Crown Eastlakes Developments Pty. Ltd.

Eastlakes South Development

Environmental Wind Assessment

Wind

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Executive summary

Arup have been commissioned by Crown Eastlakes Developments Pty. Ltd. to provide an experienced-based impact assessment of the proposed modified development relating to the south side of Eastlakes Shopping Centre on the pedestrian level wind conditions for comfort and safety in and around the site.

Arup have provided qualitative advice for the impact of the proposed development on pedestrian wind comfort. It is Arup's opinion that all locations within the proposed development would meet the safety criterion. From a wind comfort perspective, the wind conditions at the majority of locations around the site would be expected to be classified as suitable for pedestrian standing and walking activities with some locations suitable for outdoor sitting, which meets 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.

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 study has been made to develop the recommendations presented in this report.

Contents

1 Introduction

Crown Eastlakes Developments Pty. Ltd. have engaged Arup to provide a qualitative environmental wind assessment for the proposed modified development relating to the south side of the Eastlakes Shopping Centre. This report outlines the assessment and subsequent recommendations for wind engineering services related to pedestrian wind comfort and safety on the ground level. To quantify the qualitative advice provided in this report, numerical or physical modelling would be required.

2 Wind assessment

2.1 Local wind climate

Weather data recorded at Sydney Airport by the Bureau of Meteorology has been analysed for this project. The analysis is summarised in Appendix 1. Strong prevailing winds for the site are from the north-east, south, and west quadrants. This wind assessment is based on these wind directions. A general description on flow patterns around buildings is given in Appendix 2.

2.2 Specific wind controls

Wind comfort is generally measured in terms of wind speed and rate of change of wind speed with distance or time, 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 3. The wind controls used in this wind assessment are based on the work of Lawson (1990) as described in Figure 12 and Table 1. These have both a comfort and safety component and tend to better describe the usage of the space from a comfort perspective. Converting the data from the wind climate to the typical site location, the mean wind speed exceeded 5% of the time would be approximately 6 m/s. With reference to Table 1, this wind speed is on the boundary of pedestrian standing and walking conditions and from our knowledge of the environs would be considered appropriate.

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)

2.3 Site description

The proposed Eastlakes South Development site is located on the east side of the Eastlake Reserve bounded by Evans Avenue and Barber Avenue, Figure 1. The site is surrounded by low-rise buildings in all directions, with three 8-10 storey buildings about 200 m to the east, and two 9 storey buildings about 400 m to the west. Topography surrounding the side is essentially flat from a wind perspective.

Figure 1 Site location (source: SIX Maps 2016)

The proposed mixed residential and commercial development consists a multi-tower design over a common low-rise podium, Figure 2. The west towers are 11-12 storeys above the ground level with the maximum height of approximately 42 m. The three east towers are approximately 5-7 storeys above the ground level. An internal through-site link connects the north, east, and west facades. On the lower podium roof, Level 1, there are common residential areas to the south of the site, and to the south and east of the north-east building, Figure 2 (MR). On this level these is an outdoor childcare area to the west of the north-west tower, and a through-site links in between the buildings. On the upper podium roof, Level 2, there is a common outdoor area between the towers and an outdoor pool to the south of the roof, a barbeque area between north-west and north-east buildings, and a large private outdoor terrace to the west of the north-west tower, Figure 2 (BL). There are awnings along the west facade with smaller awnings on Level 1 to the south-west and a large awning on Level 2 to the north-west. There are private court yards on the roof of the three eastern buildings and a terrace to the north corner of the south-west tower on Level 8.

Figure 2: West elevation (T), floor plans level Ground (ML), Podium Level 1 (MR), Podium Level 2 (BL), and a typical tower level, Level 5 (BR)

2.4 Predicted wind conditions on ground plane

This section of the report outlines the predicted wind conditions in and around the site based on the local climate, topography, and building form. The height and massing of the proposed development is significant compared with the surrounding buildings and would therefore be expected to have an impact on the local wind conditions. From a wind perspective, the towers are close together and would act as a compound shape.

