POWERHOUSE PARRAMATTA
ENVIRONMENTAL IMPACT STATEMENT

APPENDIX W
WIND IMPACT ASSESSMENT

Arup

NSW GOVERNMENT

Infrastructure NSW

Powerhouse Precinct Parramatta

Powerhouse SSDA report – Wind impact assessment

PHM-ARP-REP-WI-0003

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Contents

Disclaimer

This report and subsequent CFD assessment were conducted based on the drawings dated 19th and 20th March 2020 agreed during 2nd March meeting with GTK Consulting. The content for Sections 1-4 is provided by the client.

1 Introduction

This report supports a State Significant Development (SSD) Development Application (DA) for the development of the Powerhouse Parramatta at 34-54 & 30B Phillip Street and 338 Church Street, Parramatta. The Powerhouse Parramatta is a museum (information and education facility) that has a capital investment value in excess of $30 million and as such the DA is submitted to the Minister for Planning pursuant to Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

Infrastructure NSW is the proponent of the DA.

2 Background

The Powerhouse is Australia's contemporary museum for excellence and innovation in applied arts and sciences. The museum was established in 1879 in the Garden Palace which emerged from a history of 19th Century grand exhibition halls, including the Grand Palais. It currently encompasses the Powerhouse in Ultimo, Sydney Observatory in The Rocks, and the Museums Discovery Centre in Castle Hill. The Powerhouse has occupied the Ultimo site since 1988.

Parramatta, in the heart of Western Sydney, is entering a period of rapid growth. It was identified in 2014's *A Plan for Growing Sydney* as the metropolis' emerging second Central Business District, with the provision of supporting social and cultural infrastructure regarded as integral to its success. The strategic importance of Parramatta as an economic and social capital for Sydney has been subsequently reinforced and further emphasised through its designation as the metropolitan centre of the Central City under the *Greater Sydney Region Plan*.

Powerhouse Parramatta will be the first State cultural institution to be located in Western Sydney – the geographical heart of Sydney. In December 2019, the Government announced the winning design, by Moreau Kusunoki and Genton, for the Powerhouse Parramatta from an international design competition.

Powerhouse Parramatta will establish a new paradigm for museums through the creation of an institution that is innately flexible. It will become a national and international destination renowned for its distinctive programs driven by original research and inspired by its expansive collections. It will be a place of collaboration, a mirror of its communities forever embedded in the contemporary identity of Greater Sydney and NSW.

3 Site Description

The site is located at the northern edge of the Parramatta CBD on the southern bank of the Parramatta River. It occupies an area of approximately 2.5 hectares and has extensive frontages to Phillip Street, Wilde Avenue, and the Parramatta River. A small portion of the site extends along the foreshore of the Parramatta River to the west, close to the Lennox Street Bridge on Church Street. The site boundary is identified in Figure 1. The site excludes the GE Office Building at 32 Phillip Street.

The site is currently occupied by a number of buildings and structures, Figure 2, including:

- Riverbank Car Park – a four-level public car park
- Willow Grove – a two-storey villa of Victorian Italianate style constructed in the 1870s
- St George's Terrace – a two-storey terrace of seven houses fronting Phillip Street constructed in the 1880s
- 36 Phillip Street – a two-storey building comprising retail and business premises
- 40 Phillip Street – a two-storey building comprising retail and business premises
- 42 Phillip Street – a substation building set back from the street

The immediate context of the site comprises a range of land uses including office premises, retail premises, hotel, serviced apartments, and residential apartments. To the north is the Parramatta River and open space corridor, beyond which are predominately residential uses. The Riverside Theatre is located to the north-west across the Parramatta River.

Figure 1- Aerial photograph of the site and its context
Source: Mark Merton Photography

Figure 2 - Site boundary, key existing features, and immediate local context
Source: Ethos Urban

4 Overview of Proposed Development

The Powerhouse was established in 1879, and Powerhouse Parramatta will radically return to its origins through the creation of seven presentation spaces of extraordinary scale that will enable the delivery of an ambitious, constantly changing program that provides new levels of access to Powerhouse Collection. The Powerhouse will set a new international benchmark in experiential learning through the creation of an immensely scaled 360-degree digital space, unique to Australia.

Powerhouse Parramatta will reflect the communities and cultures of one of Australia's fastest growing regions. It will hold First Nations culture at its core and set a new national benchmark in culturally diverse programming. The Powerhouse will be highly connected through multiple transport links, and integrate into the fine grain of the city.

Powerhouse Parramatta will be an active working precinct and include the Powerlab, which will enable researchers, scientists, artists and students from across regional NSW, Australia and around the world to collaborate and participate in Powerhouse programs. The Powerlab will feature digital studios to support music and screen industries alongside co-working spaces, life-long learning and community spaces. Integrated into the Powerlab will be a research kitchen and library that will support a NSW industry development program including archives and oral histories.

This application will deliver an iconic cultural institution for Parramatta in the heart of Sydney's Central City. The SSD DA seeks consent for the delivery of the Powerhouse Parramatta as a single stage, comprising:

- site preparation works, including the termination or relocation of site services and infrastructure, tree removal and the erection of site protection hoardings and fencing;
- demolition of existing buildings including the existing Riverbank Car Park, 'Willow Grove', 'St. George's Terrace' and all other existing structures located on the site;
- construction of the Powerhouse Parramatta, including:
    - seven major public presentation spaces for the exhibition of Powerhouse Collection;
    - front and back-of-house spaces;
    - studio, co-working and collaboration spaces comprising the 'Powerlab', supported by 40 residences (serviced apartments) for scientists, researchers, students and artists, and 60 dormitory beds for school students;
    - education and community spaces for staff, researchers and the Powerlab residents, the community, and education and commercial hirers;
    - commercial kitchen comprising the 'Powerlab Kitchen' used for cultural food programs, research, education, and events
    - film, photography, and postproduction studios that will connect communities with industry and content that will interpret the Powerhouse Collection;
    - public facing research library and archive for community, industry, students and researchers to access materials; and
    - a mix of retail spaces including food and drink tenancies with outdoor dining.
- operation and use of the Powerhouse Parramatta including use of the public domain provided on the site to support programs and functions;
- maintenance of the existing vehicular access easement via Dirrabarri Lane, the removal of Oyster Lane and termination of George Khattar Lane, and the provision of a new vehicular access point to Wilde Avenue for loading;
- public domain within the site including new public open space areas, landscaping and tree planting across the site; and
- building identification signage.

The project does not seek consent for the carrying out of works outside of the site boundary, and in particular does not involve any alterations to the existing edge of the formed concrete edge of the Parramatta River or to the waterway itself.

5 Assessment Requirements

The Department of Planning, Industry, and Environment have issued Secretary's Environmental Assessment Requirements (SEARs) to the applicant for the preparation of an Environmental Impact Statement for the proposed development. This report has been prepared having regard to the SEARs as follows:

SEAR	Where Addressed
9. Environmental Amenity The EIS shall: • include a wind impact assessment, including wind tunnel testing, to demonstrate that the wind environment in the public domain will be comfortable for its intended use.	*Sections 6 and 7*

6 Wind environment review

6.1 Local wind conditions

The wind frequency and direction information measured by the Bureau of Meteorology anemometer at a standard height of 10 m at Bankstown Airport has been used in this analysis, Figure 3. This is the closest reliable anemometer to the site. The arms of the wind rose point in the direction from where the wind is coming from. The station is located about 12 km to the south of the site. The site and Bankstown Airport anemometer station are located at the same distance from the coast to the east, and the mountains to the west and is therefore considered to be representative of the wind conditions at the site.

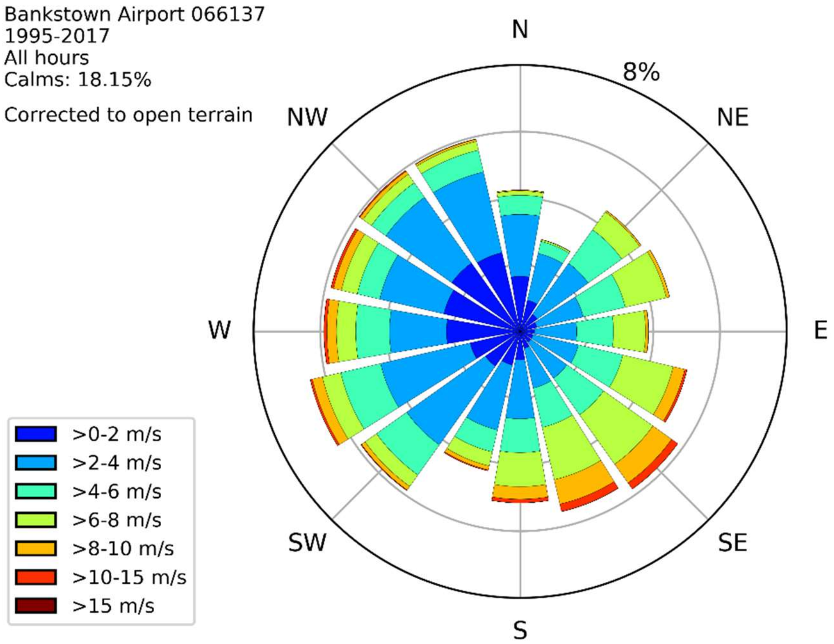

Figure 3 - Wind rose showing probability of time of wind direction and speed

It is evident from Figure 3 that prevailing strong winds are organised into two main groups which centre at about the south-east and west quadrants. The CFD simulations were conducted for 16 wind directions and integrated with the wind climate.

