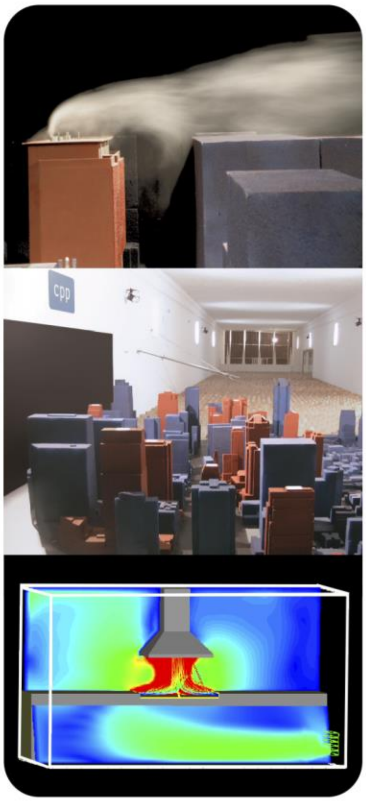
CERMAK
PETERKA
PETERSEN

WIND ENGINEERING AND AIR QUALITY CONSULTANTS

Final Report



Qualitative Wind Assessment for:

Ivanhoe Estate – Stage 1

Macquarie Park, NSW, Australia

Prepared for:

Frasers Property Ivanhoe

c/o Citta Property Group Pty Ltd

Level 23, 6 O'Connell Street

Sydney, NSW 2000

Australia

November 2018

CPP Project: 11743

Prepared by:

Joe Paetzold, Engineering Manager

Christian Rohr, CFD Manager

CPP

Unit 2, 500 Princes Highway

St. Peters, NSW 2044, Australia

info-syd@cppwind.com

www.cppwind.com

EXECUTIVE SUMMARY

This report provides an opinion based qualitative assessment of the impact of the proposed Ivanhoe Estate – Stage 1 buildings on the local pedestrian-level wind environment. This assessment is based on knowledge of the local wind climate.

With reference to the City of Ryde DCP criteria, the environmental wind conditions around the proposed development are expected to be suitable for pedestrian standing and walking from a comfort perspective and pass the safety criterion. Wind tunnel testing will be required to better quantify these conditions and required mitigation within localised windy areas.

DOCUMENT VERIFICATION

Date	Revision	Prepared by	Checked by	Approved by
19/03/18	Final Report	JP	CR	JP
27/03/18	Minor revision	JP	CR	JP
04/10/18	Updated drawings	JP	CR	JP
05/10/18	Minor revision	JP	JP	JP
01/11/18	Minor revision	JP	JP	JP

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 PROJECT BACKGROUND (CLIENT PROVIDED)

Introduction

This report supports a Development Application for Stage 1 of the Ivanhoe Estate redevelopment, a State Significant Development (SSD) submitted to the Department of Planning and Environment (DPE) pursuant to Part 4 of the Environmental Planning and Assessment Act 1979 (EP&A Act). It has been prepared for Aspire Consortium on behalf of NSW Land and Housing Corporation.

Background

In September 2015 the Ivanhoe Estate was rezoned by DPE as part of the Macquarie University Station (Herring Road) Priority Precinct, to transform the area into a vibrant centre that benefits from the available transport infrastructure and the precinct's proximity to jobs, retail and education opportunities within the Macquarie Park corridor.

The Ivanhoe Estate is currently owned by NSW Land and Housing Corporation and comprises 259 social housing dwellings. The redevelopment of the Ivanhoe Estate is part of the NSW Government Communities Plus program, which seeks to deliver new communities where social housing blends with private and affordable housing, with good access to transport, employment, improved community facilities and open space.

The Communities Plus program seeks to leverage the expertise and capacity of the private and non-government sectors. As part of this program, Aspire Consortium, comprising Frasers Property Australia and Mission Australia Housing, was selected as the successful proponent to develop the site in July 2017.

In September 2017, DPE issued the Secretary's Environmental Assessment Requirements for a comprehensive Masterplan application that will establish the framework for the staged redevelopment of the site. This Development Application for Stage 1 of the Ivanhoe Estate redevelopment represents the first stage of detailed works pursuant to the Ivanhoe Estate Masterplan.

Site Description

The Ivanhoe Estate site is located in Macquarie Park near the corner of Epping Road and Herring Road within the Ryde Local Government Area (LGA). The site is approximately 8.2 hectares and currently accommodates 259 social housing dwellings, comprising a mix of townhouse and four storey apartment buildings set around a cul-de-sac street layout. An aerial photo of the site is provided at Figure 1 below.

Immediately to the north of the site are a series of four storey residential apartment buildings. On the north-western boundary, the site fronts Herring Road and a lot that is currently occupied by four former student accommodation buildings and is likely to be subject to redevelopment. Epping Road runs along the south-western boundary of the site and Shrimptons Creek, an area of public open space, runs along the south-eastern boundary. Vehicle access to the site is via Herring Road.

Ivanhoe Estate comprised of 17 individual lots owned and managed by the NSW Land and Housing Corporation. The Masterplan site also incorporates adjoining land, being a portion of Shrimptons Creek and part of the commercial site at 2-4 Lyonpark Road. This land is included to facilitate a bridge crossing and road connection to Lyonpark Road.

Figure 1: Ivanhoe Estate site (ethos urban, 2018)

<u>Overview of the Proposed Development</u>

The proposed Stage 1 Development Application seeks consent for the first stage of detailed works within the Ivanhoe Estate, pursuant to the Ivanhoe Estate Masterplan under Section 4.22 of the EP&A Act. The Masterplan establishes the planning and development framework against which this Stage 1 Development Application will be assessed.

The Stage 1 Development Application seeks approval for:

- site preparation works, including tree removal, demolition of roads, services, and earthworks across the Ivanhoe Estate;
- the provision and augmentation of utilities and services infrastructure across the Ivanhoe Estate;
- the construction of all internal roads including public domain within the road reserves, and the bridge crossing and road connection to Lyonpark Road;
- the consolidation of existing lots and subdivision of the Ivanhoe Estate to reflect the revised road layout, open space, and provide superblocks corresponding to the Masterplan;
- the construction and use of Buildings A1 and C1 comprising residential uses (including social housing), a childcare centre, and retail/community spaces.

