Macky Corp

# Liverpool Tower

Environmental Wind Assessment

Wind

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# Document Verification

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# Executive summary

Arup have been commissioned by Macky Corp to provide an experienced-based impact assessment of the proposed Liverpool Tower development on the north corner of the intersection of Scott and Bigge Streets, Liverpoolon the pedestrian level wind conditions for comfort and safety in and around the site.

It is considered that the proposed development, which is larger than surrounding buildings, would have an impact on the wind conditions in and around the site. Depending on the location, the proposed building would improve the wind conditions for certain wind directions and increase the wind speed for others. The wind conditions are expected to be suitable for the intended use of the space from a comfort perspective and meet safety criteria.

Benefits of the design from a wind perspective include the rounded south-east and north-west corners, and the proximity to the neighbouring buildings.

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

# 1 Introduction

Macky Corp have engaged Arup to provide a qualitative environmental wind assessment for the proposed Liverpool Tower development on the corner of Scott, and Bigge Streets. 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 Bankstown 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 south-east and north-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, 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. Because pedestrians will tolerate higher wind speeds for a smaller period of time than for lower wind speeds, these criteria provide a means of evaluating the overall acceptability of a pedestrian location. A location can further be evaluated for its intended use, such as for an outdoor café or footpath.

Although not explicitly stated in the Liverpool City Council DCP, the wind controls are assumed to be based on the work of Melbourne (1978). These are based on the 3 s gust wind speed in an hour, that would occur for 0.1% (once per annum) of the time for each wind direction. The values of 10, 13, and 16 m/s stated in the DCP are for pedestrian comfort rather than safety, and are associated with long-term stationary activities, short-term stationary/standing activities, and pedestrian walking respectively. These criteria use the infrequent wind event as an estimator of the general comfort wind conditions at the site, which are more relevant to the success of the development. To combat this limitation, this study also uses the criteria of Lawson (1990), which are described in Figure 14 and Table 1 for both pedestrian comfort and distress. The limiting criteria are defined for both a mean and gust equivalent mean (GEM) wind speed. The criteria based on the mean wind speeds define when the steady component of the wind causes discomfort, whereas the GEM wind speeds define when the wind gusts cause discomfort.

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 Liverpool Tower site is located is located on the south-east corner of the block bounded by Railway, Bigge, Scott, and George Streets, Figure 1. The site is generally surrounded by low- rise buildings in all directions, with some medium-rise buildings to the immediate north and west. Topography surrounding the site is essentially flat from a wind perspective.

The site is located in close proximity to the train station hence pedestrian traffic along Scott and Railway Streets, are expected to be relatively high with a lower volume of traffic crossing the site.


Figure 1 Site location (source: Google Earth 2017)

The proposed commercial development consists of a single tower of irregular floor plan, rising to about 100 m above ground level, Figure 2. The south-east and north-west corners of the tower are curved. The tower has a two storey undercroft at ground level and a large outdoor terrace on Level 11.