6.2 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 C. The current wind criteria in the City of Parramatta Council DCP 2011are:

'To ensure public safety and comfort the following maximum wind criteria are to be met by new buildings:

- 10 m/s in retail streets
- 13 m/s along major pedestrian streets, parks and public places
- 16 m/s in all other streets'

These wind criteria do not include the duration of the wind event, nor the probability of time that they occur. These are considered to be based on the work of Melbourne (1978), which represent a peak 3 s gust event occurring in an hour, for 0.1% of time from any wind direction. The applicable 13 m/s limit for this site, is a comfort criterion appropriate for pedestrian standing activities. With reference to the wind rose in Figure 3, there are few exposed locations in Parramatta that would meet this criterion without additional shielding to improve the wind conditions. This wind speed criterion is used as an estimator of the general wind conditions at a site, which may be more relevant.

To combat this limitation, as well as the once per annum gust wind speed, the wind controls used in this wind assessment are based on the work of Lawson (1990) as described in Appendix C 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 wind climate to the site location, the mean wind speed exceeded 5% of the time would be approximately 4 m/s at pedestrian level. With reference to Table 1, this wind speed is on the boundary of pedestrian sitting and standing 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)

7 CFD assessment

7.1 Modelling

The numerical CFD simulations were conducted for the proposed Powerhouse Museum using steady-state Reynolds-Averaged Navier-Stokes (RANS) method. The urban context including surrounding buildings within a radius of 500 m around the site was explicitly modelled, Figure 4. Topography surrounding the site is included in the model. The context is placed in a much larger domain based on best practice guideline for the CFD simulation of flows in urban environment. The relevant dimensions of the domain in meter are given in Figure 4T.

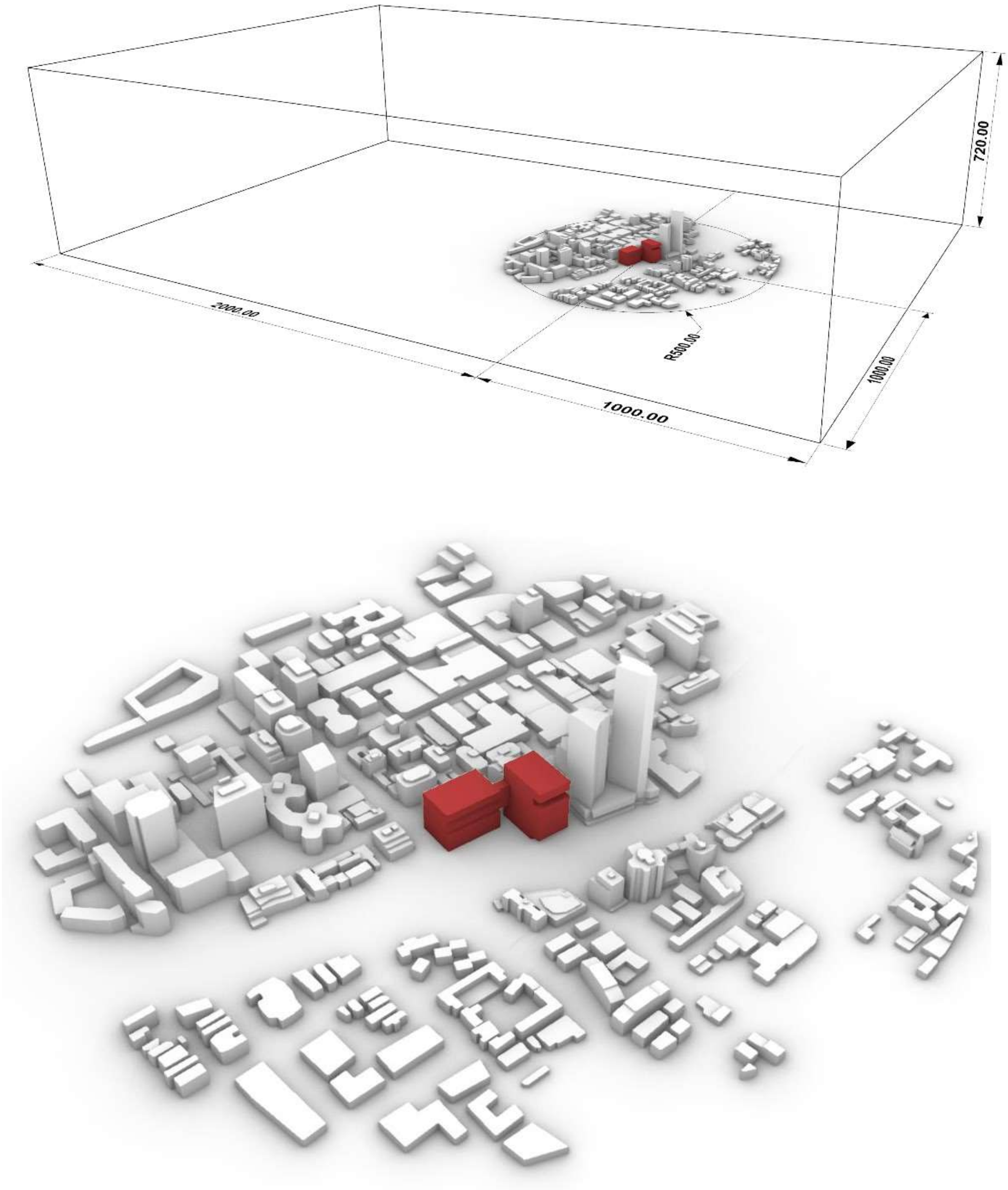

Figure 4. 3d model of Powerhouse Museum and surrounding urban context from north-east (T), and close-up view from north-east (L), and from north-west (R) (cont.)

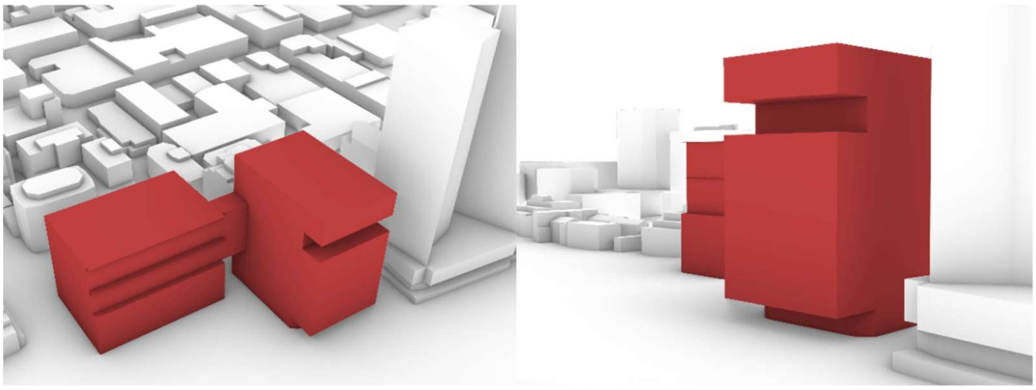

Figure 4. 3d model of Powerhouse Museum and surrounding urban context from north-east (T), and close-up view from north-east (L), and from north-west (R)

A computational mesh was constructed comprising of approximately 10.5 million tetrahedral and prism elements, Figure 5. The grid resolution is finest around the proposed building where greater resolution is required. The computational mesh size increases with distance from the regions of most interest. Other mesh sizing controls including varying the level of mesh refinement were used to more accurately capture the effects of important surrounding buildings from an aerodynamic perspective. Mesh sensitivity study was conducted to reduce the effect of mesh size on the solution.