An image of the Masterplan, identifying Buildings A1 and C1 and illustrating the road network, is provided at Figure 2 below.

Figure 2; Ivanhoe Estate Masterplan (Bates Smart, 2018)

2 INTRODUCTION

Cermak Peterka Petersen Pty. Ltd. has been engaged by Frasers Property Ivanhoe to provide a qualitative assessment of the impact of the proposed Ivanhoe Estate masterplan and Stage 1 development on the local wind environment.

The surrounding area is dominated by low- to medium-rise buildings, with the towers of Macquarie Park Village directly to the north-west being of similar height to the proposed development. The site is proposed to be developed in several stages and to include mixed-use primarily residential buildings of 8-23 storeys height. This report specifically assesses the wind environment for the Stage 1 buildings only, Buildings A1 and C1 as shown in Figure 2 and Figure 3. A separate report has been provided for the masterplan (CPP, 2018).

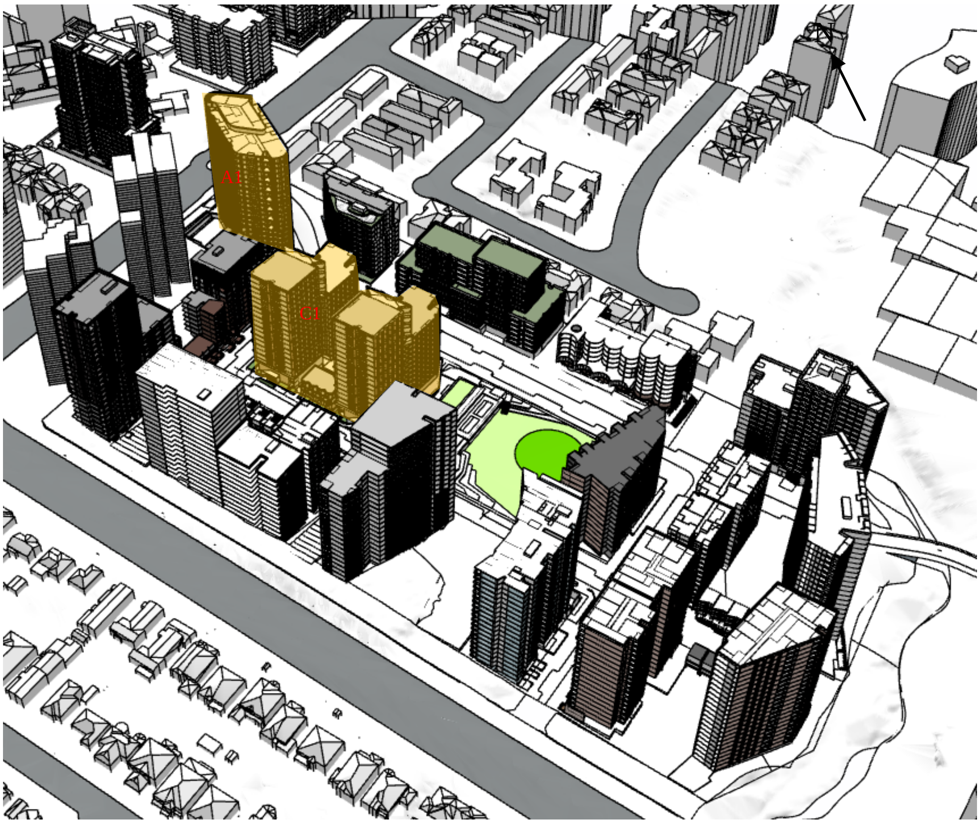


Figure 3: Massing diagram of the precinct with Stage 1 buildings highlighted.

3 MACQUARIE PARK WIND CLIMATE

The proposed development is located about 19 km to the north of the Bankstown Airport Bureau of Meteorology anemometer and 21 km to the north-west of the Sydney Airport anemometer. The general wind roses for Bankstown and Sydney Airports are presented in Figure 4. In coastal Sydney, winds from the north-east tend to be summer sea breezes and bring welcome relief on summer days but dissipate with distance from the coast and are significantly diminished at Bankstown. In terms of distance from the coast, the site is located approximately halfway between the two airports. For this development, a superstation has been created by analysing data at both stations from 1995-2017 and performing statistics on the extended dataset. The result of this analysis is indicated in Figure 4.

