WIND IMPACT ASSESMENT

APPENDIX N

Sydney Metro City & Southwest

Pitt Street South Over Station Development:

Wind Impact Assessment

Applicable to:	Sydney Metro City & Southwest
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Owner	Sydney Metro
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Table of Contents

1.0 Purpose of this report

1.1. Background

This report supports a concept State Significant Development Application (concept SSD Application) submitted to the Department of Planning and Environment (DPE) pursuant to Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act). The concept SSD Application is made in accordance with Section 4.22 of the EP&A Act.

Sydney Metro is seeking to secure concept approval for a building envelope above the southern portal of Pitt Street Station, otherwise known as the over station development (OSD). The concept SSD Application seeks consent for a building envelope, maximum building height, land use options, pedestrian and vehicular access, circulation arrangements and associated car parking as well as the strategies and design parameters for the future detailed design of development.

Sydney Metro proposes to procure the construction of the OSD as part of an integrated station development package, which would result in the combined delivery of the station, OSD and public domain improvements. The station and public domain elements form part of a separate planning approval for Critical State Significant Infrastructure (CSSI) approved by DPE on 9 January 2017.

As the development is associated with railway infrastructure and is for residential or commercial premises with a Capital Investment Value of more than $30 million, the project is State significant development (SSD) pursuant to Schedule 1, Clause 19(2)(a) of the *State Environmental Planning Policy (State and Regional Development) 2011* (SRD SEPP). The full extent of the proposed development can also be considered to be SSD by virtue of Clause 8(2) of the SRD SEPP.

This report has been prepared to specifically respond to the Secretary's Environmental Assessment Requirements (SEARs) issued for the concept SSD Application for Pitt Street South on 30th November 2017 which state that the Environmental Impact Statement (EIS) is to address the following requirements:

Wind Impact Assessment – Including a Wind Tunnel Study

1.2. Overview of the Sydney Metro in its context

The New South Wales (NSW) Government is implementing *Sydney's Rail Future*, a plan to transform and modernise Sydney's rail network so that it can grow with the city's population and meet the needs of customers in the future. Sydney Metro is a new standalone rail network identified in *Sydney's Rail Future*.

Sydney Metro is Australia's biggest public transport project, consisting of Sydney Metro Northwest, which is due for completion in 2019 and Sydney Metro City & Southwest, which is due for completion in 2024.

Sydney Metro West is expected to be operational in the late 2020s (refer to Error! Reference source not found.).

Figure 1: Sydney Metro alignment map

Sydney Metro City & Southwest includes the construction and operation of a new metro rail line from Chatswood, under Sydney Harbour through Sydney's Central Business District (CBD) to Sydenham and on to Bankstown through the conversion of the existing line to metro standards.

The project also involves the delivery of seven new metro stations, including at Pitt Street. Once completed, Sydney Metro will have capacity for 30 trains an hour (one every two minutes) through the CBD in each direction - a level of service never seen before in Sydney.

On 9 January 2017, the Minister for Planning approved the Sydney Metro City & Southwest - Chatswood to Sydenham application lodged as a Critical State Significant Infrastructure project (reference SSI 15_7400), hereafter referred to as the CSSI Approval.

The CSSI Approval includes all physical work required to construct the CSSI, including the demolition of existing buildings and structures on each site. Importantly, the CSSI Approval also includes provision for the construction of below and above-ground structures and other components of the future integrated station development (including building infrastructure and space for future lift cores, plant rooms, access, parking and building services, as relevant to each site). The rationale for this delivery approach, as identified within the CSSI Application, is to enable the integrated station development to be more efficiently built and appropriately integrated into the metro station structure.

The EIS for the Chatswood to Sydenham component of the Sydney Metro City & Southwest project identified that the OSD would be subject to a separate assessment process.

Since the CSSI Approval was issued, Sydney Metro has lodged four modification applications to amend the CSSI Approval as outlined below:

- Modification 1- Victoria Cross and Artarmon Substation which involves relocation of the Victoria Cross northern services building from 194-196A Miller Street to 50 McLaren Street together with inclusion of a new station entrance at this location referred to as Victoria Cross North. 52 McLaren Street would also be used to support construction of these works. The modification also involves the relocation of the substation at Artarmon from Butchers Lane to 98 – 104 Reserve Road. This modification application was approved on 18 October 2017.
- Modification 2- Central Walk which involves additional works at Central Railway Station including construction of a new eastern concourse, a new eastern entry, and upgrades to suburban platforms. This modification application was approved on 21 December 2017.
- Modification 3 - Martin Place Station which involves changes to the Sydney Metro Martin Place Station to align with the Unsolicited Proposal by Macquarie Group Limited (Macquarie) for the development of the station precinct. The proposed modification involves a larger reconfigured station layout, provision of a new unpaid concourse link and retention of the existing MLC pedestrian link and works to connect into the Sydney Metro Martin Place Station. This modification application was approved on 22 March 2018.
- Modification 4 - Sydenham Station and Sydney Metro Trains Facility South which incorporated Sydenham Station and precinct works, the Sydney Metro Trains Facility South, works to Sydney Water's Sydenham Pit and Drainage Pumping Station and ancillary infrastructure and track and signalling works into the approved project. This modification application was approved on 13 December 2017.