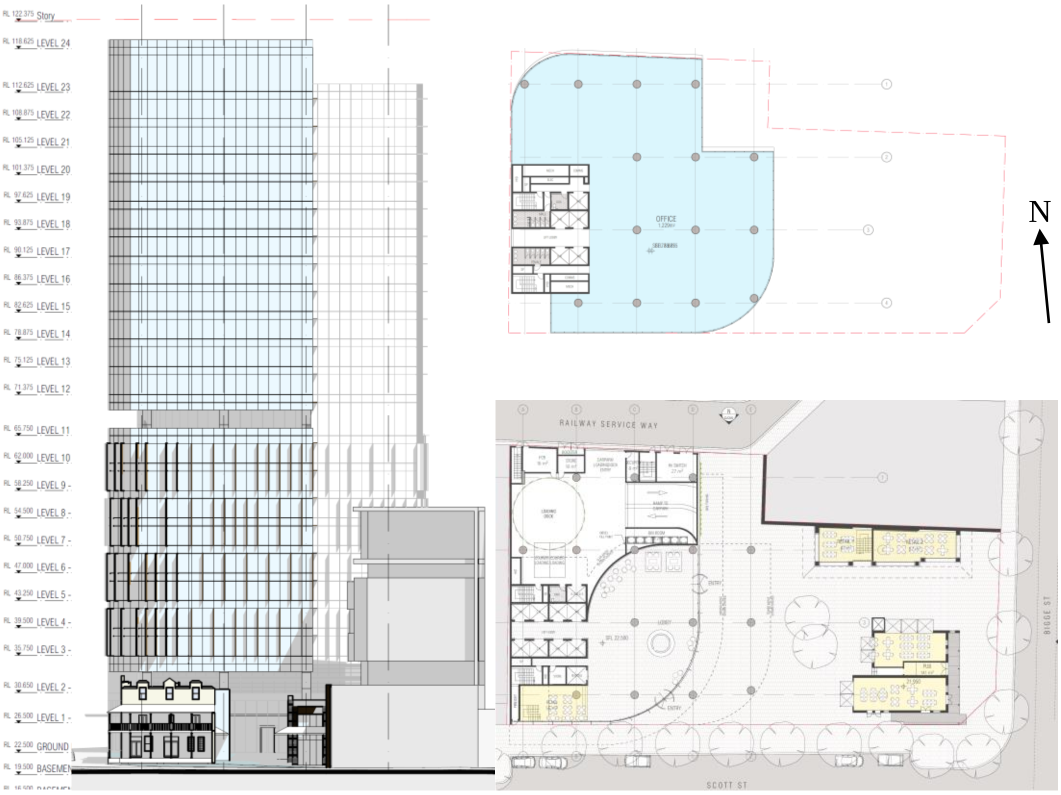


Figure 2: East elevation (L), and ground and typical high-rise floor plan (R)

## 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 massing of the proposed redevelopment is significant compared with the massing of the surrounding buildings, and will therefore have an impact on the local wind conditions.

### Winds from the south-east quadrant

Winds from the south-east will impact on the curved corner of the building, which will promote horizontal flow around the tower rather than induce downwash, Figure 3. The increased massing along Scott Street would direct more horizontal flow along the street. The relatively small gap between the proposed building and the existing medium-rise building to the immediate north would be expected to create calmer conditions in the courtyard area to the east. As the flow area reduces, the wind speed would accelerate between the buildings producing stronger, but relatively steady wind conditions through the narrowest section. As the flow area expands to the north, the wind speed will decrease. Further reducing the narrowest section would localise the wind conditions, whilst not increasing the magnitude of the wind.

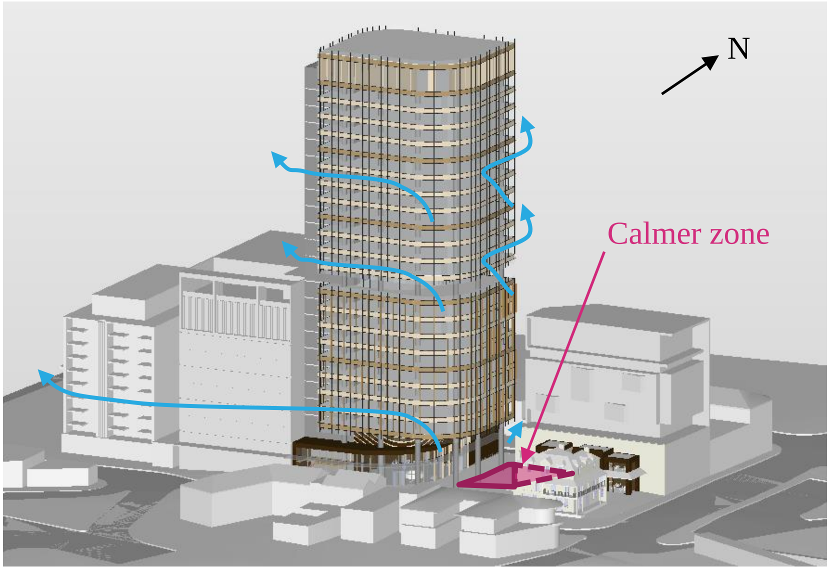


Figure 3: Flow patterns around the proposed development for winds form the south-east

## Winds from the west quadrant

On reaching the site, winds from the west will already be influenced by the building to the west causing channelled flow along Scott Street and the laneway to the north of the site. It is expected that the flow impinging on the exposed west section of the tower would induce downwash that to be redirected by the roof of the neighbouring medium-rise building rather than reaching ground level, Figure 4.

