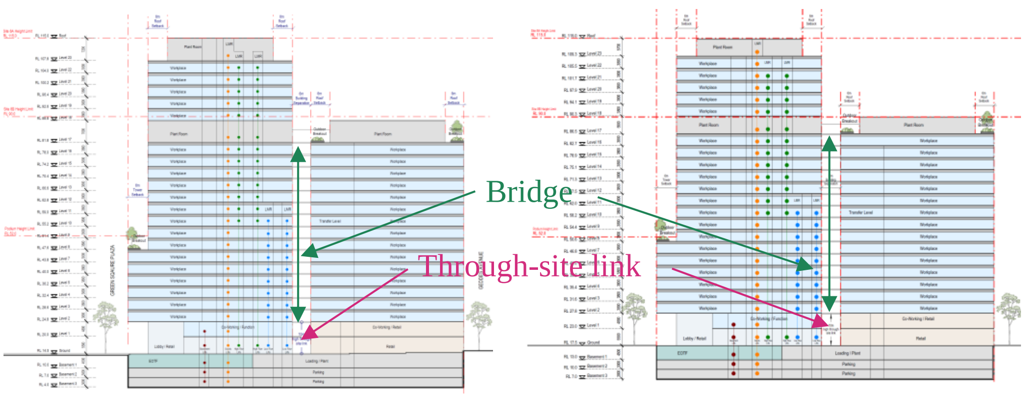

Figure 3: North-south sections looking east– 20 m wide bridge (L), 3 m wide bridge (R)

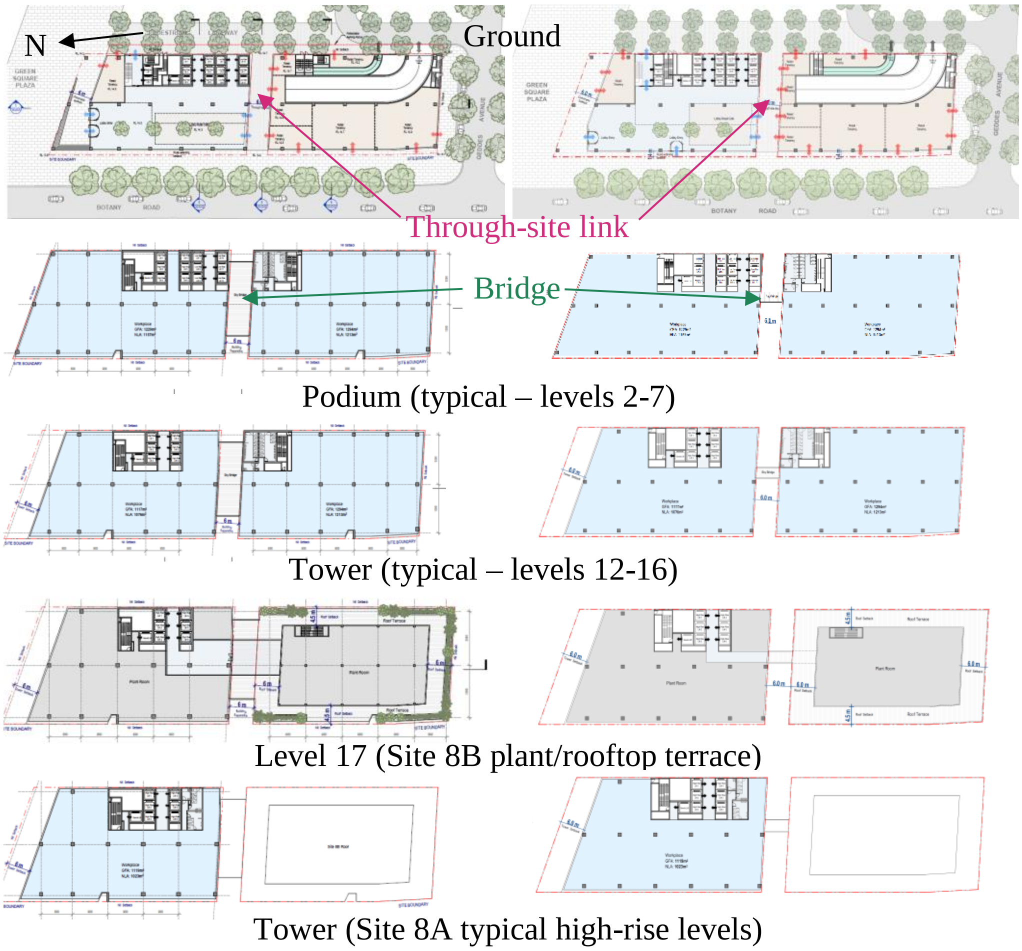

Figure 4: Various floor plans – 20 m wide bridge (L), 3 m wide bridge (R)

The north boundary of the Site 8A fronts Green Square Plaza. There are pedestrian thoroughfares all around the site and via the 6 m wide two-storey, 10 m high ‘through-site link’ between the buildings. There are a number of ground level entries to the lobby and various retail tenancies from all sides of the development, Figure 4.