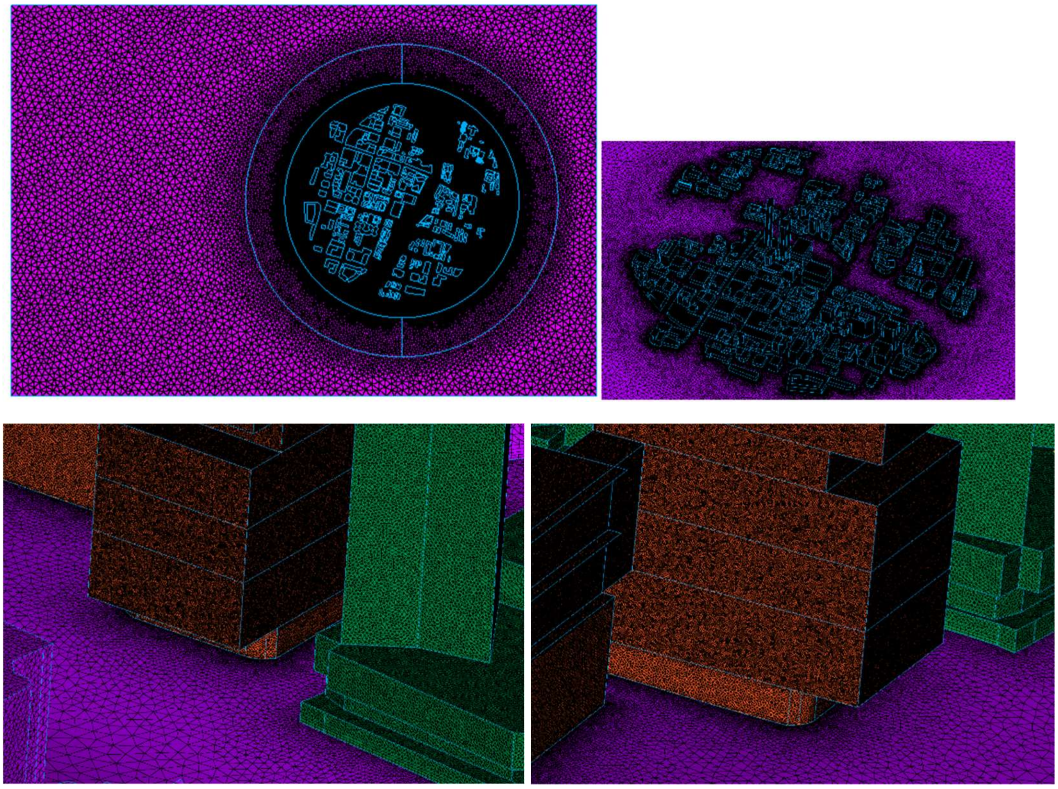

Figure 5. Mesh strategy and grid resolution

The effect of terrain outside the 1 km diameter urban context was implicitly modelled using rough wall functions reproducing the roughness characteristics corresponding to suburban, Terrain Category 3 (TC3) as defined in Standards Australia (2011). The wind speed and turbulence profiles corresponding to TC3 were employed at the inlet boundary. Simulations were conducted for 16 wind directions at 22.5° increments.

The CFD setup followed the best practices and guidelines for simulating flow in urban environments (Franke, 2011). Probes at different locations around the site and parameter residuals were used to monitor the convergence of the results and ensure the solution reached a steady state solution.

7.2 Discussion of results

7.2.1 Wind conditions on ground level

Contour maps of wind speed ratio at pedestrian level at pedestrian height of 1.5 m above the local ground level for 16 wind directions are presented in Appendix A. The extension of the assessed area around the site is aligned with guidelines for pedestrian wind effects criteria, AWES (2014). The wind speeds are integrated with historical local wind climate data presented in Section 6.1. To measure the effect of turbulent wind conditions on pedestrians, Gust Equivalent Mean (GEM) is calculated based on measured turbulent kinetic energy. Considering isotropic turbulence, standard deviation of wind speed would can be calculated using:

$$\sigma = (2/3k)^{0.5}$$

where k is turbulent kinetic energy. Using mean wind speed and standard deviation, GEM can be determined based the equation in Appendix C. The maximum of GEM and mean wind speed is statistically analysed to provide the site safety, and comfort classification based on 0.022% and 5% of the time exceedance respectively in accordance with the Lawson wind criteria. Contour maps showing the directionally integrated safety and comfort classifications are presented in Figure 6 and Figure 7 respectively.

It is evident from Figure 6 that the wind speed exceeding 0.022% of time is comparable around the site between the existing and proposed design. The measured wind speed at all areas around the site for the proposed design is below the mean wind speed Lawson safety criterion level of 15 m/s. Hence all locations pass the safety criterion.

In the proposed design, the fastest wind speed exceeding 0.022% time is about 12.4 m/s, below the undercroft (retail terrace on ground floor) around the north-west corner of the Powerhouse west building. This is comparable with the fastest wind speed of 11.8 m/s in the existing condition which occurs to the south-west corner of the carpark, where the gap between the carpark and the high-ruse building is narrowest. This similarity of highest wind speeds suggests that the common major feature in both scenarios, the high-rise buildings to the immediate west at 330 Church Street is primarily generating the fastest wind speed around the site.

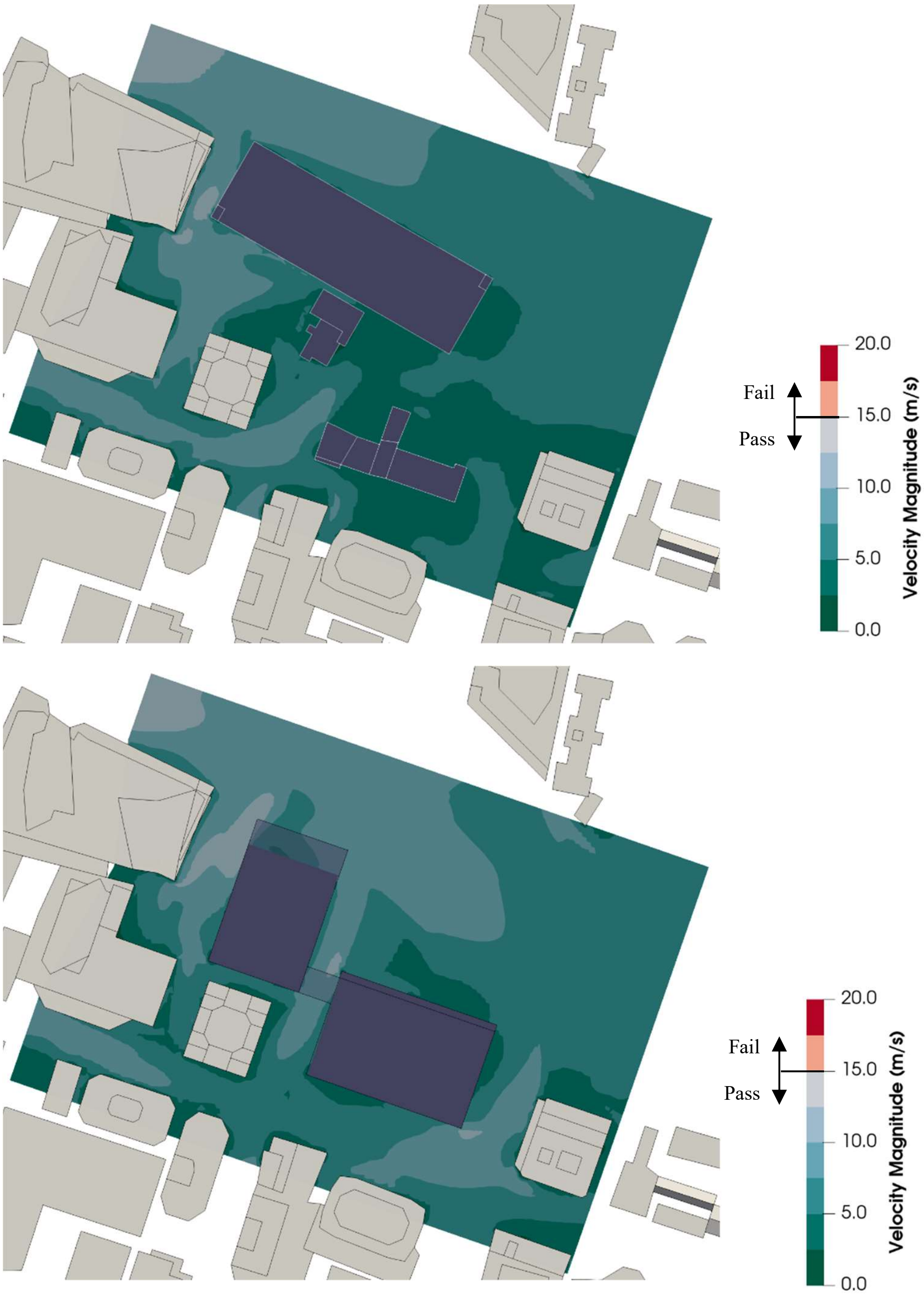

Figure 6. Classification of wind safety at 1.5 m above local ground level for the existing condition (T) and proposed design (B).

Figure 7 shows the contour map of wind classification based on Lawson comfort criteria as described in Table 1. In general, the classification of wind conditions does not change around the proposed development compared with the existing conditions. It is evident from Figure 7B that the majority of locations around the proposed development would be classified as suitable for pedestrian sitting. The areas around the north corners of the proposed west building, below the connecting bridge between the proposed buildings, and to the south-east of the proposed east building would be classified as suitable for pedestrian standing type activities.