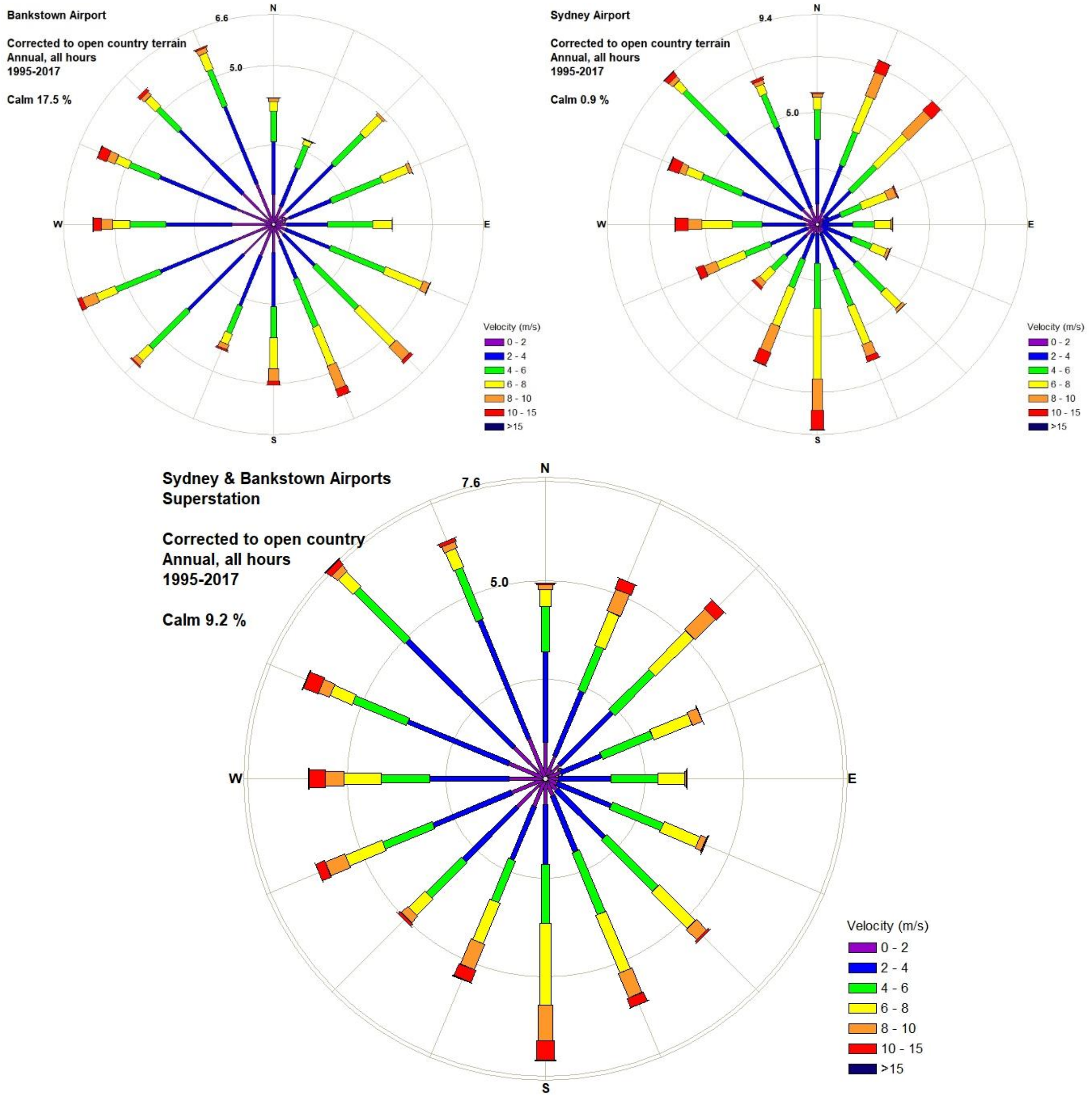


Figure 4: Wind roses for Bankstown and Sydney Airports (top), and superstation (bottom).

Winds from the south-east, which tend to be cold, are often caused by frontal systems that can last several days and occur throughout the year with reduced frequency in winter. Winds from the west tend to be the strongest of the year and are associated with large weather patterns and thunderstorm activity. These winds occur throughout the year, but are reduced in frequency in summer, and can be cold or warm depending on the inland conditions. The prevailing wind directions associated with rain are from the south and west quadrants. This wind assessment is focused on these prevailing wind directions. Seasonal wind roses for the site wind climate are presented in Appendix 1.

3 ENVIRONMENTAL WIND CRITERIA

It is generally accepted that wind speed and the rate of change of wind velocity are the primary parameters that should be used in the assessment of how wind affects pedestrians. Local wind effects can be assessed with respect to a number of environmental wind speed criteria established by various researchers. 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 remarkably good agreement.

The City of Ryde 2014 Development Control Plan (DCP) has specific wind assessment criteria for the Macquarie Park Corridor based on the maximum allowable wind velocities stating: *Buildings shall not create uncomfortable or unsafe wind conditions in the public domain, which exceeds the Acceptable Criteria for Environmental Wind Conditions.* The specified acceptable criteria are described in Table 1 for both pedestrian comfort and distress, and they appear to be derived from the criteria developed by Davenport (1972) and Melbourne (1978). The DCP criteria require the use of both a mean and gust equivalent mean (GEM) wind speed to assess the suitability of specific locations, as well as an annual maximum gust 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. For outdoor dining type activities, a more stringent criterion would be required. The annual maximum gust wind speed of 23 m/s is understood to be a safety criterion as defined by Melbourne (1978), although the necessity for directionality is not included. The gust wind speed may be suitable for safety considerations, but not necessarily for serviceability comfort issues. 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. Therefore, the weekly criteria defined in the DCP are considered most adequate to assess pedestrian comfort. It is noted that the DCP requires a wind tunnel study to be conducted for buildings over 9 storeys in height.

The superstation wind climate has an average wind speed at 10 m reference height of approximately 4 m/s (8 kt, 14 kph), and five percent of the time the mean wind speed is approximately 10 m/s (19 kt, 36 kph). Converting the five percent of the time mean wind speed to typical pedestrian level at the site using Standards Australia (2011) would result in about 6 m/s (12 kt, 22 kph). Comparing this with the comfort criteria of Table 1 indicates that pre-existing winds at any comparable location with a similar built environment surrounding the proposed development site would be classified as acceptable for footpaths and pedestrian walkways. Specific building massing of the proposed development and their interaction with approaching wind flows will dictate the actual wind environment at the site and the resulting wind acceptability levels; these are explored in detail below.

Table 1: Pedestrian comfort criteria for various activities as defined in the DCP.

Weekly maximum wind speed (understood as the maximum hourly mean wind speed exceeded 5% of the time as defined by Davenport (1972))	
< 3.5 m/s	Outdoor dining, amphitheatres etc. (sitting activities, long exposure)
3.5 – 5.5 m/s	Retail centres and streets, parks and recreational areas (standing activities)
5.5 – 7.5 m/s	Footpaths and pedestrian accessways (walking)
7.5 – 10 m/s	Infrequently used laneways, private balconies
Annual maximum gust wind speed (understood as the maximum gust wind speed exceeded in an hour for 0.1% of the time as defined by Melbourne (1978))	
< 10/13 m/s	Outdoor dining, amphitheatres etc. (sitting activities, long exposure)
10 – 13 m/s	Retail centres and streets, parks and recreational areas (standing activities, short exposure)
13 – 16 m/s	Footpaths and pedestrian accessways (walking)
16 – 23 m/s	Infrequently used laneways, private balconies

The weekly maximum wind speed is either a mean wind speed or a gust equivalent mean (GEM) wind speed. The GEM wind speed is equal to the 3 s gust wind speed divided by a gust factor, usually defined as 1.85.