3 Wind assessment

3.1 Local wind climate

Weather data recorded at Sydney Airport by the Bureau of Meteorology has been analysed for this project, Figure 5. The anemometer is located about 6 km to the south-south-west of the site. The arms of the wind rose point in the direction from where the wind is coming from. The directional wind speeds measured here are considered representative of the incident wind conditions at the site, due to close proximity to the site and similar distance from the coast.

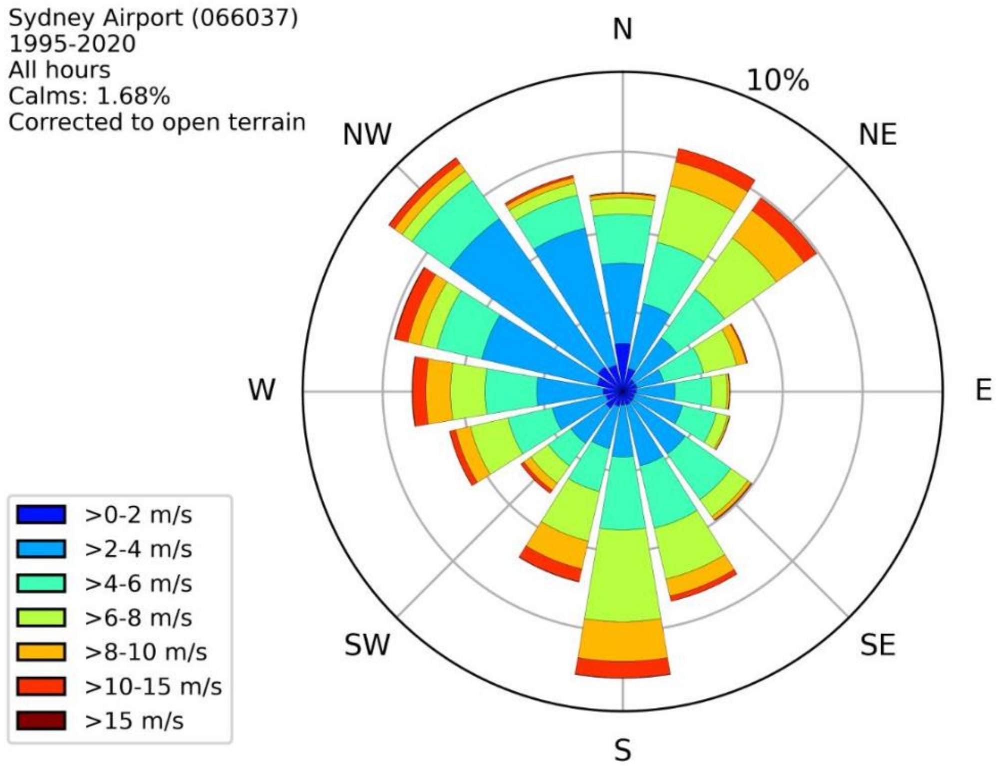

Figure 5: Wind rose showing probability of time of wind direction and speed

It is evident from Figure 5 that the prevailing wind directions are from the north-east, south, and north-west quadrants with stronger winds from these directions. The measured mean wind speed is 4.5 m/s, and the 5% exceedance mean wind speed is 9.5 m/s.

Strong summer winds occur mainly from the south and the north-east quadrants. Winds from the south are associated with large synoptic frontal systems and generally provide the strongest gusts during summer. Moderate intensity winds from the north-east tend to bring cooling relief on hot summer afternoons typically lasting from noon to dusk. These are small-scale temperature driven effects; the larger the temperature differential between land and sea, the stronger the wind.

Winter and early spring strong winds typically occur from the north-west, and west quadrants. West quadrant winds provide the strongest winds affecting the area throughout the year and tend to be associated with large scale synoptic events that can be hot or cold depending on inland conditions.

A general description on flow patterns around buildings is given in Appendix 1.

3.2 Specific wind controls

Wind comfort is generally measured in terms of wind speed and rate of change of wind speed, where higher wind speeds and gradients are considered less comfortable. Air speed has a large impact on thermal comfort and are generally welcome during hot summer conditions. This assessment is focused on wind speed in terms of mechanical comfort.

There have been many wind comfort criteria proposed, and a general discussion is presented in Appendix 2.

Wind controls applicable to this project are based on the work of Lawson (1990), described in Figure 15 and Table 1. The comfort classification is based on the wind speed exceed for 5% of the time. These categories are subjective to the individual. The wind speed is the greater of the mean or gust-equivalent mean (GEM) wind speed. The GEM is defined as the peak 3 s gust wind speed divided by 1.85; and aims to account for location where gustiness is prevalent.

Table 1: Pedestrian comfort criteria for various activities

Comfort (max. of mean or GEM wind speed exceeded 5% of the time)	
<2 m/s	Dining
2-4 m/s	Sitting
4-6 m/s	Standing
6-8 m/s	Walking
8-10 m/s	Objective walking or cycling
>10 m/s	Uncomfortable
Safety (max. of mean or GEM wind speed exceeded 0.022% of the time)	
<15 m/s	General access
<20 m/s	Able-bodied people (less mobile or cyclists not expected)

Transferring the measured 5% of the time wind speed to ground level around the site would result in a mean wind speed of about 6 m/s. From Table 1, these conditions would be classified as on the border of pedestrian standing and walking. From knowledge of the wind conditions in the locale, this would be a considered a correct classification for the area.