Winds from the north-east

Winds from the north-east would impact on the north facade of the north buildings. The aspect ratio of these buildings and their orientation towards the wind, would encourage flow to travel around the northern towers horizontally rather than induce downwash. Due to the orientation of the northern buildings relative to each other, a portion of the incident flow would be funnelled through the gap between the buildings. The wind speeds would be greatest at the narrowest distance between the buildings. The remaining flow around the northern corners would be slightly accelerated causing windier conditions around the corner of the outdoor childcare. Wind conditions to the south of the outdoor childcare area, the central section of the upper podium level, and the lower podium level will be protected by the surrounding buildings and general massing of the building. The stepped podium design is considered good for winds from the north-east.

Winds from the south

Winds from the south would impact on south side of the southern buildings. The curved corners of these buildings and aspect ratio of the south elevation of the south towers would encourage horizontal flow minimising downwash. The setback of the south-east building from the east and south edge of the podium, and the relatively open nature of the podium, would be expected to redirect any downwash flow before reaching ground level across the Level 2 open areas. The awnings on the south-west side of the development would help minimize the downwash flow reaching ground level.

Winds from the west

The site is exposed to winds from the west due to the development massing and the open nature of Eastlakes Reserve. The flow impinging on the west towers would induce downwash. Due to the wide aspect ratio of the compound shape of the west towers, flow would have a strong horizontal component along the west façade. The setback of the west buildings from the podium edge, along with relatively deep awnings to the west would prevent the downwash component reaching ground level, which would then discharge around the north and south sides of the site and through the relatively large gap between the towers. Wind conditions through the outdoor childcare area would be expected to be relatively fast without some form of permanent or temporary additional vertical amelioration to the facade. The raised terrace on the west side provides protection to pedestrians around the south-west corner on Barber Avenue.

Wind conditions across the common outdoor areas on the podium roof are expected to be protected by the western buildings, with the exception of the are between the western buildings. The provision of dense landscaping in this area would improve the local wind conditions in the area. The large extent of space would ensure that there would be some calm areas on the podium regardless of incident wind direction.

Summary

The proposed development is taller than immediately surrounding buildings and is therefore exposed to all prevailing wind directions. In particular, Eastlakes Reserve extending 200 m to the west of the development provides little shielding for winds from the west. Qualitatively, integrating the expected directional wind conditions around the site with the wind climate, it is considered that wind conditions at the majority of locations around the site would be classified as suitable for pedestrian standing and walking. The final comfort categories have been annotated in Figure 3; any area not marked is expected to be classified as suitable for pedestrian standing or marginally into the pedestrian walking classification. These comfort conditions are considered to be suitable for the intended use of the spaces around the development. Additional local amelioration, such as vertical barriers or landscaping may be required around any outdoor eating areas to ensure usability of the space for as much of the time as possible. The wind conditions at all locations are expected to pass the safety criteria.