4 ENVIRONMENTAL WIND ASSESSMENT

The proposed masterplan of the precinct includes buildings of up to 24 storeys in height, which are taller than the existing surrounding buildings. The precinct is primarily surrounded by low-rise buildings with the exception of several towers of similar height to the north-west. The site has significant slope of approximately 30 m rising from the south-east to the north-west side of the site.

The Stage 1 buildings, A1 and C1, are located in the northern part of the precinct, Figure 2. Building A1 is the tallest building in the masterplan with 24 storeys, and Building C1 rises up to 20 storeys. The masterplan includes buildings of similar height to the west of Building C1. This assessment considers the Stage 1 buildings in isolation and with the potential surrounding buildings. The wind conditions around the Stage 1 buildings in isolation would be considered the worst case, and wind conditions would be expected to improve in several locations as future stages are constructed.

Several wind flow mechanisms such as downwash and channelling flow are described in Appendix 2, and the effectiveness of some common wind mitigation measures are described in Appendix 3. The sheer façade of a tall building, such as the Stage 1 buildings, has the potential to produce significant downwash flow, which will accelerate around the windward corners at the base of the towers. The inclusion of a colonnade or reverse podium on the side walls of such buildings has the potential to induce strong winds through these areas. Despite these local flow accelerations the wind conditions around the Stage 1 buildings would be expected to be suitable for the intended purpose of the spaces. The wind climate is not expected to be strong enough to cause safety issues.

4.1 Building A1

Building A1 is oriented with its broad face towards frequent winds from the north-west, and less frequent but stronger winds from the west. In the opposite direction, winds from the south-east have potential to generate downwash on the broad façade of the tower. In addition, an undercut on both the north and south sides allows downwash to accelerate under the overhang and spill around the building corners, Figure 5. The rounded shape of the tower is beneficial to reduce the amount of downwash. It is expected that the wind conditions near the building corners, especially under the overhang, are suitable for pedestrian accessways, but not for stationary activities.

The floor plans for the Building A1 show the main pedestrian entries to the buildings well located from a wind perspective being away from the corners and inset with the areas affected most by the accelerated flow around the corners not intended for pedestrian use, Figure 6. If calmer wind conditions are desired, additional solid or porous screens could be installed at the northern corner of the tower in due course as indicated in Figure 6.

The plans provided do not foresee any outside seating areas around the A1 tower. The outdoor play areas of the child care centre benefit from the significant drop below ground level from a wind perspective and would be expected to be classified as suitable for parks and recreational areas under the DCP criteria.

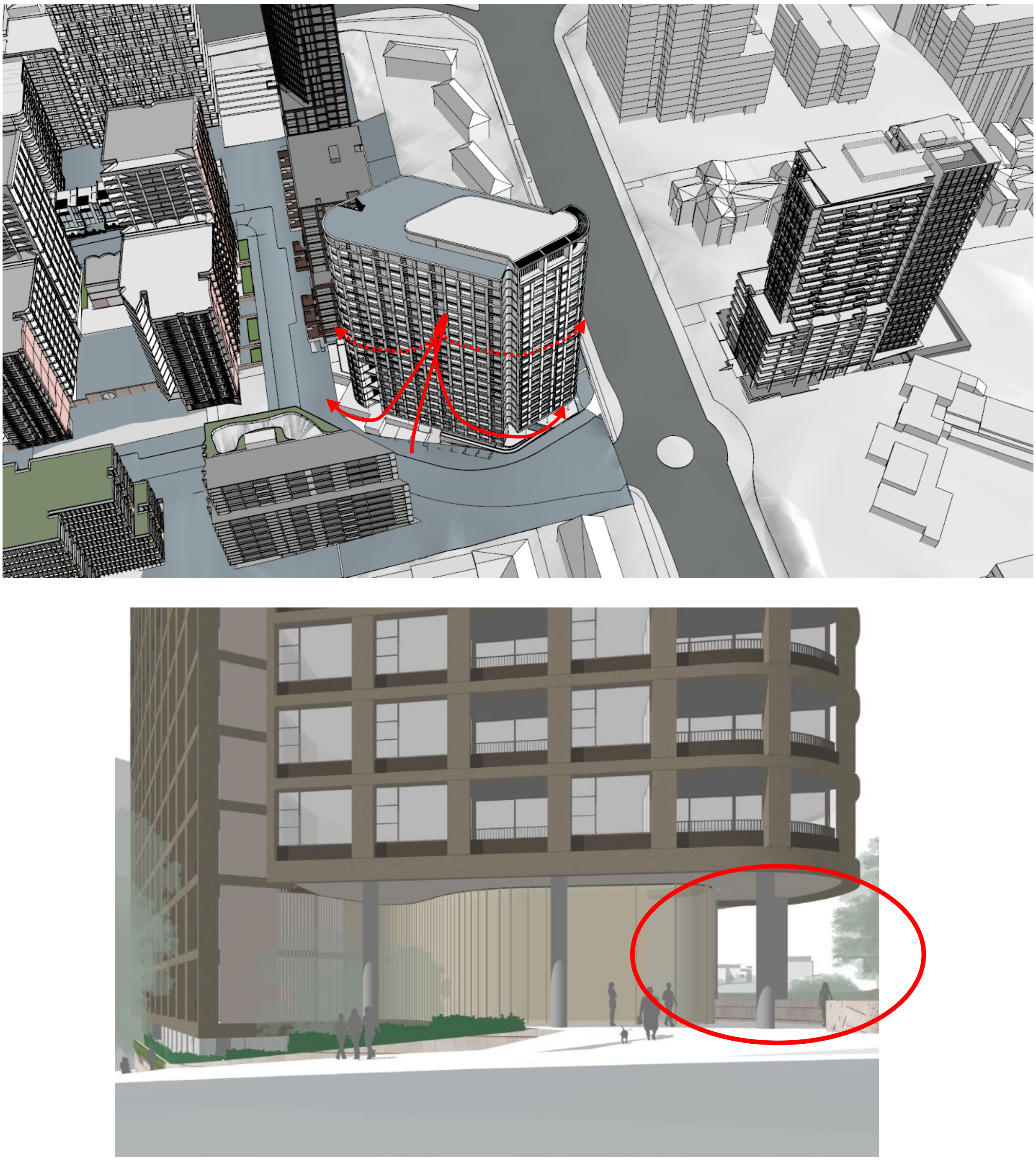


Figure 5: Downwash on the east façade of building A1 (top) and the negative setback area on the northern corner of the building most impacted by accelerated flows (bottom).