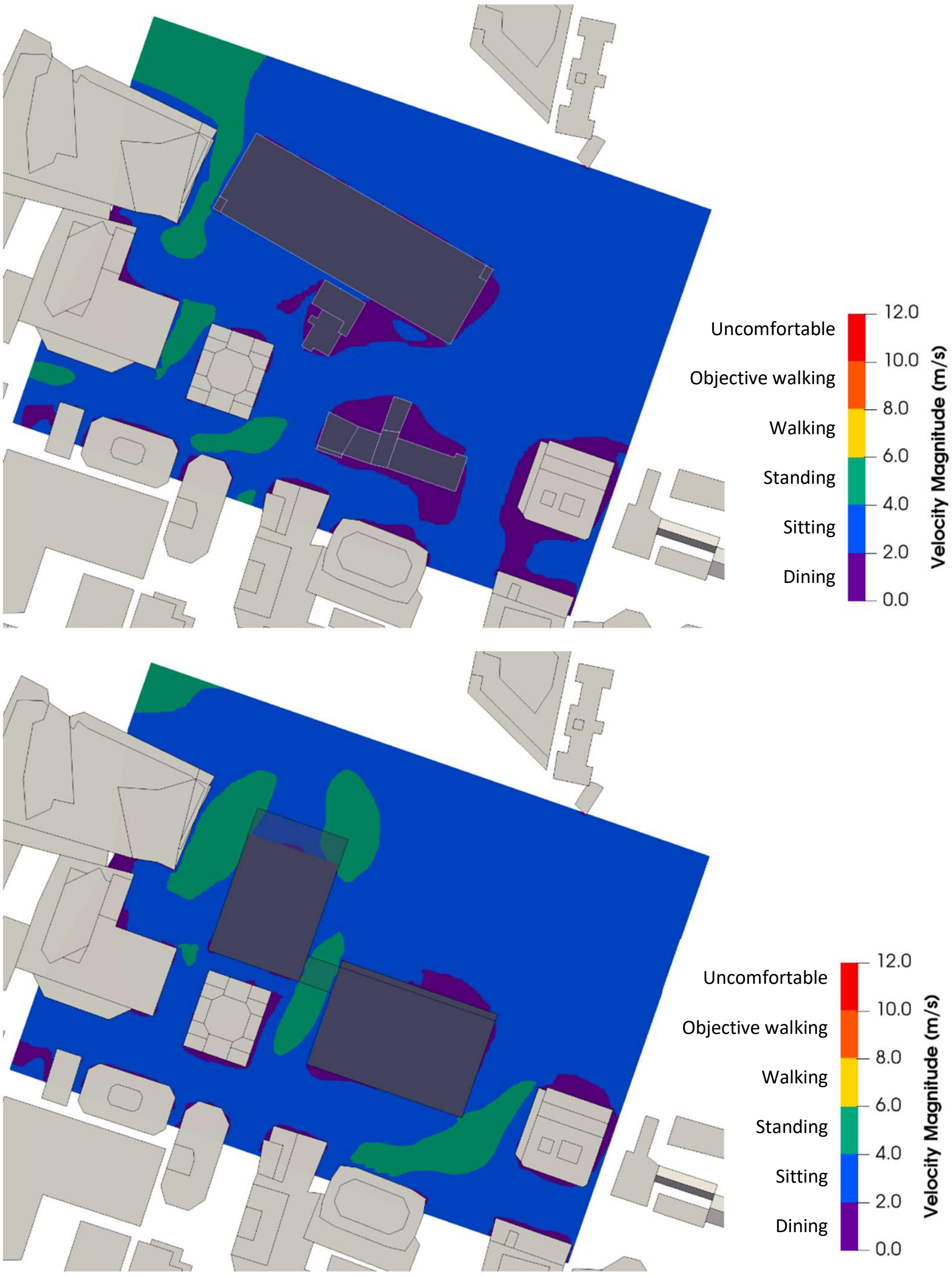

Figure 7. Classification of wind comfort at 1.5 m above local ground level for the existing condition (T) and proposed design (B).

The high wind speeds around the north corners of the west tower and below undercroft are mainly created by downwash flow from the proposed development and the high-rise building at 330 Church Street accelerating around the corners. The high winds speeds under the bridge between the Powerhouse buildings is mainly pressure-driven and occurs for most of wind directions; as can be seen from the directional results in Appendix A. The high wind speeds on the south-east corner are the result of downwash and horizontal flow depending on the wind direction.

The measured fastest wind speed of 5.7 m/s for 5% of time was experienced under the bridge connecting the two proposed buildings. This is similar in magnitude to the fastest wind speed of 5.4 m/s for the existing design. The orientation of the building and the back pressure generated by the high-rise buildings at 330 Church Street are beneficial in improving wind conditions for the prevalent winds from the south-east as can be seen in Appendix A for wind direction of 135º.

7.2.2 Summary

Arup have provided a quantitative assessment of the impact of the proposed development on pedestrian wind comfort and safety in and around the site using Computation Fluid Dynamics (CFD) integrated with a local wind climate statistical analysis from Bankstown Airport.

The proposed development and surrounding building within the radius of 500 m around the site were explicitly modelled, meshed and solved for 16 wind directions at 22.5° increments. A mesh sensitivity study was conducted to minimize the effect of cell size on the final result. Inlet boundary condition were modelled to a wind profile corresponding to Terrain Category 3 in Standards Australia (2011) and an appropriate atmospheric rough wall function is applied. The CFD results were integrated with historic wind climate data to obtain classification of the area with respect to Lawson pedestrian safety and comfort criteria.

The results show that all location in and around the proposed Powerhouse museum would pass the safety criterion. The simulated wind conditions show the majority of locations in the vicinity of the site are classified as suitable for sitting type activities. Some areas to the north corners of the proposed west building, below the undercroft (retail terrace on the ground floor), between the two proposed buildings, and around the south-east corner of the east building are classified as suitable for pedestrian standing type activities. Downwash from the compound shape of the proposed development and the high-rise buildings to the immediate west accelerating around the corners are main flow mechanism causing stronger wind conditions. Pressure-driven flow is the primary mechanism for the windy conditions in the gaps in between the proposed buildings and between the high-rise building to the west and the Powerhouse.

The wind comfort and safety conditions around the site are considered suitable for the intended use of these spaces.

8 Conclusion

Arup have been commissioned by Infrastructure NSW to provide a quantitative assessment of the proposed Powerhouse Precinct Parramatta on the pedestrian level wind conditions for comfort and safety in and around the site.

Arup have quantified the wind conditions through numerical modelling using Computation Fluid Dynamics (CFD) and subsequent integration with the local wind climate analysis. Based on the results, all locations around the proposed Powerhouse Precinct Parramatta would pass the safety criterion. The majority of locations in the vicinity of the site at ground level are classified as suitable for sitting type activities with some regions below the undercroft region (retail terrace on the ground floor) and around the corners, between the two proposed building and below the connecting bridge, and the south-east corner fall into standing criterion.

In general, the additional massing changes the flow pattern around the site, resulting in some locations becoming windier, and others calmer depending on the incident wind direction. The general, the maximum comfort and safety classification of wind would not change around the proposed development compared with the existing condition. It is considered that the wind conditions generated by the general massing of the development would produce an environment suitable for the intended use of the space around the precinct.

9 Potential Mitigation Measures

To improve the wind conditions around the windy areas, a few potential wind mitigation measures could be utilised and developed during detailed design stage when the external geometry is fixed. These measures may include:

1. Placing vertical screens or landscape elements around the corners of the undercroft (retail terrace on the ground floor). It would be recommended that these elements wrap around the corners and are attached to the building. It is expected that using this strategy wind conditions in undercroft regions would be suitable for sitting type activities.
2. Employing a vertical downstand at the entrances to the connecting bridge to minimize the open area. This would locally increase the wind speed under downstand, but improve the wind conditions away from the downstands. This amelioration would be recommended if the areas close to the bridge are intended to be activated for sitting type activities.
3. Utilizing landscape elements or tree planting within the public domain to mitigate wind conditions within these areas.