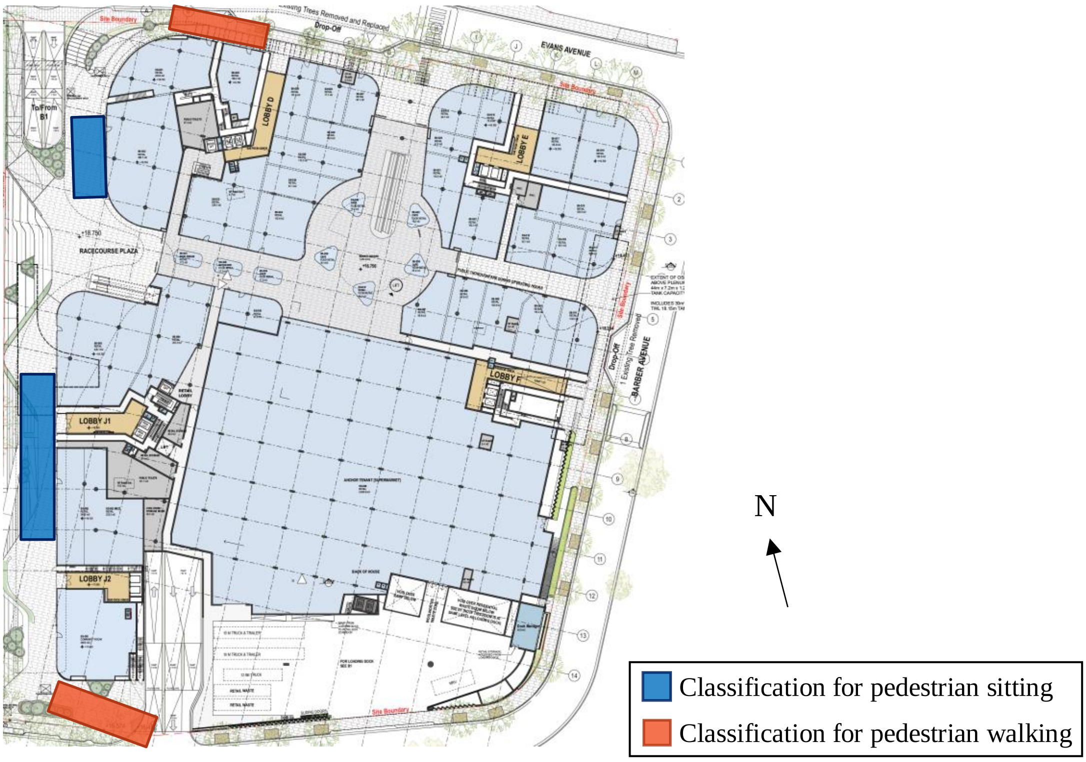

Figure 3: Expected wind comfort classification around the development

General Observation

There are podium through-site links on ground and lower podium levels. The wind conditions in these areas are primarily driven by the pressure difference at the external openings. To eliminate internal flow problems, it is recommended to use revolving doors at the entries. In places where revolving door cannot be an option, it is recommended to have the ability to minimise the open cross-sectional area of the entries. The current design with sliding doors in line with the corridors will induce a jet of air into the area when the windward door is open. On passing through the door, the jet expands into the larger volume and slows down. The jet is typically felt for about 10 m from the entry. These jets are currently directed along the corridors past the island tenancies. To improve the wind conditions, the entry doors could be angled to direct the jet to a wall rather than along the corridor, porous wayfinding screens could be installed inside the building in the jet location, or local amelioration such as vertical screens installed on the island close to the entry doors.

The western buildings form a funnel for winds from the west, accelerating the flow between the towers and discharging it across the open area on the upper podium, Level 2 before impinging on Building F. The positioning of Building F is good to avoid a constant undisturbed flow path across the podium roof. It is expected wind conditions on the open areas, especially on the rooftop terrace to the west of the north-west tower and between the western towers would be windy for winds from the west. Local amelioration would be required for any open areas on the upper podium level if they are intended for seating type activities.

The childcare outdoor area on the lower podium, Level 1 is exposed to winds from the west and the north-east. Wind mitigation strategies for this location would be to divide the outdoor space into two separate areas with a fin wall extending from the building corner, of installing closely spaced vertical screens around the perimeter of the entire outdoor section.

The private rooftop courtyards on the eastern buildings are exposed to winds from the south and north-east. Being remote from the building edge, wind conditions in these areas are likely to be relatively good, but would be improved with perimeter vertical screens or landscaping. Vertical screens typically provide shelter to a horizontal distance of about 5 times of the height of the screen: for example, a vertical screen with a height of 3 m offers protection to 10 m behind the screen at a height of 1 m above ground, and at a height of 2 m would offer protection to 5 m behind the screen.

3 Summary

Arup have provided qualitative advice for the impact of the proposed development on pedestrian wind comfort. It is Arup's opinion that all locations within the proposed development would meet the safety criterion. From a wind comfort perspective, the wind conditions at the majority of locations around the development would be expected to be classified as suitable for pedestrian standing and walking activities with some locations classified as suitable for outdoor sitting. These classifications generally match 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.

4 References

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Appendix 1: Wind climate

The wind frequency and direction information measured by the Bureau of Meteorology anemometer at a standard height of 10 m at Sydney Airport from 1995 to 2016 have been used in this analysis, Figure 4. The arms of the wind rose point in the direction from where the wind is coming from. The anemometer is located about 8 km to the east of the site. The directional wind speeds measured here are considered representative of the wind conditions at the site.

It is evident from Figure 4 that strong prevailing winds are organised into three main groups which centre at about the north-east, south, and west quadrants.

Strong summer winds occur mainly from the south quadrant and the north-east. 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 south-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.