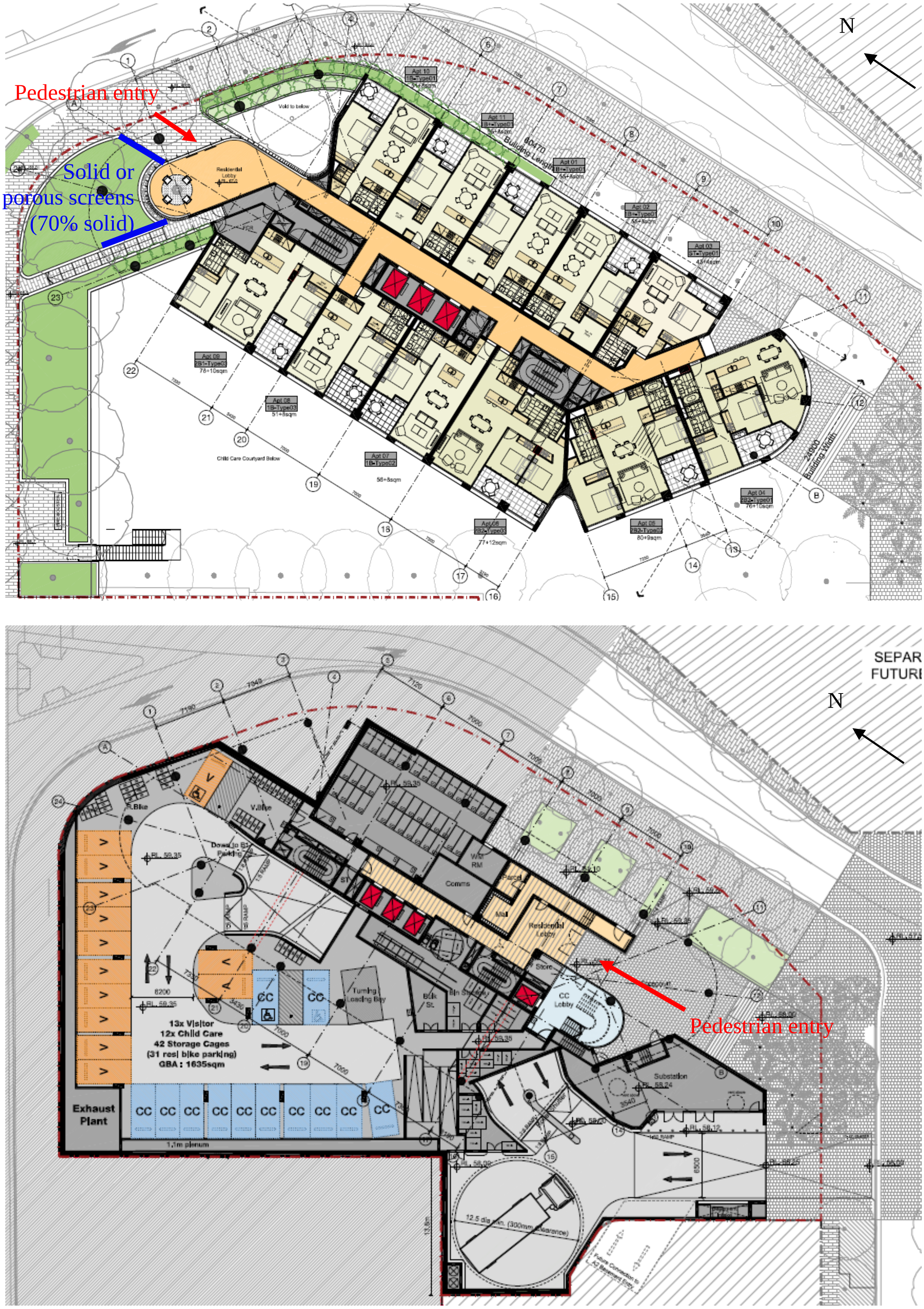


Figure 6: Level 01 (top) and Lower Ground (bottom) floor plan of Building A1.

Balconies of Building A1 are mostly inset which is a good feature from a wind perspective. These balconies would be expected to experience mostly calm wind conditions. The large balconies on Levels 22 and 23 spanning around the building corners are likely subjected to windy conditions particularly for strong winds from the south-east and west quadrants. It would be expected that these balconies fulfil the DCP criterion for private balconies, however if calmer conditions are desired on the corner balconies the addition of solid screens or the partial enclosure of the balcony space, permanent or temporary, could be added on Level 22. The planned height of the balcony balustrade of 1.8 m would provide some protection from strong winds, particularly close to the balustrade. If calmer conditions are desired, an increase of the height of the balustrade would further improve the wind conditions on the rooftop balconies of Level 23 and increase the amount of time the balcony space will be usable by the occupants. It is understood that an awning is planned to span over parts of the rooftop balconies as indicated in blue in Figure 7.

The planned landscaping on the southern end of the rooftop, Figure 7, would likely be subjected to strong winds and would need to be extremely resistant to high wind speeds. A full-height parapet around the perimeter of the rooftop would provide some protection on the rooftop. However, this is not required for pedestrian comfort or safety, as it is understood that this rooftop area is not used as private balcony space and not generally accessible.

Figure 7: Level 23 floor plan of Building A1.

Due to its size and exposed location, the wind environment around Building A1 is not expected to change significantly upon completion of the future stages of the precinct. Additional channelling of winds from the south-east caused by the upstream buildings would be expected along the road to the east of Building A1, which would be expected to still be suitable as a public accessway.

4.2 Building C1

Building C1 is located in the centre of the precinct towards the northern end, Figure 2. Prior to completion of the future buildings foreseen in the masterplan, C1 will be exposed to prevailing winds from the west and south quadrants. C1 consists of two towers, both of which feature a taller portion on the western side (19 storeys) and a shorter one on the eastern side (13 storeys), and a 3 storey building between the towers, Figure 3 and Figure 8. The taller portions of the towers are expected to generate downwash particularly for winds from the south-west and south-east. This would generate windy conditions near the building corners specifically along the south-west façade of the buildings. The shorter portions of the towers would be expected to generate some downwash as well, however of reduced impact due to the lower building height. Most areas around C1 would be expected to be suitable for standing activities with local hotspots with windier conditions particularly near the building corners, which would be expected to meet the criteria for pedestrian accessways.