3.3 Impact of bridge width on wind conditions

The through-site link is in the same location and has the same cross-sectional area in both schemes with a width of 6 m and height of 10 m, Figure 4. The bridge above extends above the through-site link for a height of 57 m and 58.7 m for the 20 m wide and 3 m wide bridges respectively, Figure 3. The 3 m wide bridge is recessed further from both the east and west facades.

The wind conditions in any through-site link are governed by the pressure difference between the entrances from the east and west, Figure 7 in Appendix 1. The pressure difference is generated by the massing of the subject and surrounding buildings, as well as the incident wind speed and direction.

As the site is relatively exposed, particularly to prevailing winds from the west, wind would be expected to be occur in the link for all incident wind directions. As the general massing of Sites 8A and 8B is very similar between the two schemes, the pressure distribution at either end of the through-site link would be expected to be similar. For the 3 m wide bridge design, the greater recess from the building façade would be expected to slightly increase the magnitude of the mean pressure on the windward side, and reduce the turbulence. The narrow bridge would be expected to slightly increase the magnitude of the negative mean pressure on the leeward side. Thus the pressure differential for the narrow bridge would be expected to be slightly greater than for the 20 m wide bridge. As the mean pressure differential between either end of the link is similar, the fastest wind speed, related to the square root of the pressure difference, would be similar for all bridge widths, Figure 6.

However, for the 20 m wide bridge being of constant cross-section area along the entire length of the through-site link, the wind speed would be similar along the entire length of the link, Figure 6. Reducing the width of the bridge to 3 m would not change the wind speed significantly, but would reduce the extent of the faster flow. The bridge forming a calmer region on the windward side, like a dam on a river. Introducing a constriction to the cross-sectional area within the link controls the flow rate improving wind conditions everywhere except close to the constriction, Figure 6 where similar faster wind speeds would be experienced. This localises the fast flow, reducing the speed in the rest of the link, similar to a partially closed tap in a pipe. If a constriction is not incorporated, the wind speed will be at the faster speed along the entire length of the laneway.

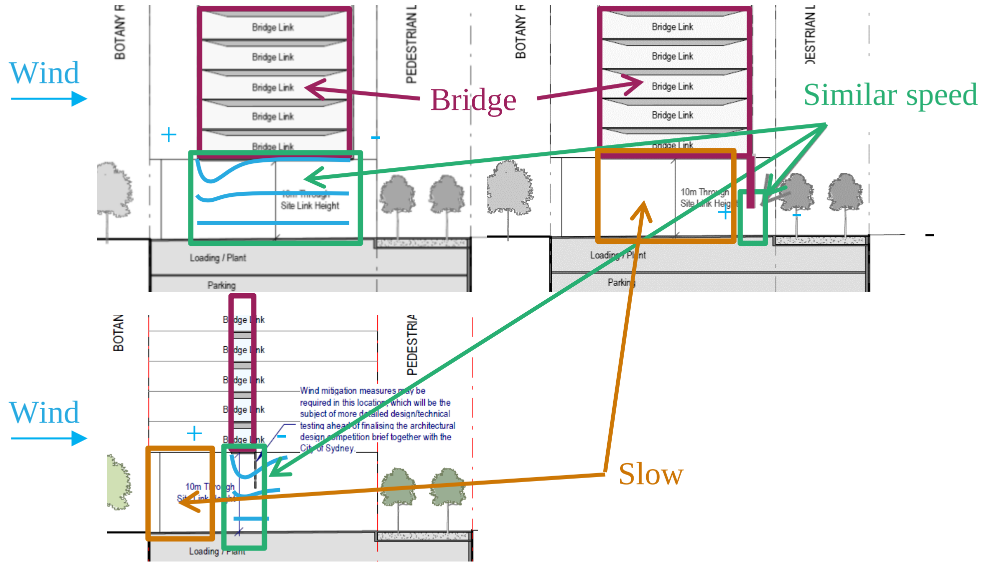

Figure 6: Section of through site link

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Appendix 1: Wind flow mechanisms

An urban environment generates a complex wind flow pattern around closely spaced structures, hence it is exceptionally difficult to generalise the flow mechanisms and impact of specific buildings as the flow is generated by the entire surrounds. However, it is best to start with an understanding of the basic flow mechanisms around an isolated structure.

Isolated building

When the wind hits an isolated building, the wind is decelerated on the windward face generating an area of high pressure, Figure 7, with the highest pressure at the stagnation point at about two thirds of the height of the building. The higher pressure bubble extends a distance from the building face of about half the building height or width, whichever is lower. The flow is then accelerated down and around the windward corners to areas of lower pressure, Figure 7. This flow mechanism is called **downwash** and causes the windiest conditions at ground level on the windward corners and along the sides of the building.

Rounding the building corners or chamfering the edges reduces downwash by encouraging the flow to go around the building at higher levels. However, concave curving of the windward face can increase the amount of downwash. Depending on the orientation and isolation of the building, uncomfortable downwash can be experienced on buildings of greater than about 6 storeys.