As the flow direction is more from the north-west, the flow will impinge on the curved north-west corner of the building, which would induce horizontal flow around the tower. Stronger winds can be expected through the gap to the east of the development, but would be expected to be lower than for winds from the south-east.

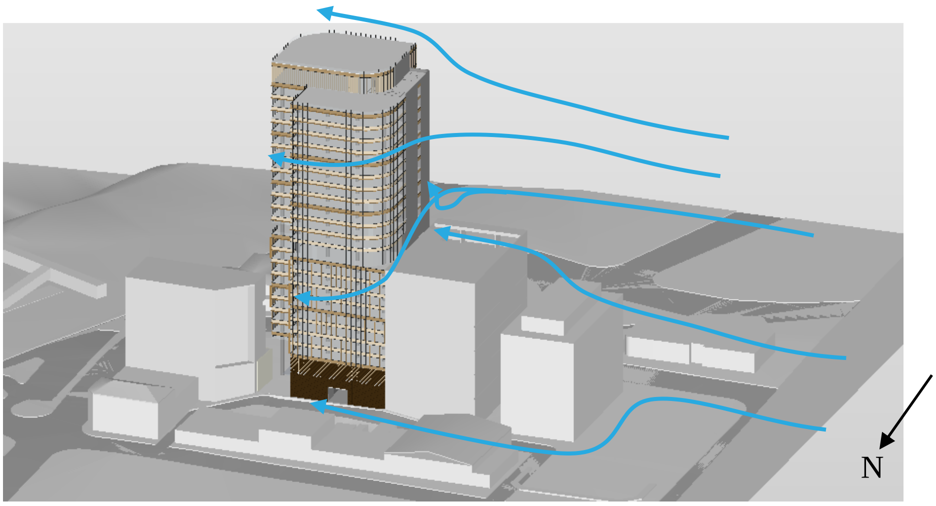


Figure 4: Flow patterns around the proposed development for winds form the west

### Summary

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 or short-term stationary activities. Local windier conditions are expected through the laneway to the east, calmer conditions in the courtyard to the east. A summary of the predicted wind conditions at locations around the proposed development is presented in Figure 5, the areas would be acceptable for pedestrian standing (DCP 13 m/s) unless noted.


Figure 5 Predicted wind conditions around the site

# 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 majority of the surrounding areas are expected to meet the requirements 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.

# 4 References

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Netherlands Standardization Institute, NEN, (2006). Wind comfort and wind danger in the built environment, NEN 8100 (in Dutch) Dutch Standard.

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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 Bankstown Airport from 1993 to 2017 have been used in this analysis, Figure 6. The arms of the wind rose point in the direction from where the wind is coming from. The anemometer is located about 6 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 6 that strong prevailing winds are organised into two main groups which centre at about the south-east, and west quadrants.

Strong summer winds occur mainly from the south-east quadrant, which are generally associated with large synoptic frontal systems and generally provide the strongest gusts during summer.

Winter and early spring strong winds typically occur from the west quadrant. 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.