Main building entrances are located well from a wind perspective, as are most of the individual entrances to the ground level apartments, Figure 9. The entrances of the neighbourhood street facing ground level apartments of the towers on the south-western façade of the building are in an area subjected to accelerated flow for winds from the south-west, highlighted in Figure 9. Local vertical screening would be suggested to improve the wind conditions near these entrances, if calmer conditions are desired. It is expected that the wind conditions in these areas improve upon completion of the future stages, as the downwash winds on the facades of C1 are reduced.

The balconies of the C1 building are mostly inset with corner balconies featuring a solid or porous side wall, which reduces the impact of strong winds around the corners on these balconies and increases the time the balconies will be usable by the occupants.

Upon completion of the future stages of the precinct the C1 building will be surrounded by buildings of similar height on all sides, which would reduce the amount of downwash generated on the façades of the building. Channelling effects on the surrounding roads would be expected due to the regular pattern of the roads, which would be expected to remain usable as pedestrian accessways.

Figure 8: North-east (top) and north-west (bottom) elevation of C1.

Figure 9: Lower Ground (top) and Upper Ground (bottom) floor plans of Building C1

4.3 Summary

In general, wind conditions around the proposed Stage 1 buildings are expected to be suitable for use as a main public accessway. In relation to the DCP criteria, the wind conditions around the precinct are mostly expected to be classified as suitable for pedestrian standing from a comfort perspective with the exception of some localised windier areas which would be classified as suitable for pedestrian walking, and to pass the distress criterion.

Mitigation measures would be required in most areas if comfortable wind conditions for outdoor seating are required, which are not present in the current plans for the Stage 1 buildings. In the absence of tower setbacks, it is expected that horizontal awnings will be required in some locations to help mitigate downwash and wind driven rain. Wind tunnel testing will be conducted to better quantify these conditions and required mitigation within the localised problem areas.

5 CONCLUSION

Cermak Peterka Petersen Pty. Ltd. has provided a qualitative opinion-based assessment of the impact of the proposed Ivanhoe Estate – Stage 1 buildings on the local wind environment in and around the development site.

The proposed development includes buildings that are taller than most surrounding buildings. The environmental wind conditions at ground level around the proposed development are expected to meet the comfort criteria for pedestrian standing and walking and to pass the safety criterion. Viewed in isolation the Stage 1 buildings are exposed to prevailing winds and hence create some downwash which would cause local zones of accelerated flow. The areas of high pedestrian activity are well located away from these hotspots. Upon completion of all future buildings foreseen in the masterplan, the wind conditions around Building C1 would be expected to improve.

All areas around the Stage 1 buildings would be expected to meet the DCP criteria for the intended purpose. Recommendations have been made to improve the wind conditions in some areas, if calmer conditions are desired.

6 REFERENCES

Cermak Peterka Petersen Pty Ltd (CPP) (2018) Wind Assessment for Ivanhoe Estate, CPP11743_Ivanhoe Estate Masterplan_REP_DS_01R02, 18th September 2018.

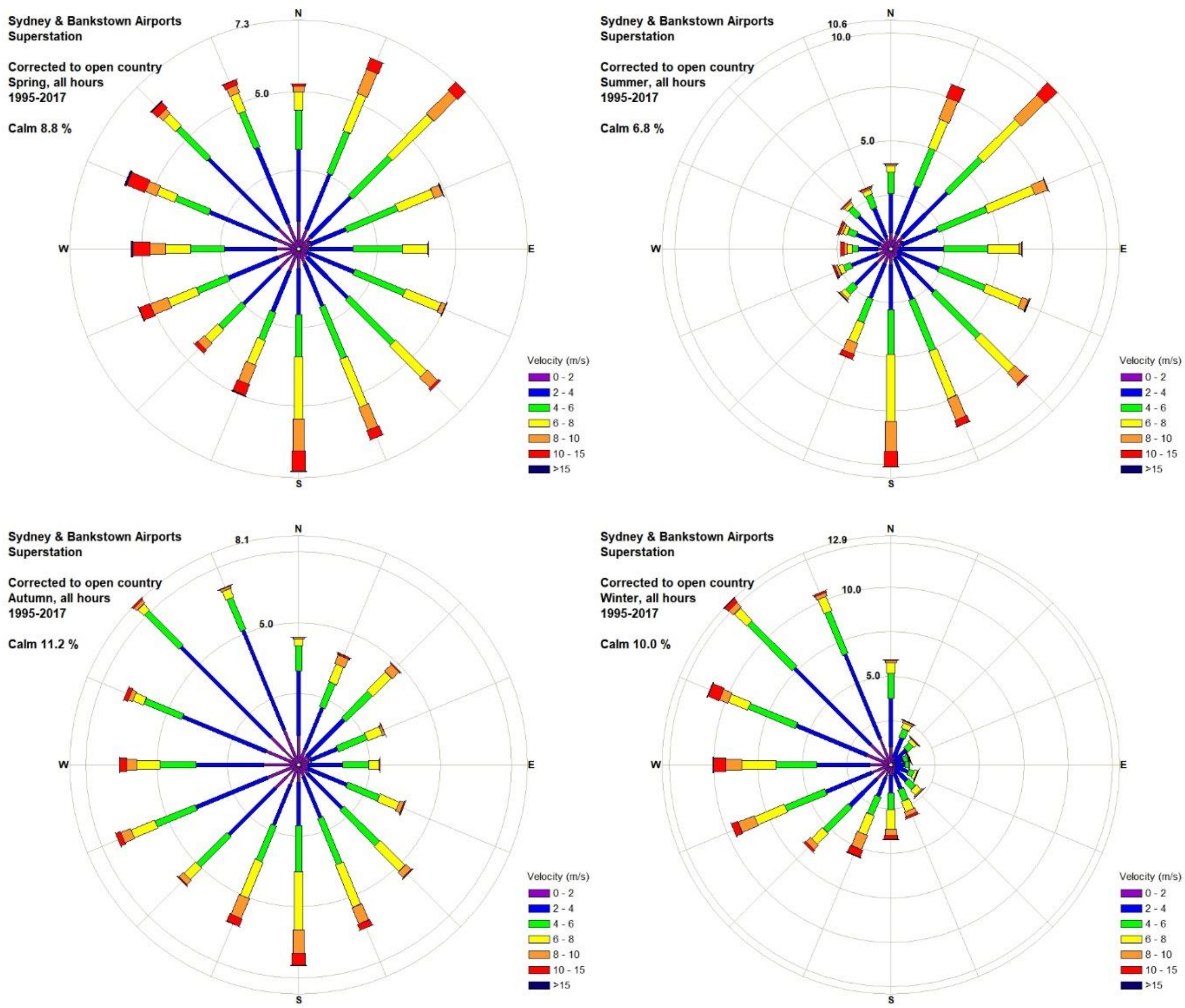
City of Ryde Council (2014) City of Ryde Development Control Plan 2014, Part: 4.5 Macquarie Park Corridor.