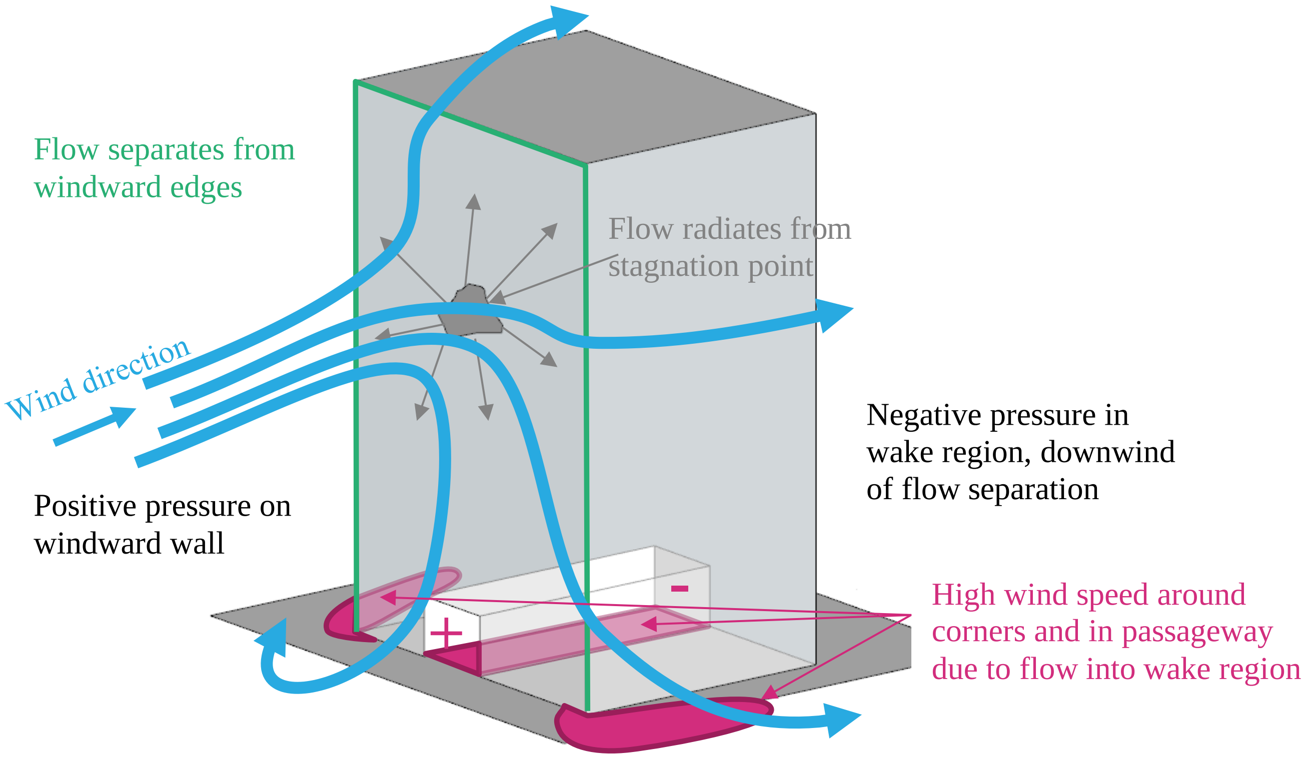

Figure 7: Schematic wind flow around tall isolated building

Techniques to mitigate the effects of downwash winds at ground level include the provision of horizontal elements, the most effective being a podium to divert the downward flow away from pavements and building entrances, but this will generate windy conditions on the podium roof, Figure 11. Generally, the lower the podium roof and deeper the setback from the podium edge to the tower improves the ground level wind conditions. The provision of an 8 m setback on an isolated building is generally sufficient to improve ground level conditions, but is highly dependent on the building isolation, orientation to prevailing wind directions, shape and width of the building, and any plan form changes at higher level.

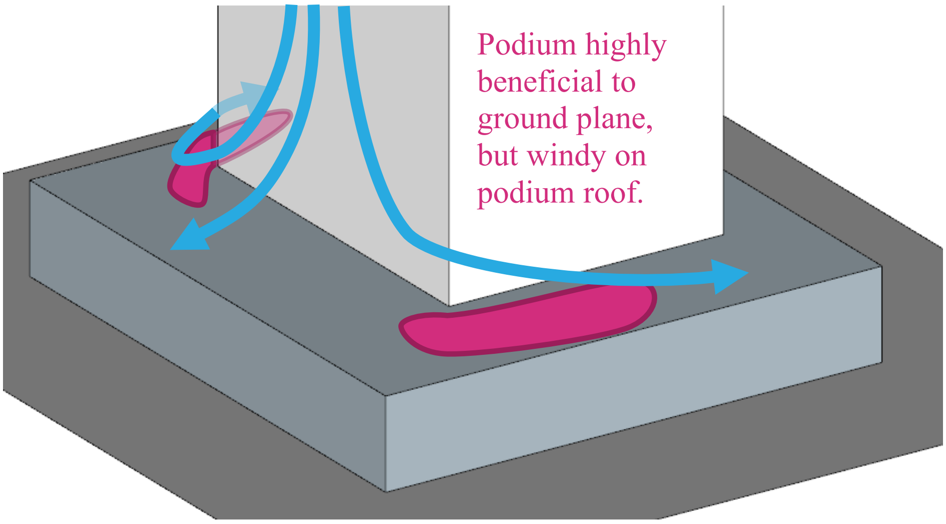

Figure 8: Schematic flow pattern around building with podium

Awnings along street frontages perform a similar function as a podium, and generally the larger the horizontal projection from the façade, the more effective it will be in diverting downwash flow, Figure 9. Awnings become less effective if they are not continuous along the entire façade, or on wide buildings as the positive pressure bubble extends beyond the awning resulting in horizontal flow under the awning.