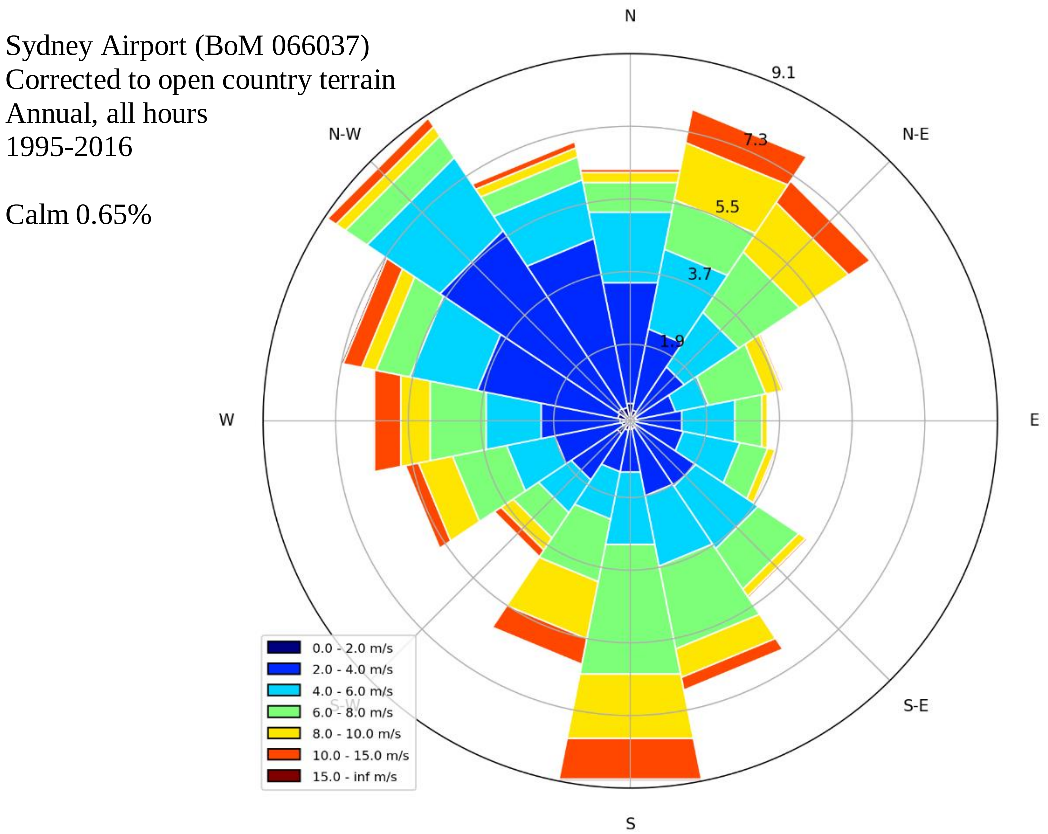

Figure 4 Wind rose showing probability of time of wind direction and speed

Appendix 2: 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 5, 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 5. 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.