Davenport, A.G., (1972), An approach to human comfort criteria for environmental conditions, Colloquium on Building Climatology, Stockholm.

Melbourne, W.H., 1978, Criteria for Environmental Wind Conditions, Journal of Wind Engineering and Industrial Aerodynamics, Vol.3, No.2-3, pp.241-249.

Standards Australia (2011), Australian/New Zealand Standard, Structural Design Actions, Part 2: Wind Actions (AS/NZS1170 Pt.2).

Appendix 1: Wind Climate Analysis – Seasonal



Appendix 2: Wind flow mechanisms

When the wind hits a large isolated building, the wind is accelerated down and around the windward corners, Figure 10; this flow mechanism is called downwash and causes the windiest conditions at ground level on the windward corners and sides of the building. In Figure 10, smoke is being released into the wind flow to allow the wind speed, turbulence, and direction to be visualised. The image on the left shows smoke being released across the windward face, and the image on the right shows smoke being released into the flow at about third height in the centre of the face.

Techniques to mitigate the effects of downwash winds on pedestrians include the provision of horizontal elements, the most effective being a podium to divert the flow away from pavements and building entrances. Awnings along street frontages perform a similar function, and the larger the horizontal element, the more effective it will be in diverting the flow.

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

Figure 11 shows the wind at mid and upper levels on a building being accelerated substantially around the corners of the building. When balconies are located on these corners, they are likely to be breezy, and will be used less by the owner due to the regularity of stronger winds. Owners quickly become familiar with when and how to use their balconies. If the corner balconies are deep enough, articulated, or have regular partition privacy fins, then local calmer conditions can exist.

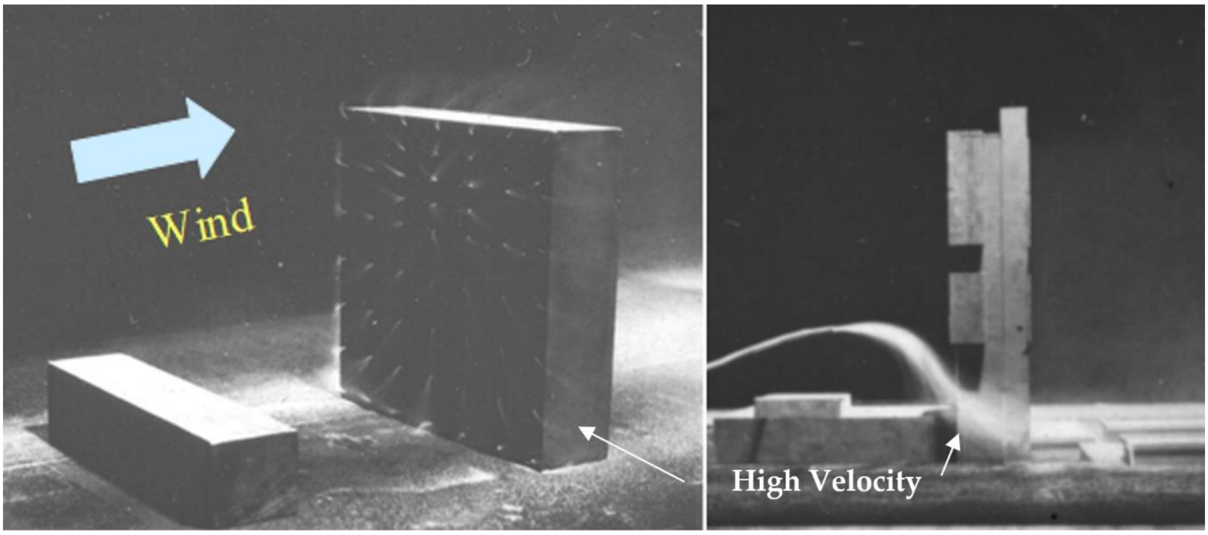


Figure 10: Flow visualisation around a tall building.

Figure 11: Visualisation through corner balconies (L) and channelling between buildings (R).

Appendix 3: Wind Impact Planning Guidelines

It is well known that the design of a building will influence the quality of the ambient wind environment at its base. Below are some suggested wind mitigation strategies that should be adopted into precinct planning guidelines and controls (see also Cochran, 2004).

Building form – Canopies

A large canopy may interrupt the flow as it moves down the windward face of the building. This will protect the entrances and sidewalk area by deflecting the downwash at the second storey level, Figure 12. However, this approach may have the effect of transferring the breezy conditions to the other side of the street. Large canopies are a common feature near the main entrances of large office buildings.