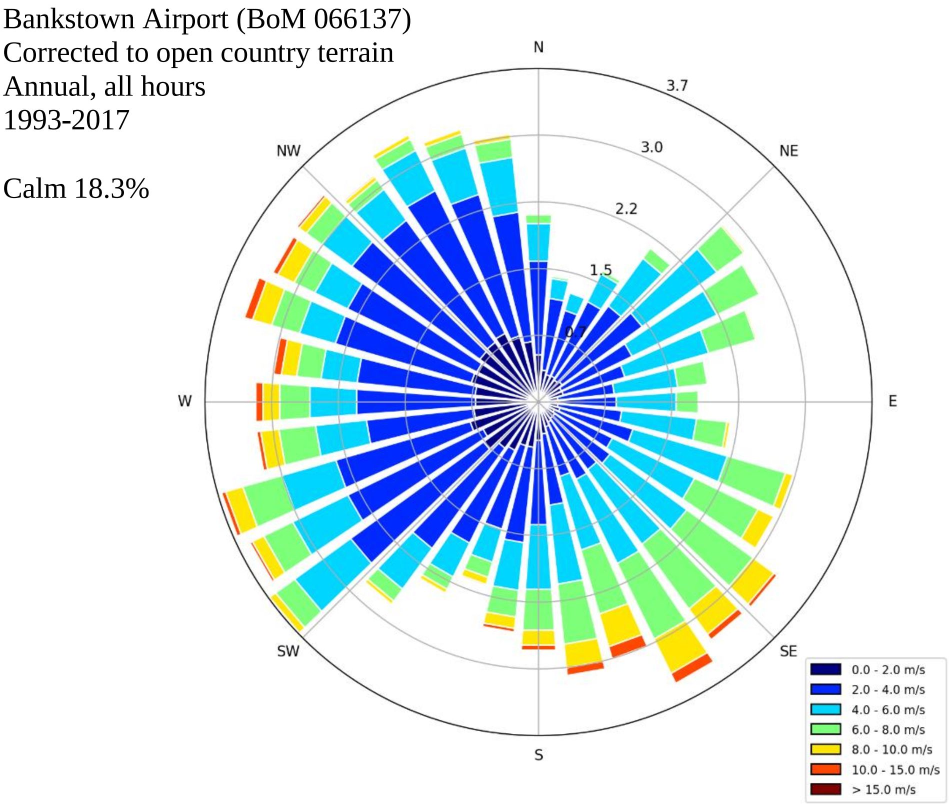


Figure 6 Wind rose showing probability of time of wind direction and speed

# 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 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.

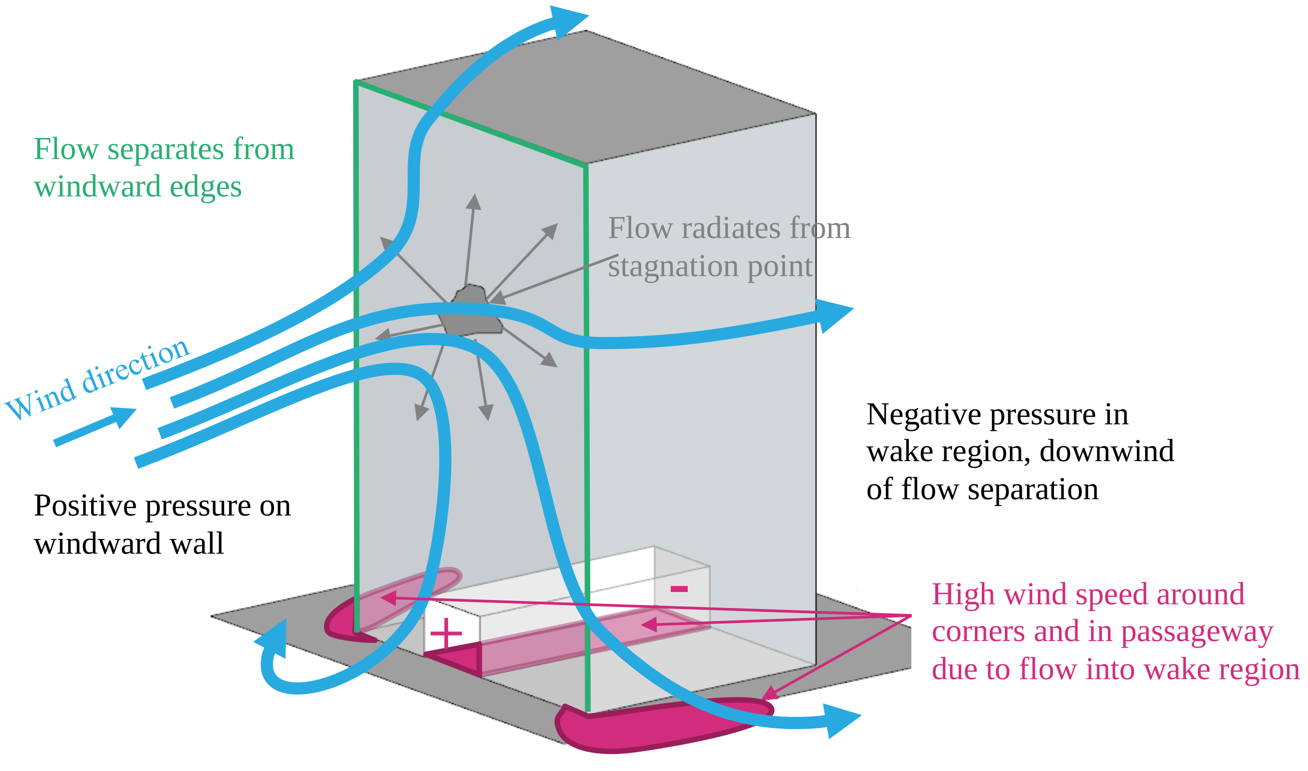


Figure 7 Schematic wind flow around tall isolated building