10 References

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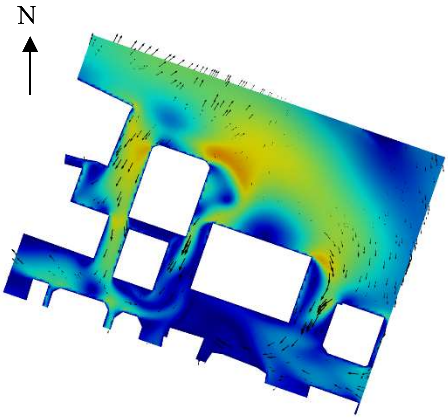
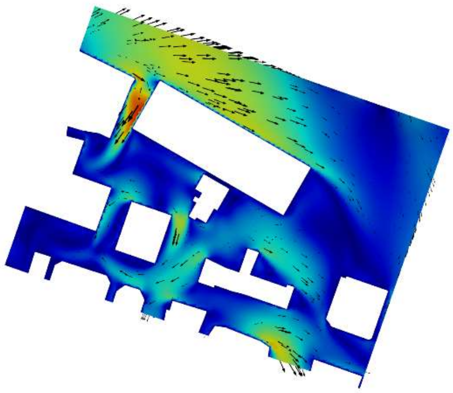
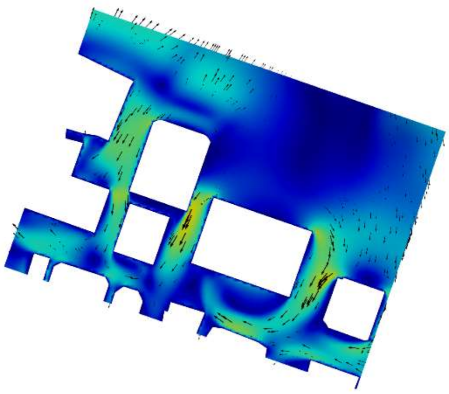
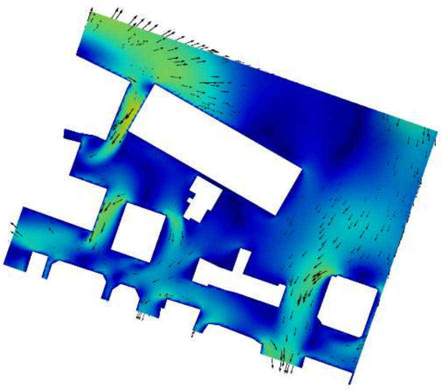
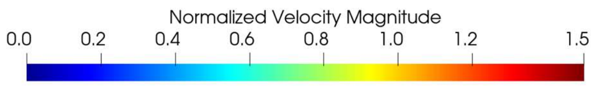
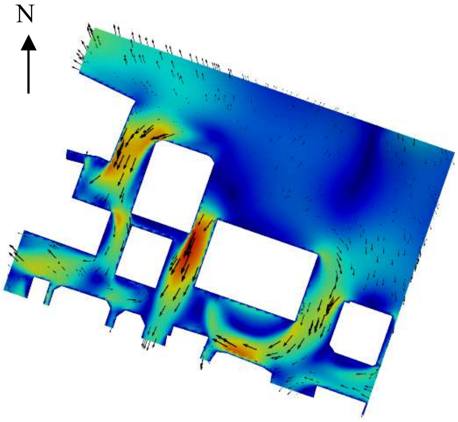
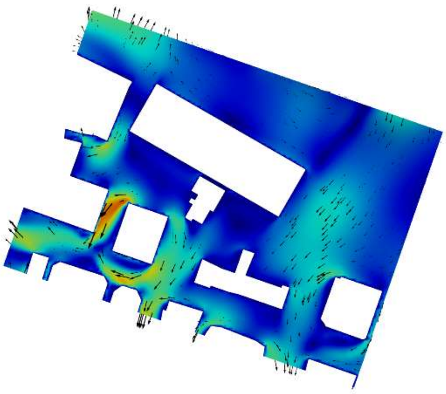
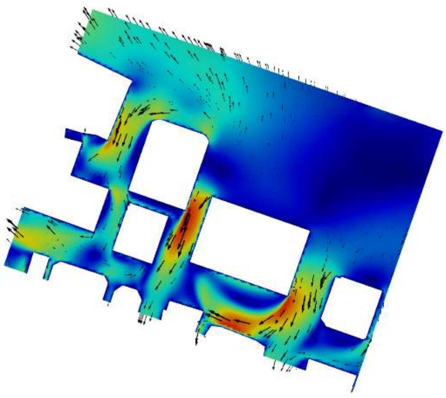
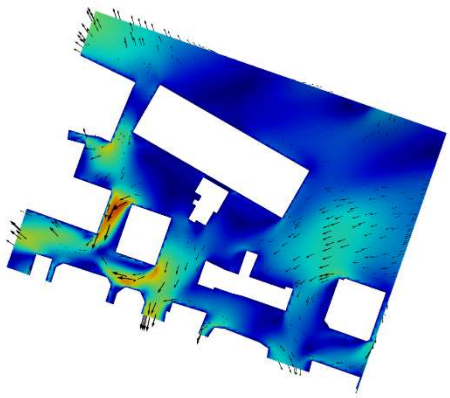
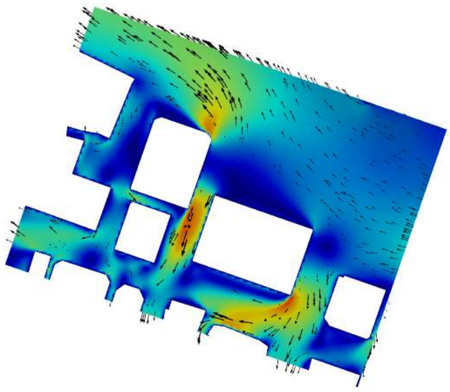
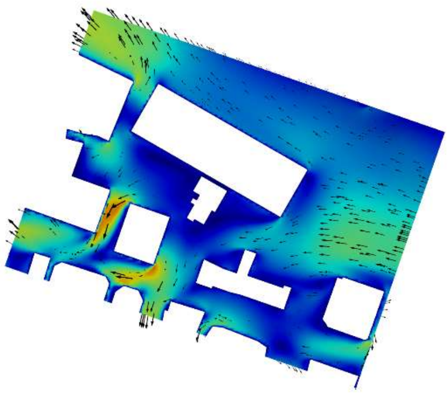
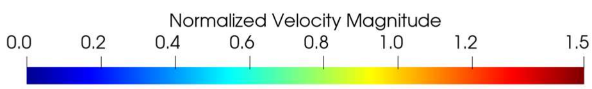
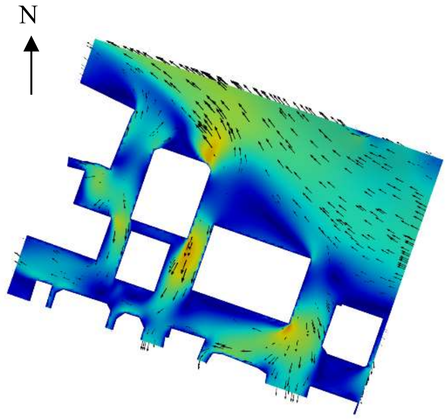
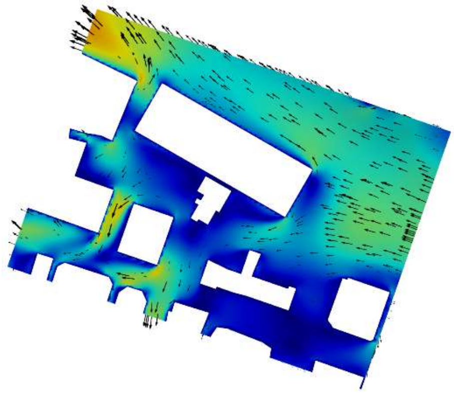
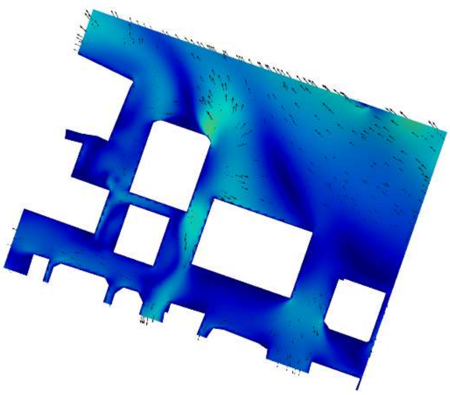
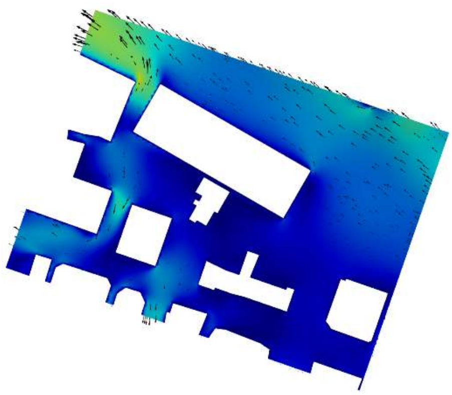
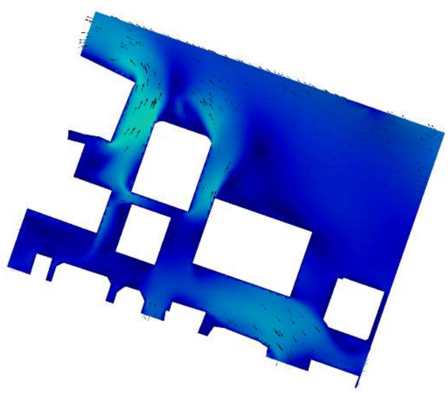
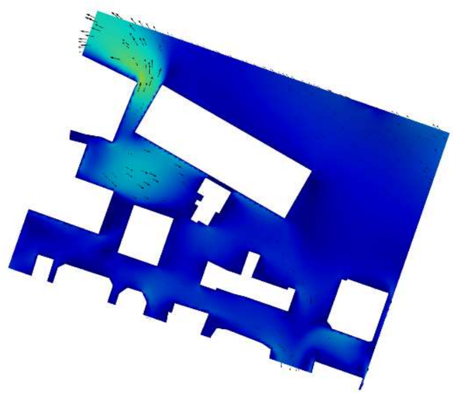
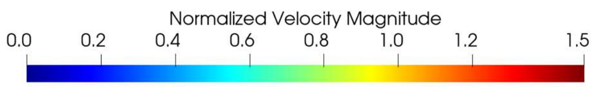
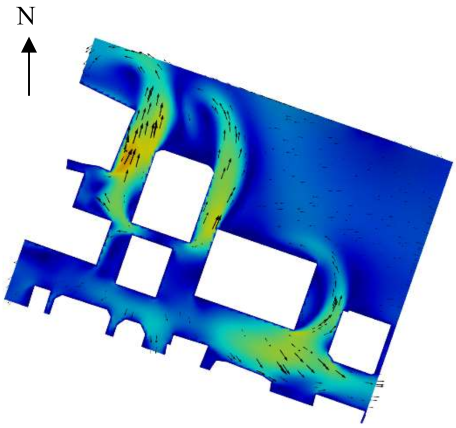
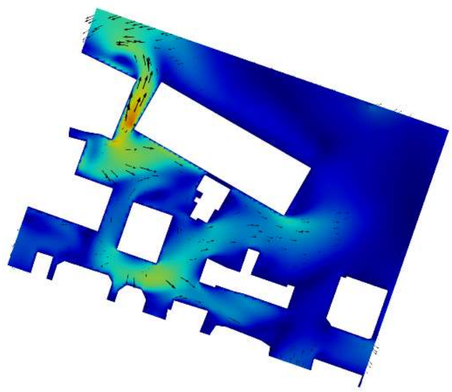
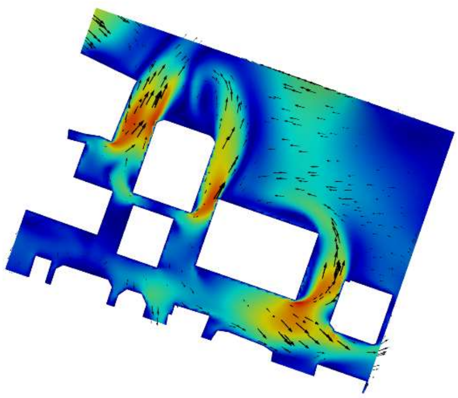
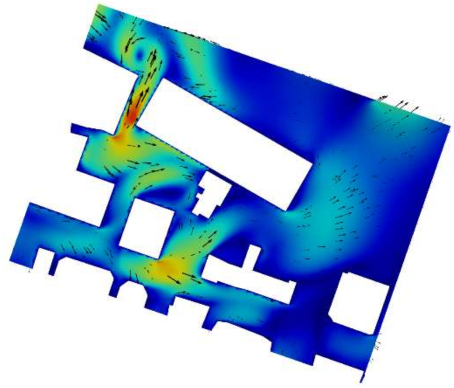
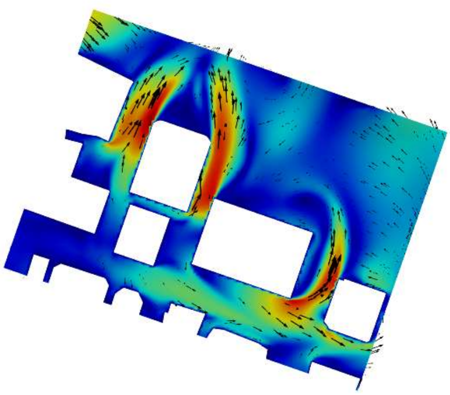
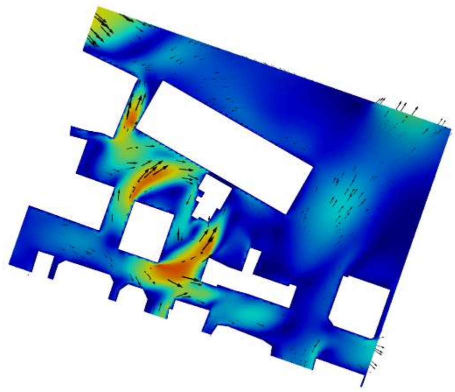
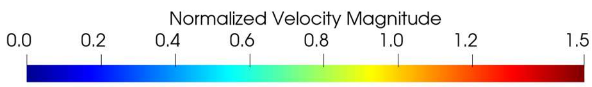
Appendix A: Wind condition on pedestrian level