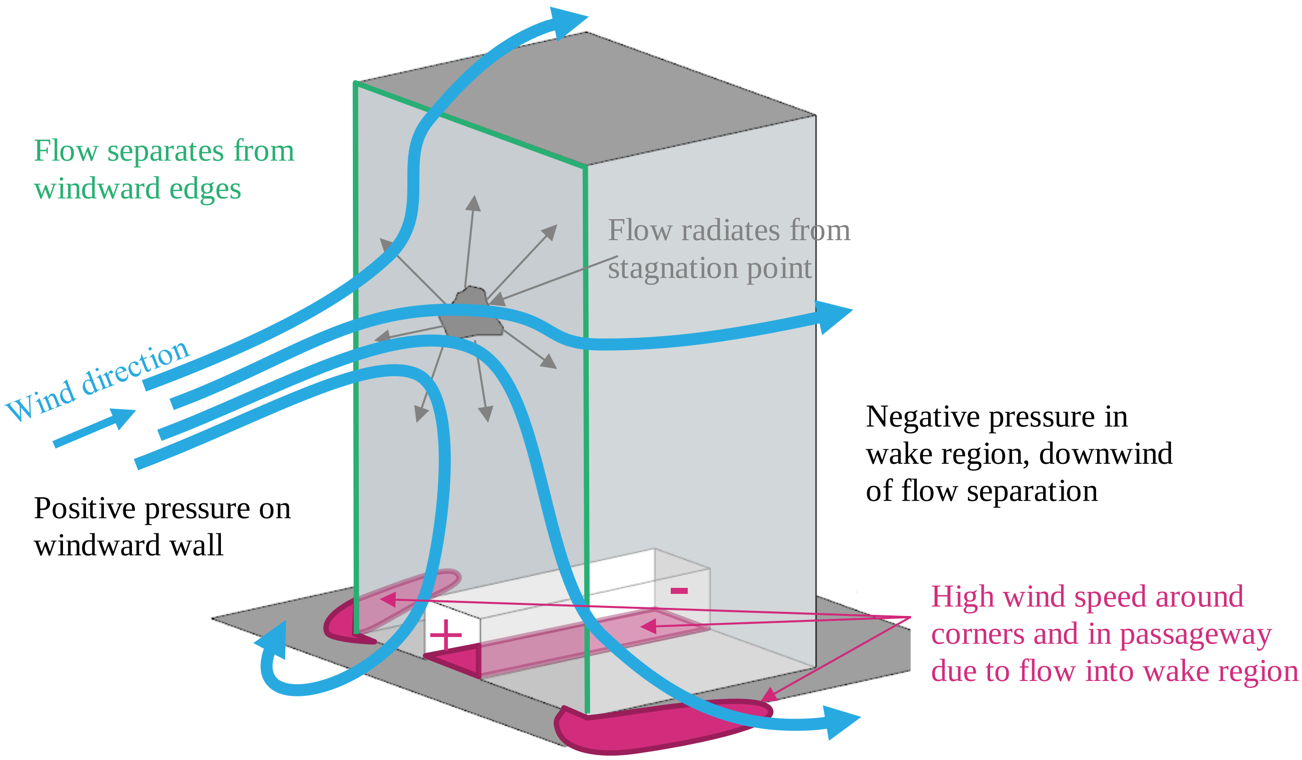

Figure 5 Schematic wind flow around tall isolated building

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 6. 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.

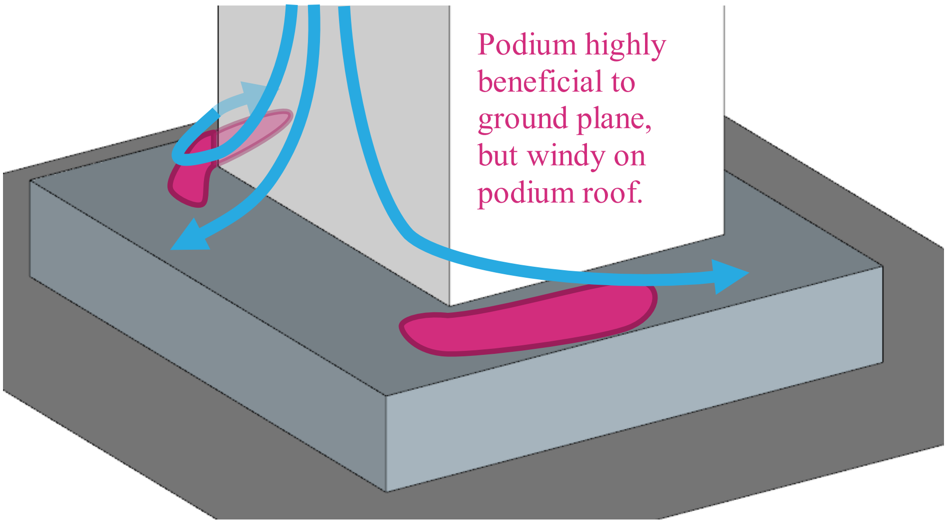

Figure 6 Schematic flow pattern around building with podium

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 7. 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.

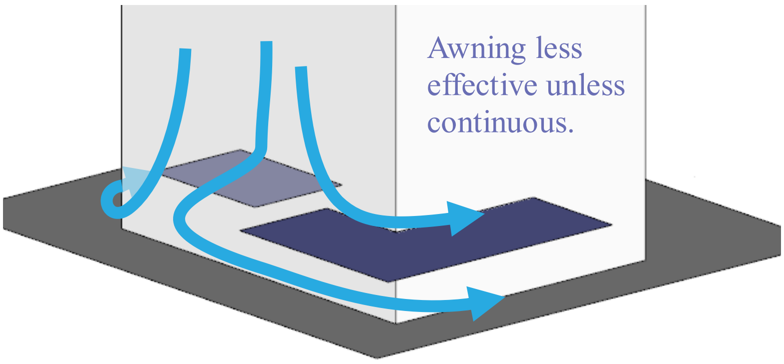

Figure 7 Schematic flow pattern around building with awning

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 8. 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 5. If the link is blocked, wind conditions will be calm unless there is a flow path through the building, Figure 9. 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 9.