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.

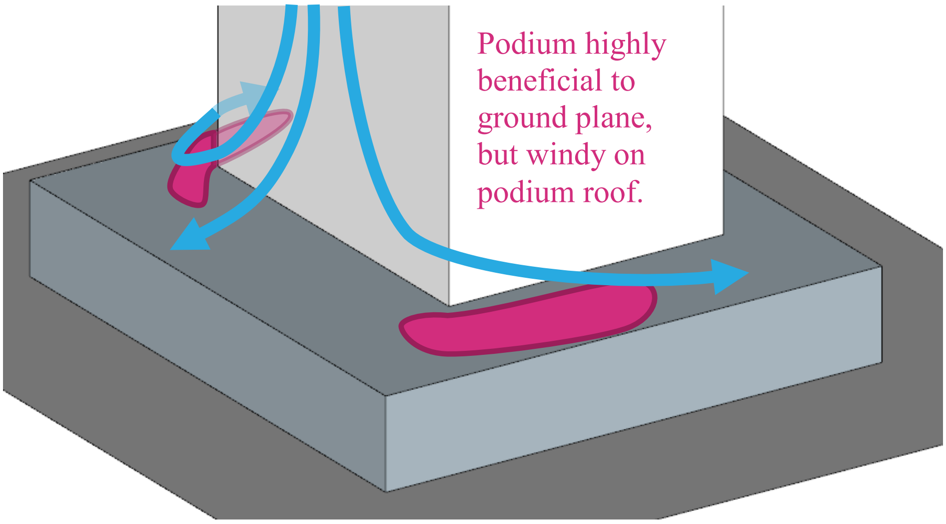


Figure 8 Schematic flow pattern around building with podium

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.

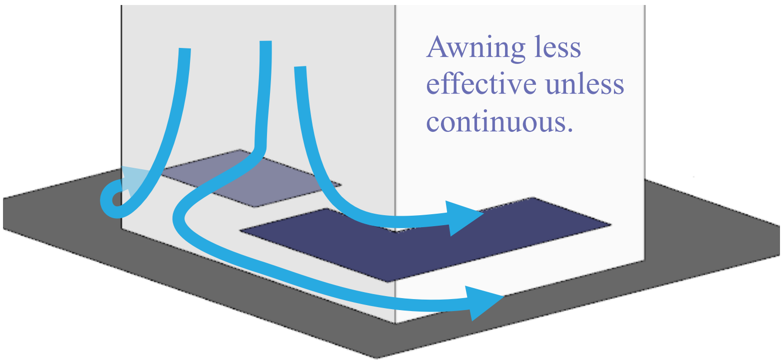


Figure 9 Schematic flow pattern around building with awning

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.