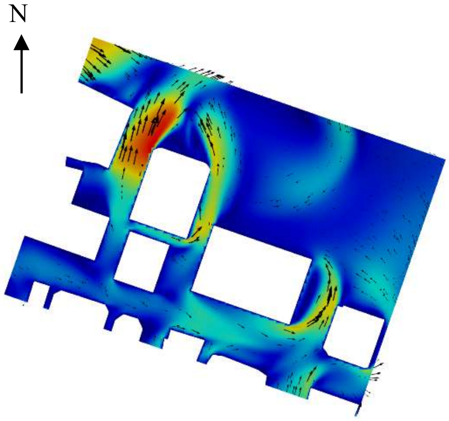
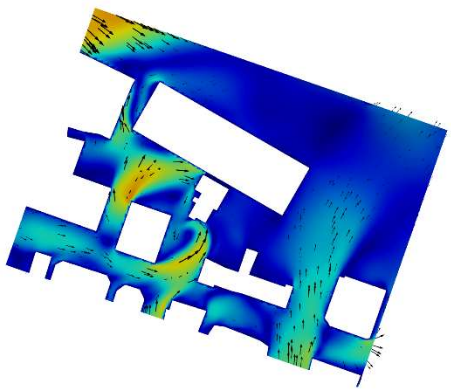
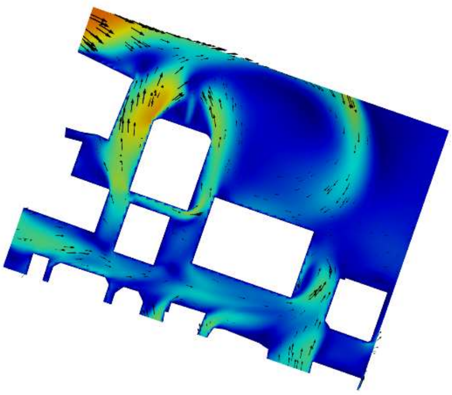
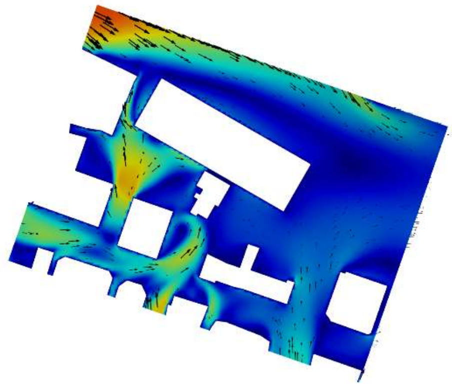
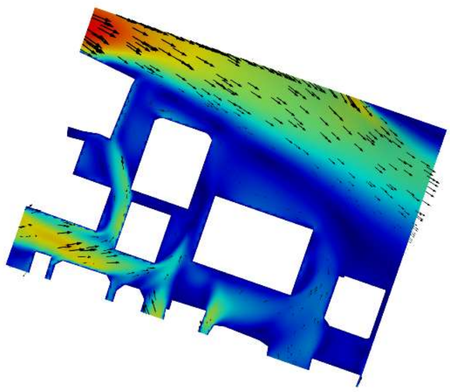
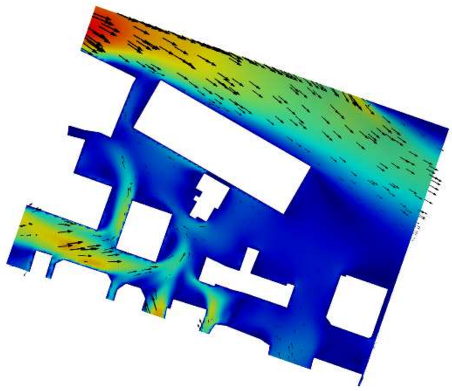
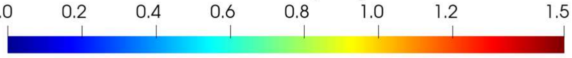
The coloured contour map of mean wind speed ratio 1.5 m above the ground for different wind directions are presented below. The wind speed ratio is calculated as the local wind speed to the reference undisturbed mean wind speed of 4 m/s at 10 m in suburbia region (TC3). These directional CFD results were integrated with local wind climate data to provide wind speeds occurring 0.022% and 5% of time per annum from all directions for safety (Figure 6) and comfort (Figure 7) respectively.

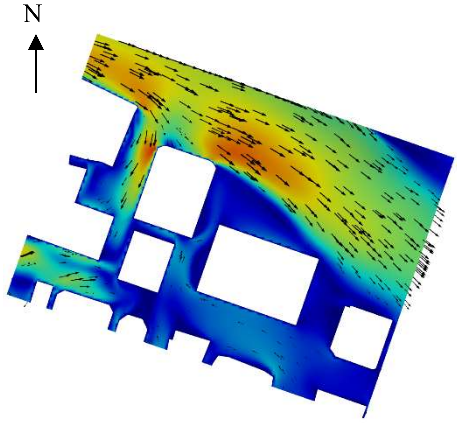
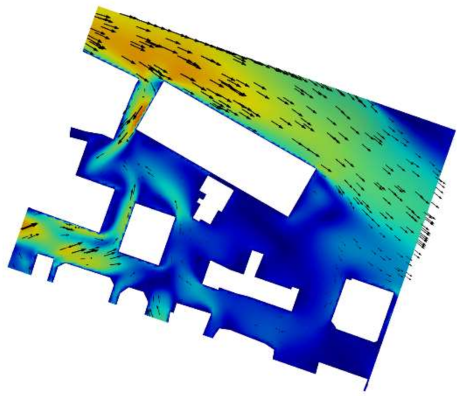
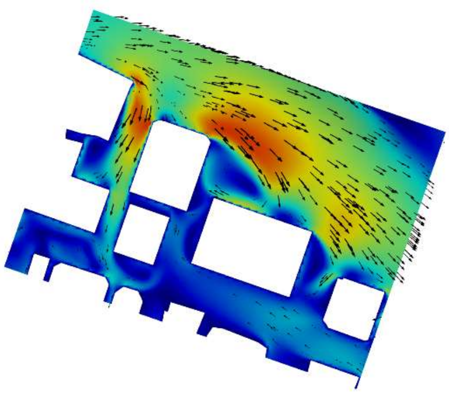
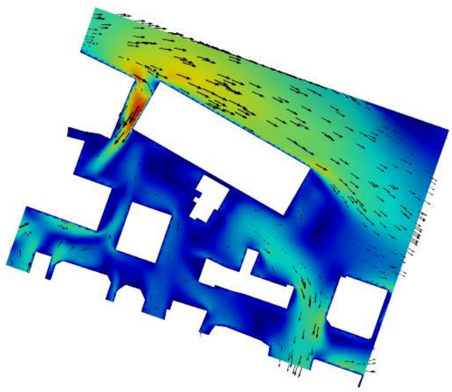
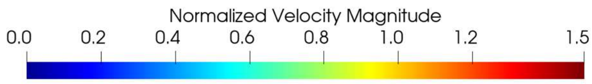
Wind direction	Proposed	Existing
0º ↓		
22.5º ↙		
		