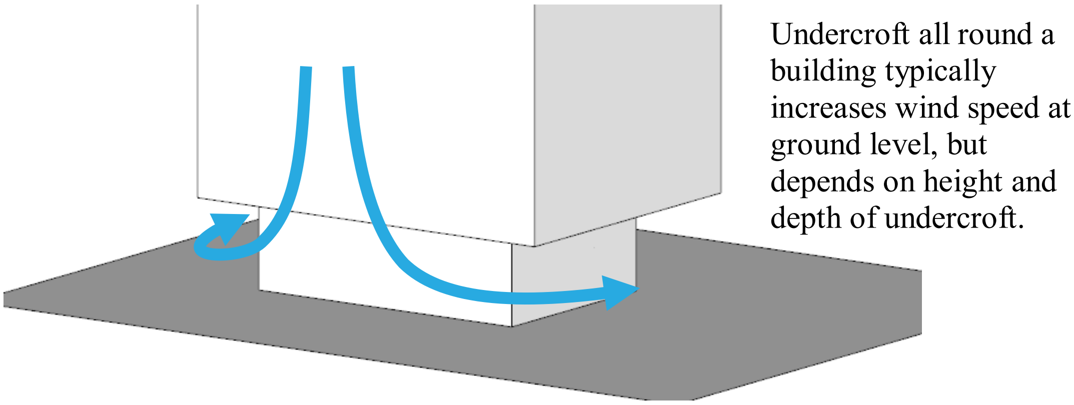

Figure 8 Schematic of flow patterns around isolated building with undercroft

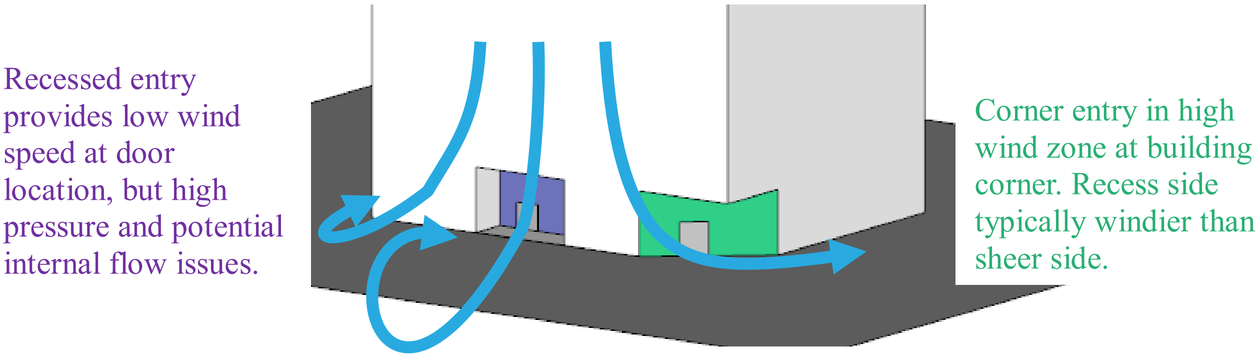

Figure 9 Schematic of flow patterns around isolated building with ground articulation

Multiple buildings

When a building is located in a city environment, depending on upwind buildings, the interference effects may be positive or negative, Figure 10. 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.

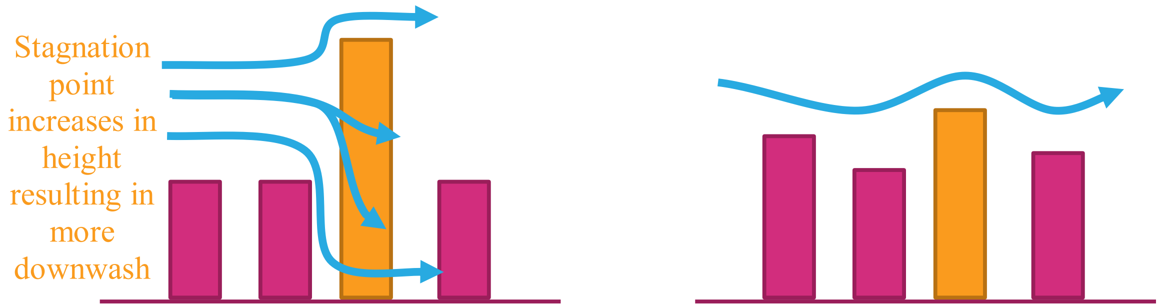

Figure 10 Schematic of flow pattern interference from surrounding buildings

The above discussion becomes more complex when three-dimensional effects are considered, both with orientation and staggering of buildings, and incident wind direction, Figure 11.