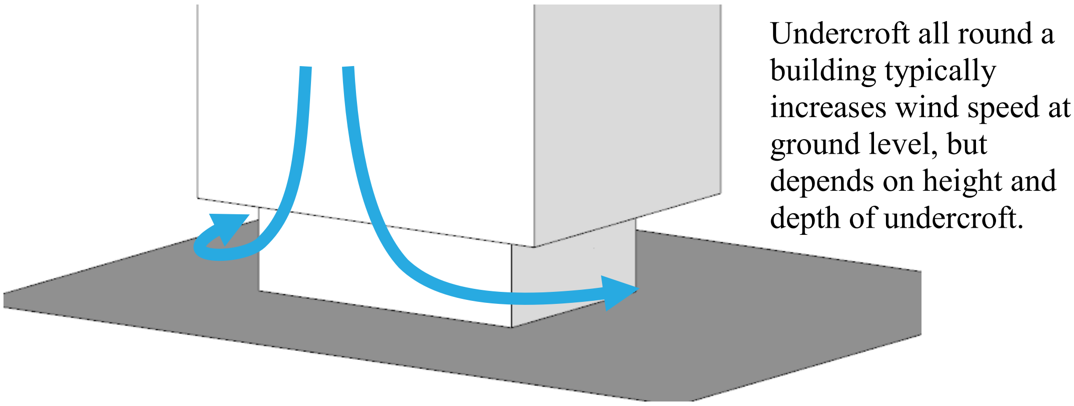


Figure 10 Schematic of flow patterns around isolated building with undercroft

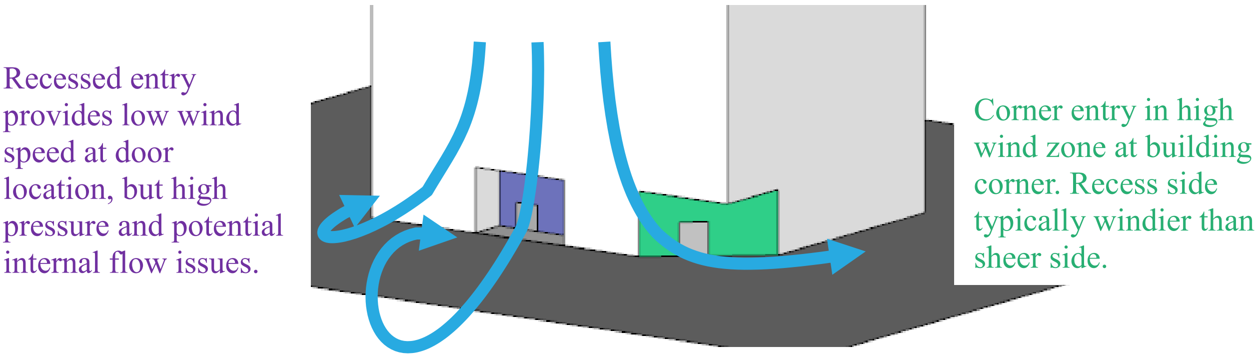


Figure 11 Schematic of flow patterns around isolated building with ground articulation

## 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.

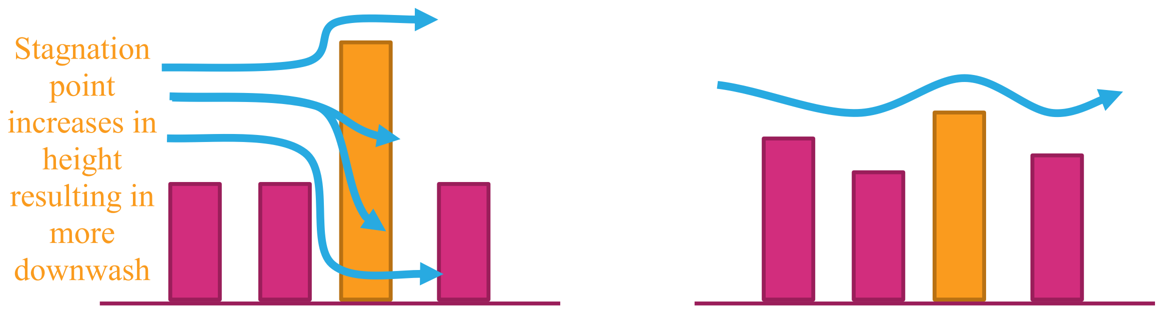


Figure 12 Schematic of flow pattern interference from surrounding buildings

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.