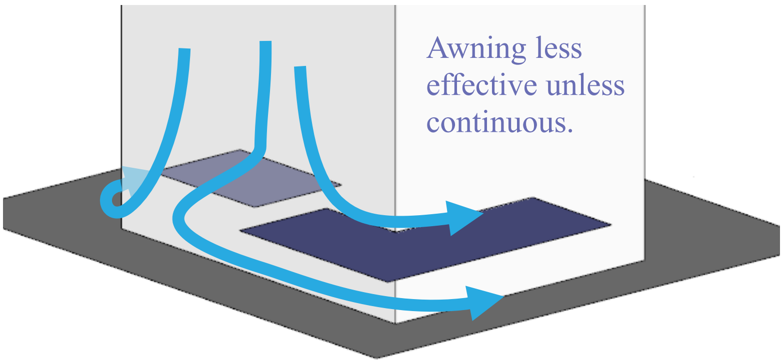

Figure 9: Schematic flow pattern around building with awning

It should be noted that colonnades at the base of a building with no podium generally create augmented windy conditions at the corners due to an increase in the pressure differential, Figure 10. Similarly, open through-site links through a building cause wind issues as the environment tries to equilibrate the pressure generated at the entrances to the link, Figure 7. If the link is blocked, wind conditions will be calm unless there is a flow path through the building, Figure 11. This area is in a region of high pressure and therefore the is the potential for internal flow issues. A ground level recessed corner has a similar effect as an undercroft, resulting in windier conditions, Figure 11.

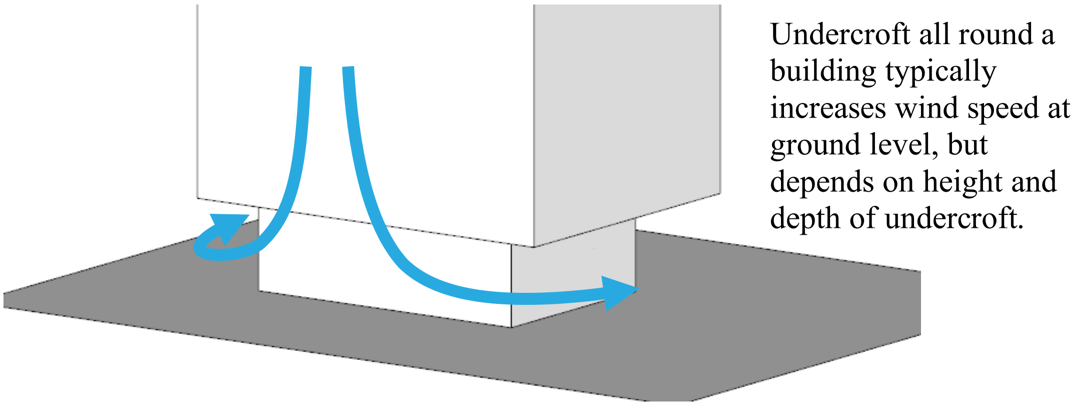

Figure 10: Schematic of flow patterns around isolated building with undercroft

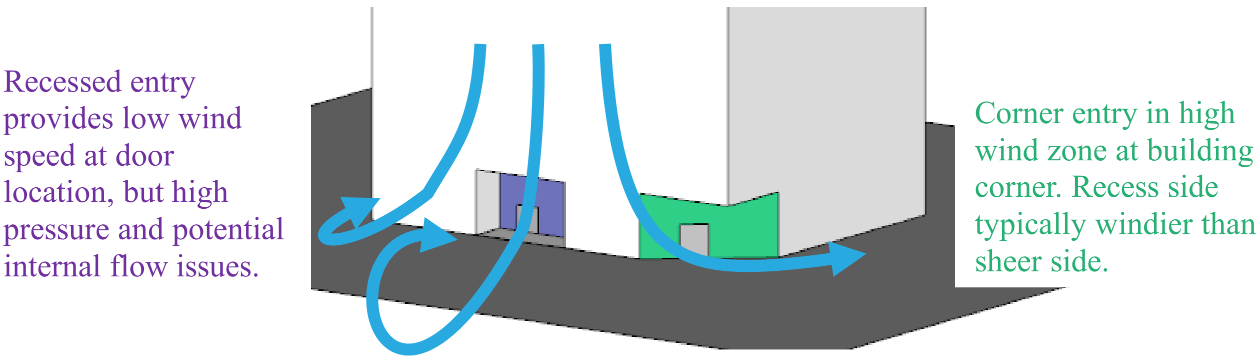

Figure 11 Schematic of flow patterns around isolated building with ground articulation

Multiple buildings

When a building is located in a city environment, depending on upwind buildings, the interference effects may be positive or negative, Figure 12. If the building is taller, more of the wind impacting on the exposed section of the building is likely to be drawn to ground level by the increase in height of the stagnation point, and the additional negative pressure induced at the base. If the upwind buildings are of similar height then the pressure around the building will be more uniform hence downwash is typically reduced with the flow passing over the buildings.