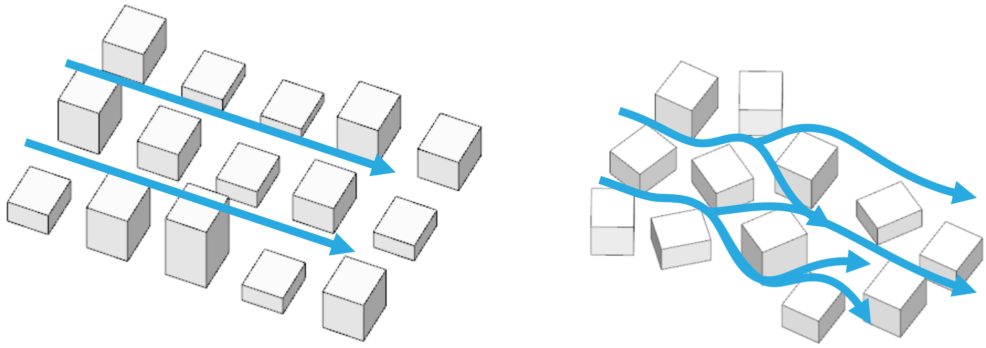

Figure 11 Schematic of flow patterns through a grid and random street layout

Channelling occurs when the wind is accelerated between two buildings, or along straight streets with buildings on either side, Figure 11(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 11(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.

Appendix 3: 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:

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

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 12 and Figure 14. 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 12 with definitions of the intended use of the space categories defined in Figure 13.

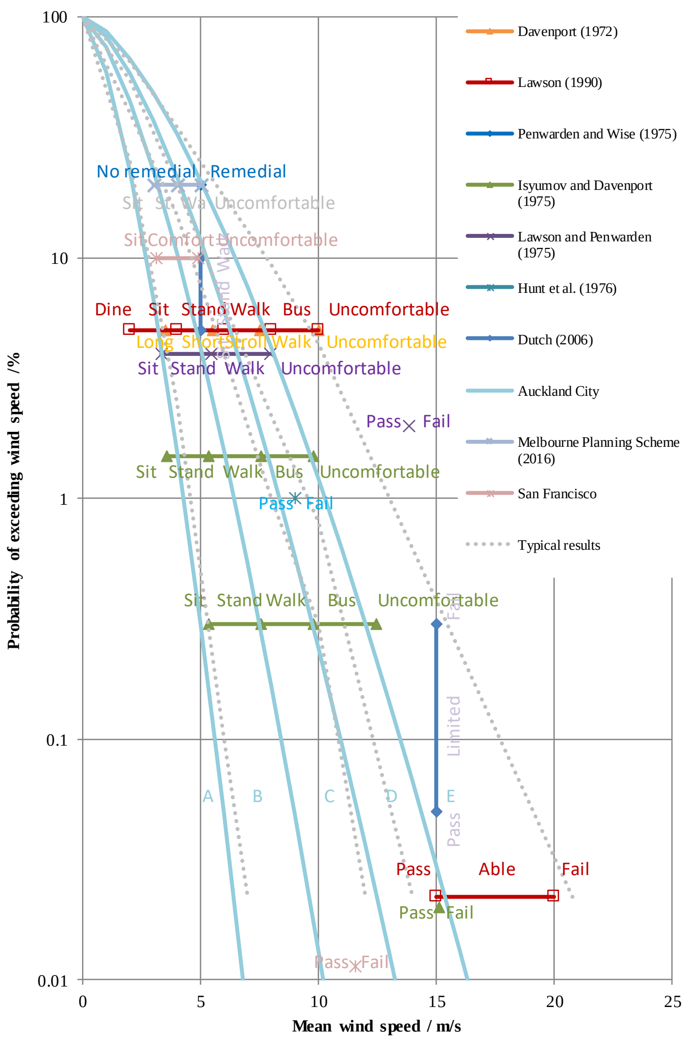

Figure 12 Probabilistic comparison between wind criteria based on mean wind speed