Wind direction	**Proposed**	**Existing**
45°		
67.5°		
90°		
		

Wind direction	Proposed	Existing
112.5º		
135º		
157.5º		
		

Wind direction	Proposed	Existing
180º		
202.5º		
225º		
		

Wind direction	Proposed	Existing
247.5º		
270º		
292.5º		
		

Wind direction	Proposed	Existing
315º		
337.5º		
		

Appendix B: 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 8, 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 8. 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.

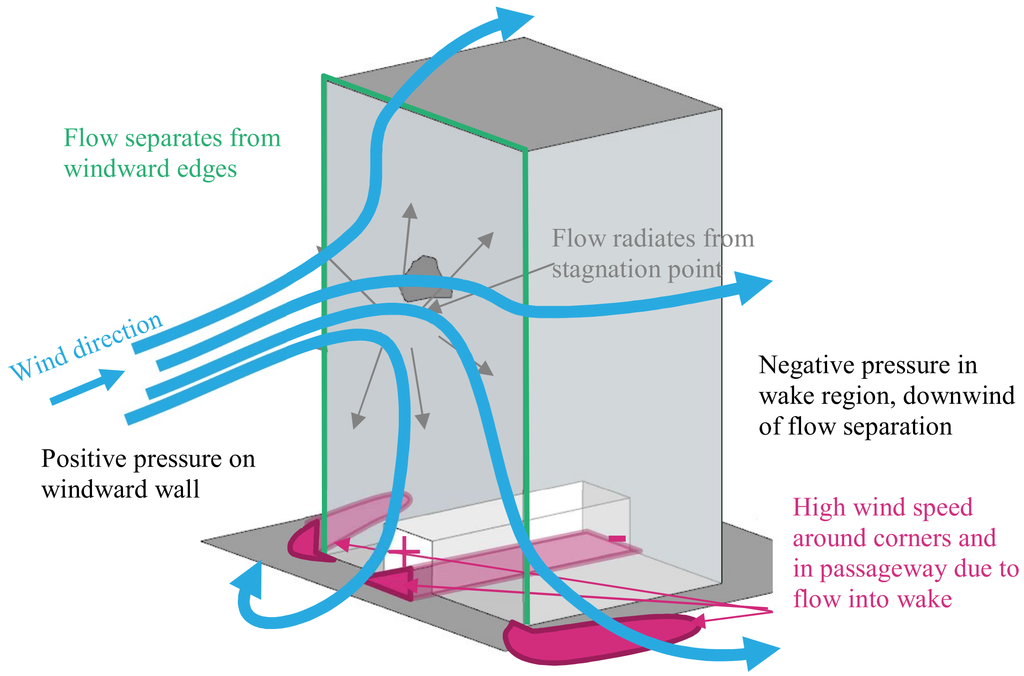


Figure 8 Schematic wind flow around tall isolated building

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 9. 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.

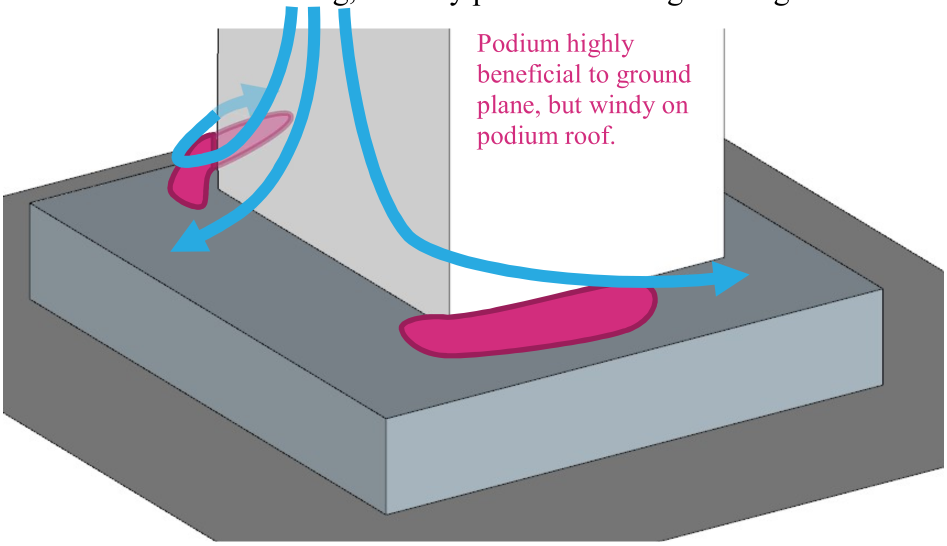


Figure 9 Schematic flow pattern around building with podium

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 10. 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.

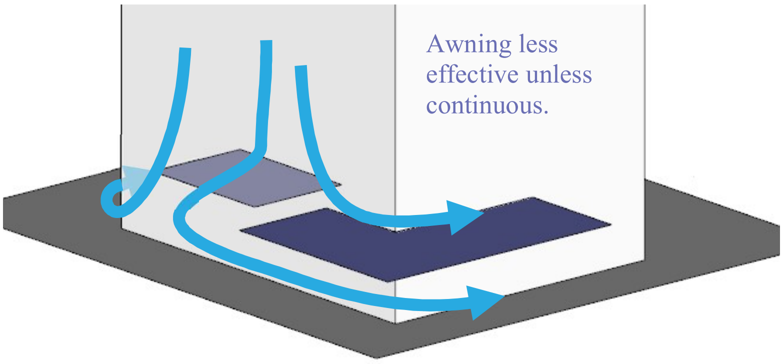


Figure 10 Schematic flow pattern around building with awning

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 11. 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 8. If the link is blocked, wind conditions will be calm unless there is a flow path through the building, Figure 12. 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 12.

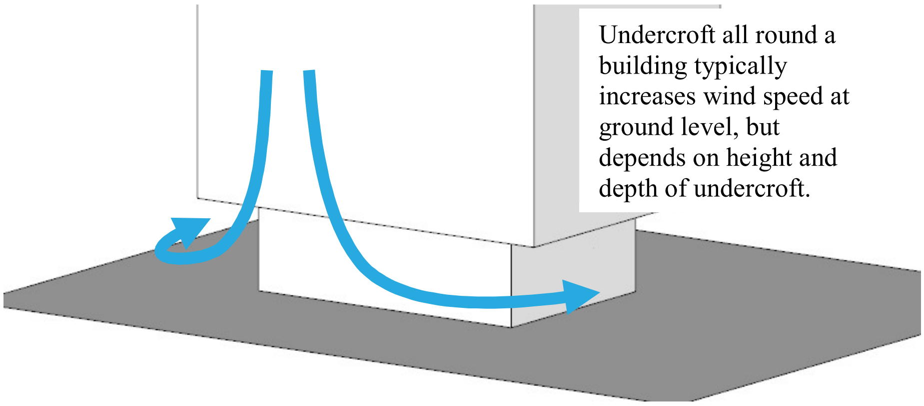


Figure 11 Schematic of flow patterns around isolated building with undercroft

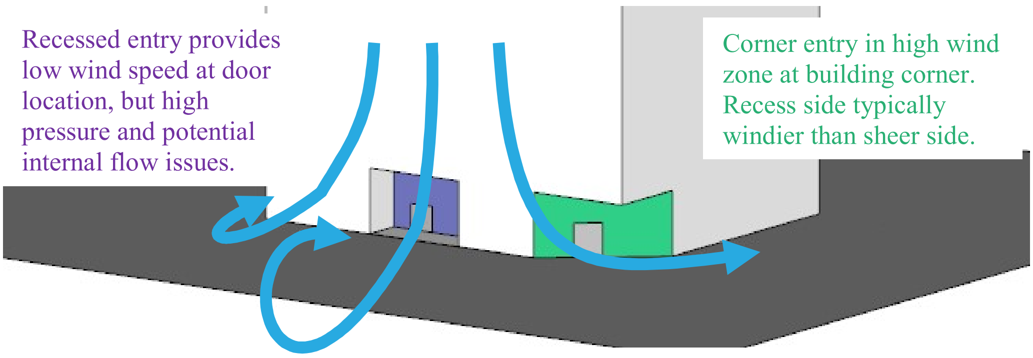


Figure 12 Schematic of flow patterns around isolated building with ground articulation

Multiple buildings

When a building is located in a city environment, depending on upwind buildings, the interference effects may be positive or negative, Figure 13. 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.