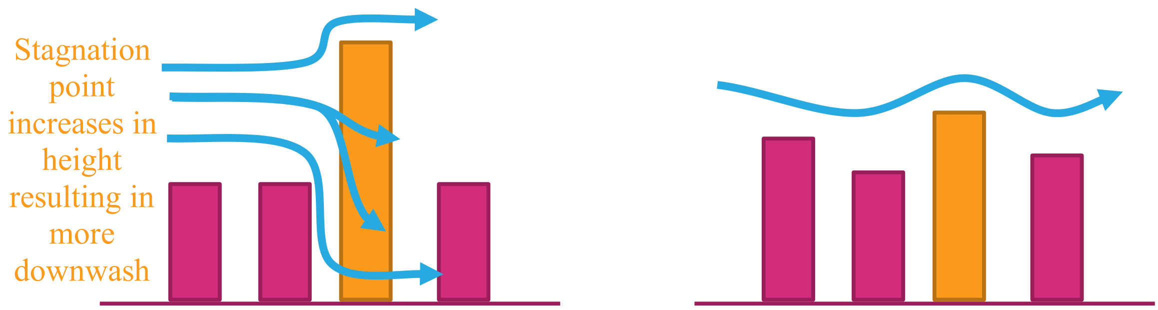

Figure 12: Schematic of flow pattern interference from surrounding buildings

The above discussion becomes more complex when three-dimensional effects are considered, both with orientation and staggering of buildings, and incident wind direction, Figure 13.

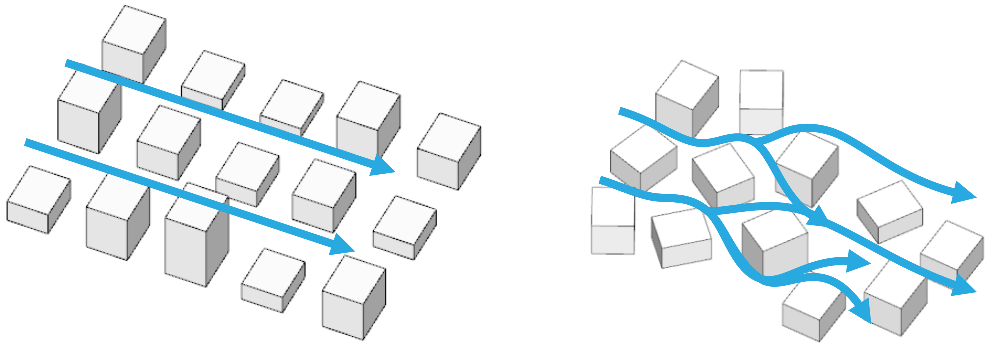

Figure 13: Schematic of flow patterns through a grid and random street layout

Channelling occurs when the wind is accelerated between two buildings, or along straight streets with buildings on either side, Figure 13(L), particularly on the edge of built-up areas where the approaching flow is diverted around the city massing and channelled along the fringe by a relatively continuous wall of building facades. This is generally the primary mechanism driving the wind conditions for this perimeter of a built-up area, particularly on corners, which are exposed to multiple wind directions. The perimeter edge zone in a built-up area is typically about two blocks deep. Downwash is more important flow mechanism for the edge zone of a built-up area with buildings of similar height.

As the city expands, the central section of the city typically becomes calmer, particularly if the grid pattern of the streets is discontinued, Figure 13(R). When buildings are located on the corner of a central city block, the geometry becomes slightly more important with respect to the local wind environment.

Single barriers and screens

The wind flow pattern over a vertical barrier is illustrated in Figure 14, showing there will be recirculation zones near the windward wall and in the immediate lee of the barrier. The typical extent of these recirculation zones relative to the height of the barrier, h, is illustrated in Figure 14. These regions are not fixed but fluctuate in time. The mean wind speed in the wake areas drops significantly compared with the incident flow. With increasing distance from the barrier the flow pattern will resort to the undisturbed state. Typically the mean velocity and turbulence intensity at barrier height would be expected to be within 10% of the free stream conditions at 10 times the height of the structure downwind from the barrier.

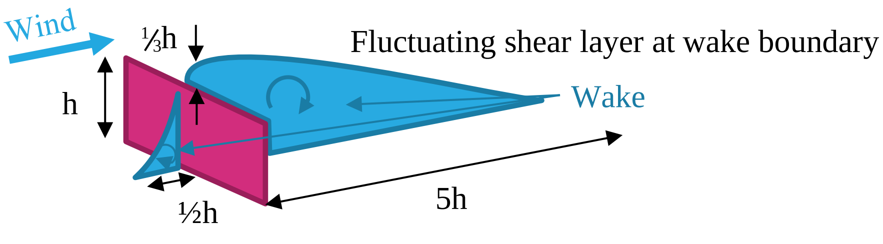

Figure 14: Sketch of the flow pattern over an isolated structure

Appendix 2: Wind speed criteria

General discussion

Primary controls that are used in the assessment of how wind affects pedestrians are the wind speed, and rate of change of wind speed. A description of the effect of a specific wind speed on pedestrians is provided in Table 2. It should be noted that the turbulence, or rate of change of wind speed, will affect human response to wind and the descriptions are more associated with response to mean wind speed.