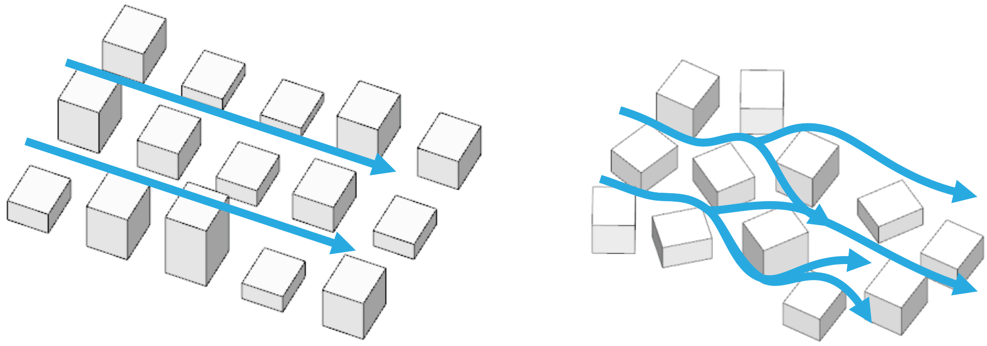

Figure 13 Schematic of flow patterns through a grid and random street layout

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.

# 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.<br>Napkins blown away and newspapers flutter at about 1 m/s. |
| Light breeze | 2–3 | Wind felt on face. Light clothing disturbed.<br>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.<br>Sand on beach saltates at about 5 m/s.<br>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.<br>Umbrellas used with difficulty.<br>Wind sock fully extended at about 8 m/s. |
| Strong breeze | 11–14 | Hair blown straight. Difficult to walk steadily.<br>Wind noise on ears unpleasant.<br>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 14 and Figure 16. 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 14 with definitions of the intended use of the space categories defined in Figure 15.

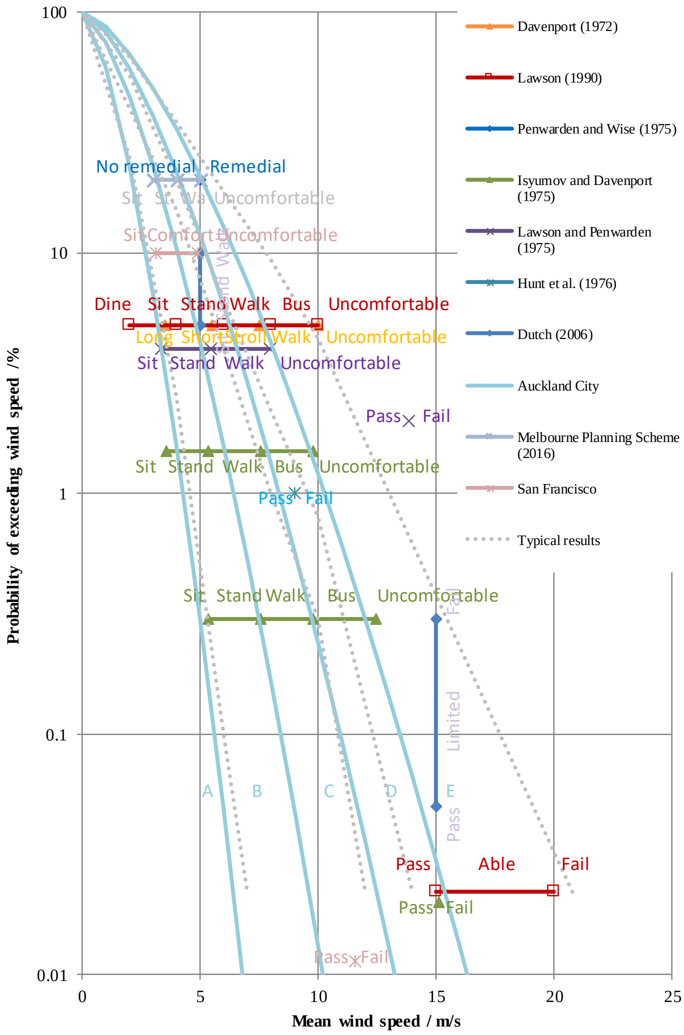


Figure 14 Probabilistic comparison between wind criteria based on mean wind speed

| | |
|---|---|
| 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 15: Auckland Utility Plan (2016) wind categories