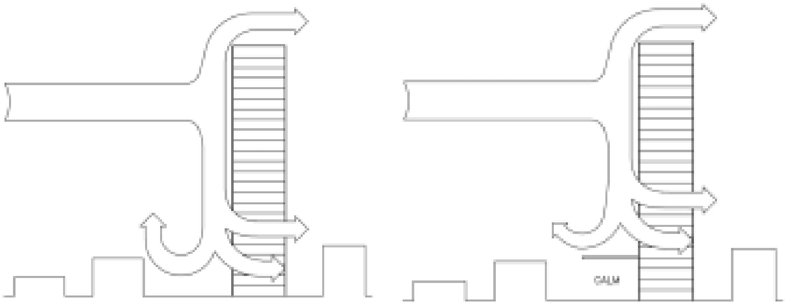


Figure 12: Canopy Windbreak Treatment. (L) Downwash to street level may generate windy conditions for pedestrians. This is particularly true for buildings much taller than the surrounding buildings. (R) A large canopy is a common solution to this pedestrian-wind problem at street level.

Building form – Podiums

The architect may elect to use an extensive podium for the same purpose if there is sufficient land and it complies with the design mandate, Figure 13. This is a common architectural feature for many major projects in recent years, but it may be counterproductive if the architect wishes to use the podium roof for long-term pedestrian activities, such as a pool or tennis court.

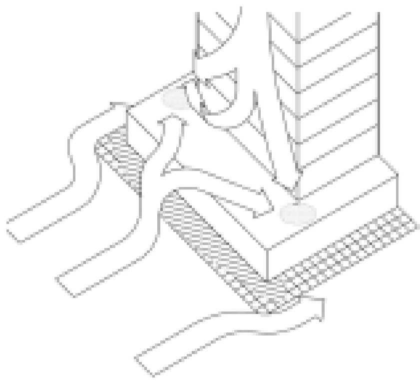


Figure 13: The tower-on-podium massing often results in reasonable conditions at ground level, but the podium may not be useable.

Building form – Arcades

Another massing issue, which may be a cause of strong ground-level winds, is an arcade or thoroughfare opening from one side of the building to the other. This effectively connects a positive pressure region on the windward side with a negative pressure region on the lee side; a strong flow through the opening often results, Figure 14. The uninvitingly windy nature of these open areas is a contributing reason behind the use of arcade airlock entrances (revolving or double sliding doors).

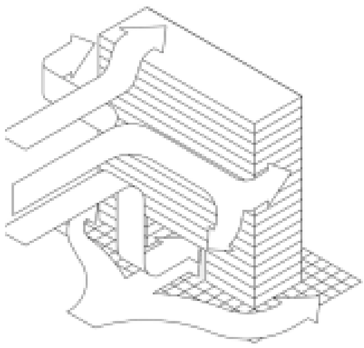


Figure 14: An arcade or open column plaza under a building frequently generates strong pedestrian wind condition.

Building form – Alcove

An entrance alcove behind the building line will generally produce a calmer entrance area at a mid-building location, Figure 15(L). In some cases, a canopy may not be necessary with this scenario, depending on the local geometry and directional wind characteristics. The same undercut design at a building corner is usually quite unsuccessful, Figure 15(R), due to the accelerated flow mechanism described in Figure 10 and the ambient directional wind statistics. If there is a strong directional wind preference, and the corner door is shielded from those common stronger winds, then the corner entrance may work. However, it is more common for a corner entrance to be adversely impacted by this local building geometry. The result can range from simply unpleasant conditions to a frequent inability to open the doors.

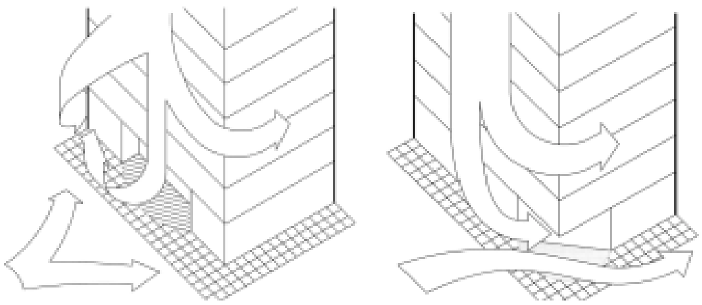


Figure 15: Alcove Windbreak Treatment. (L) A mid-building alcove entrance usually results in an inviting and calm location. (R) Accelerated corner flow from downwash often yields an unpleasant entrance area.

Building form – Façade profile and balconies

The way in which a building's vertical line is broken up may also have an impact. For example, if the floor plans have a decreasing area with increased height the flow down the stepped windward face may be greatly diminished. To a lesser extent the presence of many balconies can have a similar impact on ground level winds, although this is far less certain and more geometry dependent. Apartment designs with many elevated balconies and terrace areas near building ends or corners often attract a windy environment to those locations. Mid-building balconies, on the broad face, are usually a lot calmer, especially if they are recessed. Corner balconies are generally a lot windier and so the owner is likely to be selective about when the balcony is used or endeavours to find a protected portion of the balcony that allows more frequent use, even when the wind is blowing.

Use of canopies, trellises, and high canopy foliage

Downwash Mitigation – As noted earlier, downwash off a tower may be deflected away from ground-level pedestrian areas by large canopies or podium blocks. The downwash then effectively impacts the canopy or podium roof rather than the public areas at the base of the tower, Figure 13. Provided that the podium roof area is not intended for long-term recreational use (e.g. swimming pool or tennis court), this massing method is typically quite successful. However, some large recreational areas may need the wind to be deflected away without blocking the sun (e.g. a pool deck), and so a large canopy is not an option. Downwash deflected over expansive decks like these may often be improved by installing elevated trellis structures or a dense network of trees to create a high, bushy canopy over the long-term recreational areas. Various architecturally acceptable ideas may be explored in the wind tunnel prior to any major financial commitment on the project site.

Horizontally accelerated flows between two tall towers, Figure 11(R), may cause an unpleasant, windy, ground-level pedestrian environment, which could also be locally aggravated by ground topography. Horizontally accelerated flows that create a windy environment are best dealt with by using vertical porous screens or substantial landscaping. Large hedges, bushes or other porous media serve to retard the flow and absorb the energy produced by the wind. A solidity ratio (i.e. proportion of solid area to total area) of about 60-70% has been shown to be most effective in reducing the flow's momentum. These physical changes to the pedestrian areas are most easily evaluated by a model study in a boundary-layer wind tunnel.

References

Cochran L., (2004) Design Features to Change and/or Ameliorate Pedestrian Wind Conditions, Proceedings of the ASCE Structures Congress, Nashville, Tennessee, May 2004.