Table 2: Summary of wind effects on pedestrians

Description	Speed (m/s)	Effects
Calm, light air	0–2	Human perception to wind speed at about 0.2 m/s. Napkins blown away and newspapers flutter at about 1 m/s.
Light breeze	2–3	Wind felt on face. Light clothing disturbed. Cappuccino froth blown off at about 2.5 m/s.
Gentle breeze	3–5	Wind extends light flag. Hair is disturbed. Clothing flaps.
Moderate breeze	5–8	Raises dust, dry soil. Hair disarranged. Sand on beach saltates at about 5 m/s. Full paper coffee cup blown over at about 5.5 m/s.
Fresh breeze	8–11	Force felt on body. Limit of agreeable wind on land. Umbrellas used with difficulty. Wind sock fully extended at about 8 m/s.
Strong breeze	11–14	Hair blown straight. Difficult to walk steadily. Wind noise on ears unpleasant. Windborne snow above head height (blizzard).
Near gale	14–17	Inconvenience felt when walking.
Gale	17–21	Generally impedes progress. Difficulty with balance in gusts.
Strong gale	21–24	People blown over by gusts.

Local wind effects can be assessed with respect to a number of environmental wind speed criteria established by various researchers. These have all generally been developed around a 3 s gust, or 1 hour mean wind speed. During strong events, a pedestrian would react to a significantly shorter duration gust than a 3 s, and historic weather data is normally presented as a 10 minute mean.

Despite the apparent differences in numerical values and assumptions made in their development, it has been found that when these are compared on a probabilistic basis, there is some agreement between the various criteria. However, a number of studies have shown that over a wider range of flow conditions, such as smooth flow across water bodies, to turbulent flow in city centres, there is less general agreement among. The downside of these criteria is that they have seldom been benchmarked, or confirmed through long-term measurements in the field, particularly for comfort conditions. The wind criteria were all developed in temperate climates and are unfortunately not the only environmental factor that affects pedestrian comfort.

For assessing the effects of wind on pedestrians, neither the random peak gust wind speed (3 s or otherwise), nor the mean wind speed in isolation are adequate. The gust wind speed gives a measure of the extreme nature of the wind, but the mean wind speed indicates the longer duration impact on pedestrians. The extreme gust wind speed is considered to be suitable for safety considerations, but not necessarily for serviceability comfort issues such as outdoor dining. This is because the instantaneous gust velocity does not always correlate well with mean wind speed, and is not necessarily representative of the parent distribution. Hence, the perceived ‘windiness’ of a location can either be dictated by strong steady flows, or gusty turbulent flow with a smaller mean wind speed.

To measure the effect of turbulent wind conditions on pedestrians, a statistical procedure is required to combine the effects of both mean and gust. This has been conducted by various researchers to develop an equivalent mean wind speed to represent the perceived effect of a gust event. This is called the ‘gust equivalent mean’ or ‘effective wind speed’ and the relationship between the mean and 3 s gust wind speed is defined within the criteria, but two typical conversions are:

$$U_{GEM} = \frac{(U_{1\text{ hour mean}} + 3 \cdot \sigma_u)}{1.85} \quad \text{and} \quad U_{GEM} = \frac{1.3 \cdot (U_{1\text{ hour mean}} + 2 \cdot \sigma_u)}{1.85}$$

It is evident that a standard description of the relationship between the mean and impact of the gust would vary considerably depending on the approach turbulence, and use of the space.

A comparison between the mean and 3 s gust wind speed criteria from a probabilistic basis are presented in Figure 15 and Figure 17. The grey lines are typical results from modelling and show how the various criteria would classify a single location. City of Auckland has control mechanisms for accessing usability of spaces from a wind perspective as illustrated in Figure 15 with definitions of the intended use of the space categories defined in Figure 16.