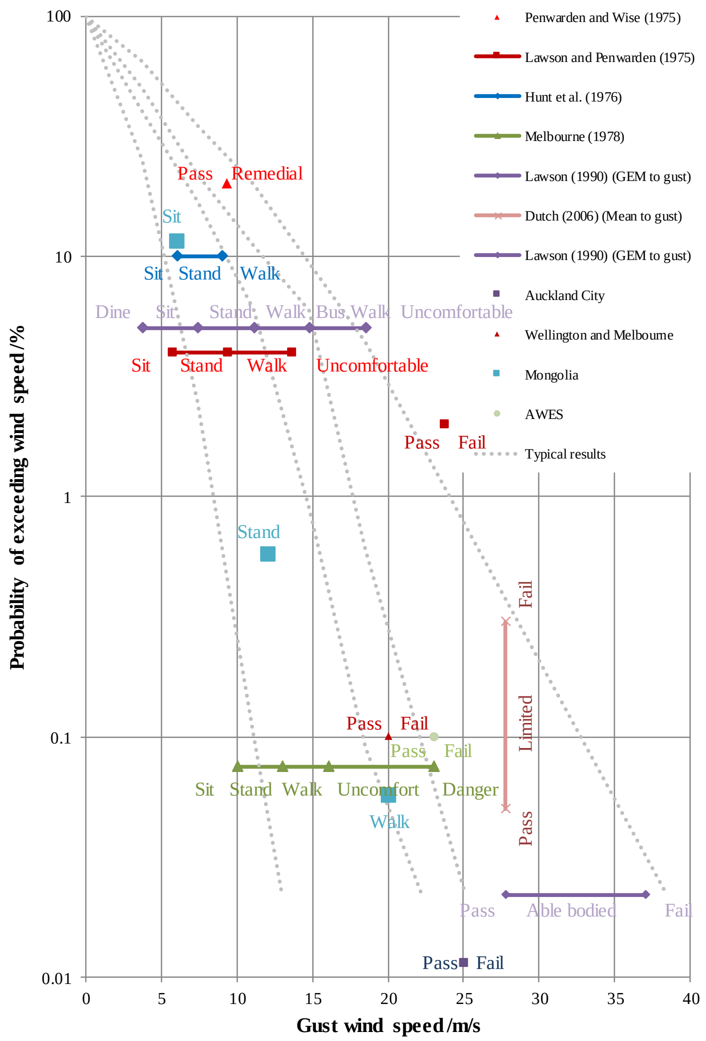


Figure 16 Probabilistic comparison between wind criteria based on 3 s gust wind speed

# Appendix 4: Reference documents

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

- 0. GROUND FLOOR.dwg
- 0. GROUND FLOOR1.Shx
- -1. BASEMENT 1.dwg
- 1. LEVEL 1 - BOH.dwg
- -2. BASEMENT 2.dwg
- 2. LEVEL 2 - PLANT.dwg
- 3. LEVEL 3 - TYPICAL LOWRISE.dwg
- 11. LEVEL 11 - OASIS.dwg
- 12. LEVEL 12 - TYPICAL HIGHRISE LOR.dwg
- 13. LEVEL 13 - TYPICAL HIGHRISE LMR.dwg
- 14. LEVEL 14 - TYPICAL HIGHRISE.dwg
- 23. LEVEL 23 - PLANT.dwg
- 24. LEVEL 24 - ROOF.dwg
- 180622 - Liverpool Tower - FKA - Progress Model.ifc
- LIVERPOOL TOWER - DA Package DRAFT.pdf