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 13: Auckland Utility Plan (2016) wind categories

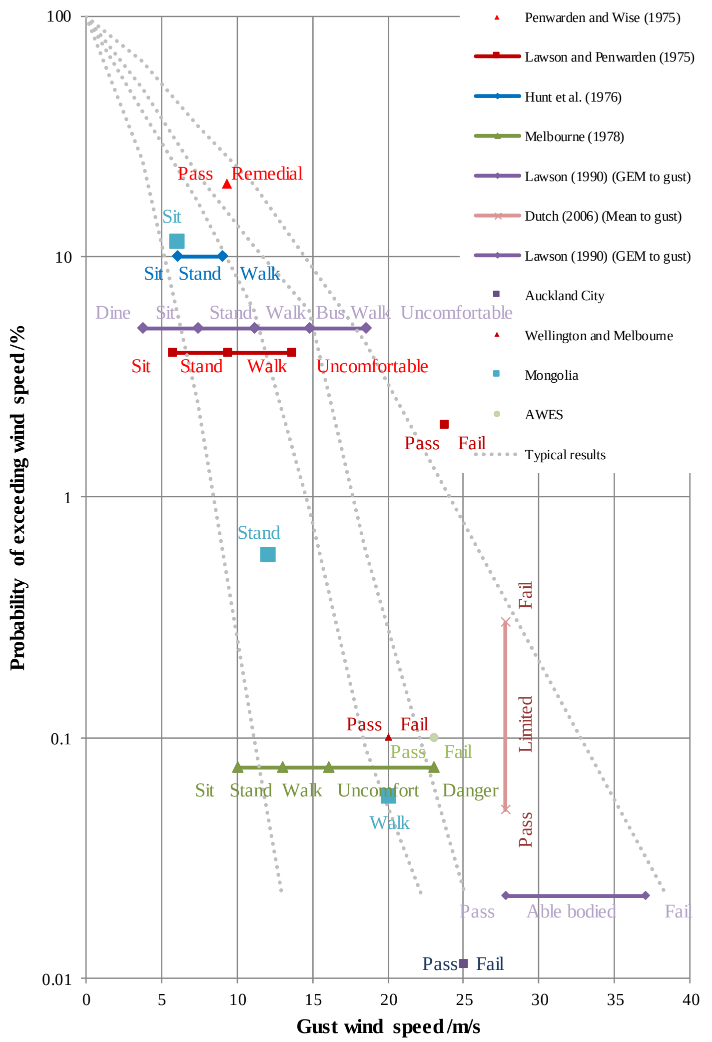

Figure 14 Probabilistic comparison between wind criteria based on 3 s gust wind speed

Appendix 4: Reference documents

In preparing the assessment, the following documents have been referenced to understand the building massing and features.

- 191014 Eastlakes Sout Site - Development Summary Schedule.pdf
- ARC-FJMT-CGES-2000.00_SITE PLAN 1_500_PDF[M01].pdf
- ARC-FJMT-CGES-2000.00GF_GROUND LEVEL_PDF[M01].pdf
- ARC-FJMT-CGES-2000.01_LEVEL 1 LOWER PODIUM_PDF[M01].pdf
- ARC-FJMT-CGES-2000.02_LEVEL 2 UPPER PODIUM_PDF[M01].pdf
- ARC-FJMT-CGES-2000.03_LEVEL 3_PDF[M01].pdf
- ARC-FJMT-CGES-2000.04_LEVEL 4_PDF[M01].pdf
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- ARC-FJMT-CGES-2000.06_LEVEL 6_PDF[M01].pdf
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- ARC-FJMT-CGES-3000.01_EAST & WEST ELEVATION_PDF[M01].pdf
- ARC-FJMT-CGES-3000.02_NORTH & SOUTH ELEVATION_PDF[M01].pdf
- ARC-FJMT-CGES-4000.01_LONGITUDINAL SECTION_PDF[M01].pdf
- ARC-FJMT-CGES-4000.02_CROSS SECTION_PDF[M01].pdf
- ARC-FJMT-CGES-9100.01_SOLAR ACCESS COMPLIANCE SUMMARY PLAN_PDF[M01].pdf
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