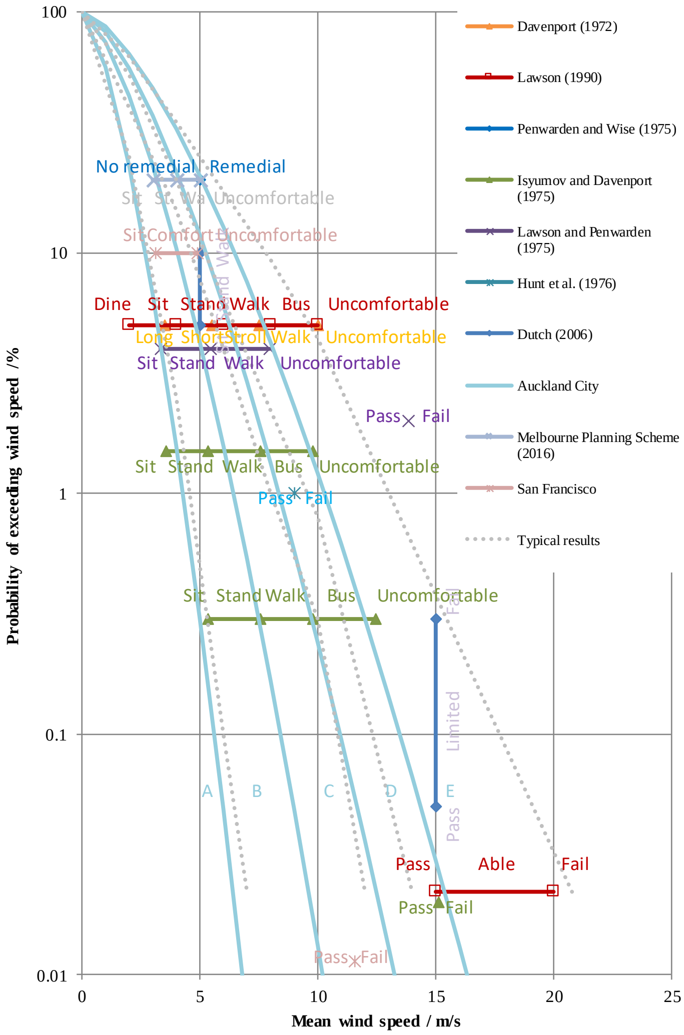

Figure 15: Probabilistic comparison between wind criteria based on mean wind speed

Category A	Areas of pedestrian use or adjacent dwellings containing significant formal elements and features intended to encourage longer term recreational or relaxation use i.e. public open space and adjacent outdoor living space
Category B	Areas of pedestrian use or adjacent dwellings containing minor elements and features intended to encourage short term recreation or relaxation, including adjacent private residential properties
Category C	Areas of formed footpath or open space pedestrian linkages, used primarily for pedestrian transit and devoid of significant or repeated recreational or relaxational features, such as footpaths not covered in categories A or B above
Category D	Areas of road, carriage way, or vehicular routes, used primarily for vehicular transit and open storage, such as roads generally where devoid of any features or form which would include the spaces in categories A - C above.
Category E	Category E represents conditions which are dangerous to the elderly and infants and of considerable cumulative discomfort to others, including residents in adjacent sites. Category E

Figure 16: Auckland Utility Plan (2016) wind categories

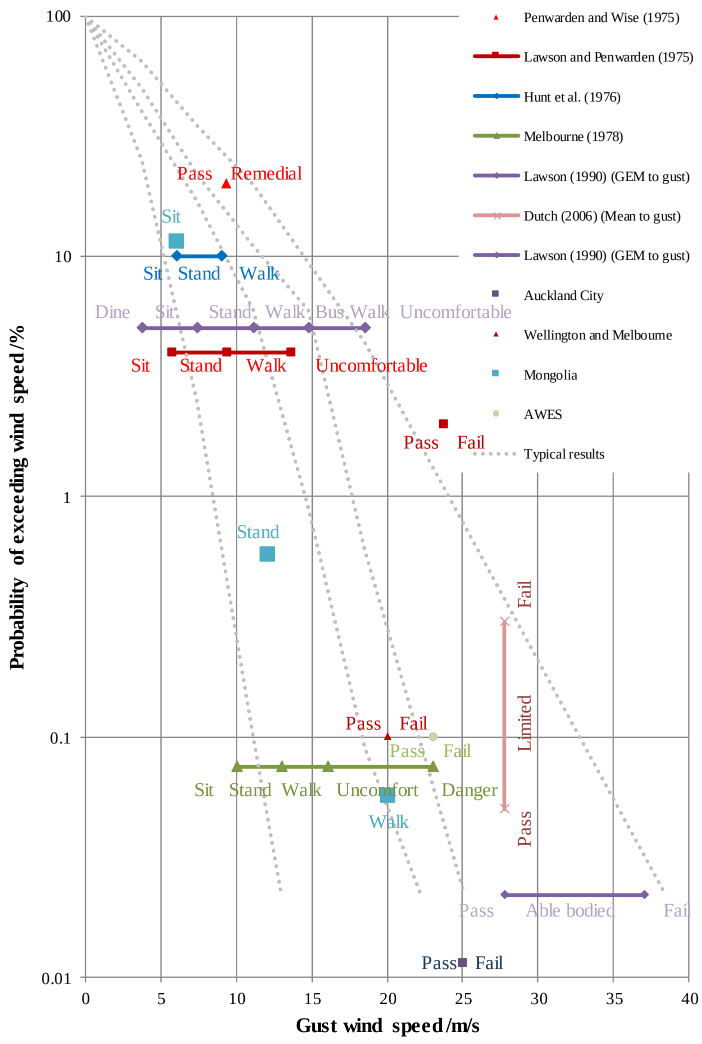

Figure 17: Probabilistic comparison between wind criteria based on 3 s gust wind speed

Appendix 3: Reference documents

In preparing the assessment, the following documents have been referenced to understand the building massing and features. The drawings are dated 4 June 2021.

- Green Square Site 8A 8B - 3m Option.pdf
- Green Square Site 8A & 8B - Building Envelope.pdf
- Green Square Site 8A & 8B - Reference Design.pdf