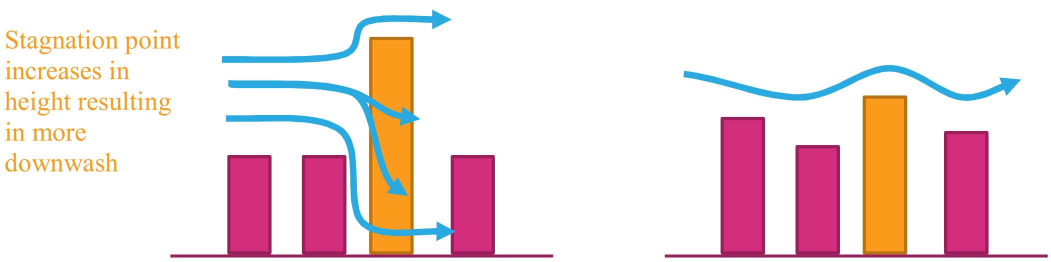


Figure 13 Schematic of flow pattern interference from surrounding buildings

The above discussion becomes more complex when three-dimensional effects are considered, both with orientation and staggering of buildings, and incident wind direction, Figure 14.

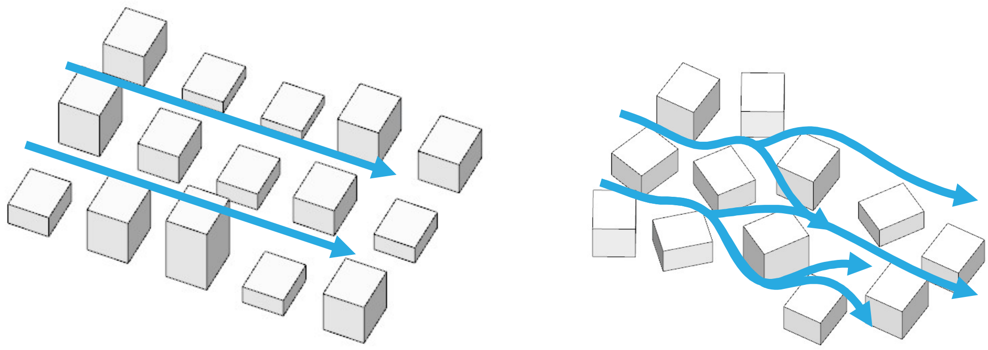


Figure 14 Schematic of flow patterns through a grid and random street layout

Channelling occurs when the wind is accelerated between two buildings, or along straight streets with buildings on either side, Figure 14(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 14(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 C: Wind speed criteria

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:

$$\mathrm{U_{GEM}} = \frac{(\mathrm{U_{mean}} + 3 \cdot \sigma_\mathrm{u})}{1.85} \quad \text{and} \quad \mathrm{U_{GEM}} = \frac{1.3 \cdot (\mathrm{U_{mean}} + 2 \cdot \sigma_\mathrm{u})}{1.85}$$

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 respectively. 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 by the blue lines in Figure 15 with definitions of the intended use of the space categories defined in Figure 16.

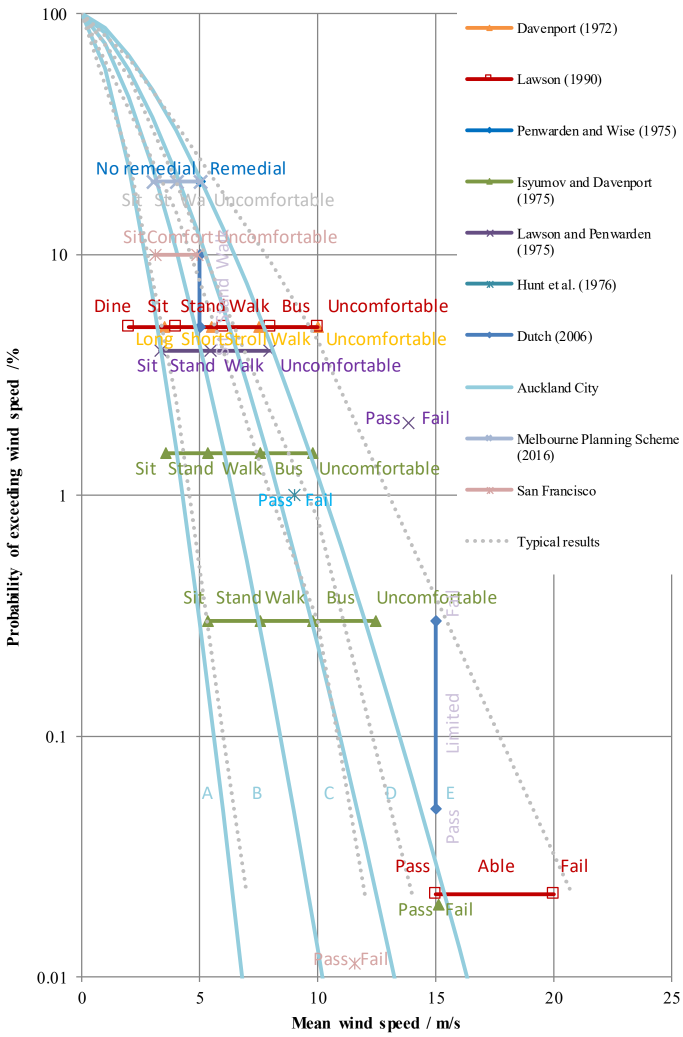


Figure 15: Probabilistic comparison between wind criteria based on mean wind speed

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

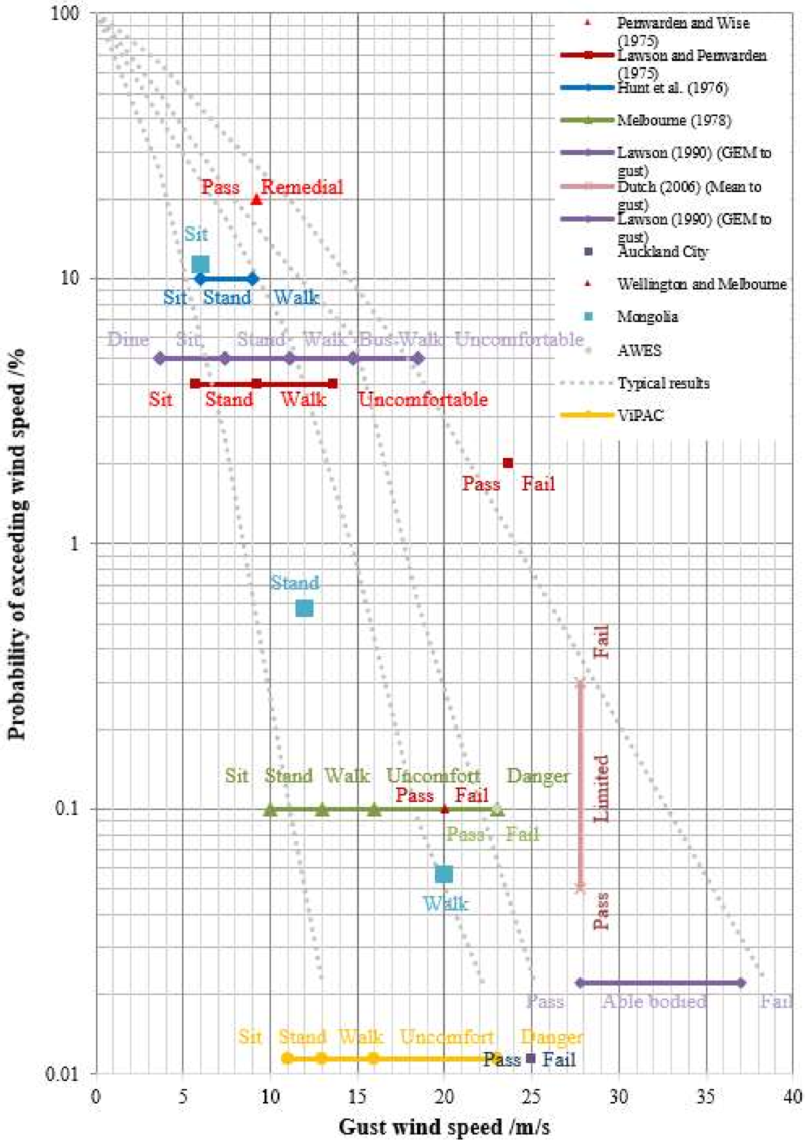


Figure 17: Probabilistic comparison between wind criteria based on 3 s gust wind speed

Appendix D: Reference documents

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

190912_Site_Surroundings_Ref.3dm

200302_DesignModel_REV B.3dm

200320_PowerhouseParramatta Plans_MK Draft.pdf