Given the modifications, the CSSI Approval is now approved to operate to Sydenham Station and also includes the upgrade of Sydenham Station.

The remainder of the City & Southwest project (Sydenham to Bankstown) proposes the conversion of the existing heavy rail line and the upgrade of the existing railway stations along this alignment to metro standards. This portion of the project, referred to as the Sydenham to Bankstown Upgrade, is the subject of a separate CSSI Application (No. SSI 17_8256) for which an Environmental Impact Statement was exhibited between September and November 2017 and a Response to Submissions and Preferred Infrastructure Report was submitted to the NSW Department of Planning & Environment (DPE) in June 2018 for further exhibition and assessment.

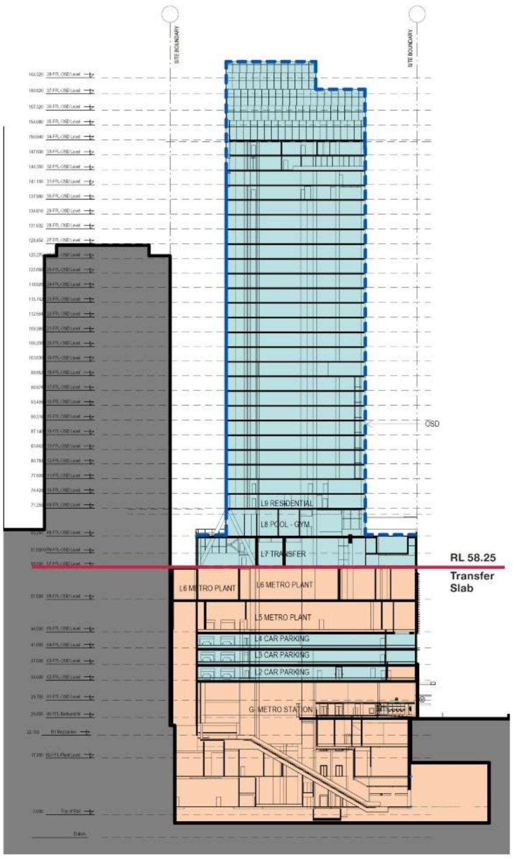
1.3. Planning relationship between Pitt Street Station and the OSD

While the southern portal of Pitt Street Station and the OSD will form an integrated station development, the planning pathways under the *Environmental Planning and Assessment Act 1979* involve separate approval for each component of the development. In this regard, the approved station works (CSSI Approval) are subject to the provisions of Part 5.1 of the EP&A Act (now referred to as Division 5.2) and the OSD component is subject to the provisions of Part 4 of the EP&A Act.

For clarity, the approved station works under the CSSI Approval included the construction of below and above ground structures necessary for delivering the station and also enabling construction of the integrated OSD. This included but is not limited to:

- demolition of existing development
- excavation
- station structure including concourse and platforms
- lobbies
- retail spaces within the station building
- public domain improvements
- station portal link (between the northern and southern portals of Pitt Street Station)
- access arrangements including vertical transport such as escalators and lifts
- structural and service elements and the relevant space provisioning necessary for constructing OSD, such as columns and beams, space for lift cores, plant rooms, access, parking, retail and building services.

The vertical extent of the approved station works above ground level is defined by the 'transfer slab' level (which for Pitt Street South is defined by RL 58.25), above which would sit the OSD. This delineation is illustrated in Error! Reference source not found. below.



Section North-South - CSSI Podium Approval below RL 58.25

Figure 2: Delineation between station and OSD

The CSSI Approval also establishes the general concept for the ground plane of Pitt Street Station including access strategies for commuters and pedestrians. In this regard, pedestrian access to the station would be from Bathurst Street and the OSD lobby would be accessed from Pitt Street.

Since the issue of the CSSI Approval, Sydney Metro has undertaken sufficient design work to determine the space planning and general layout for the station and identification of those spaces within the station area that would be available for the OSD. In addition, design work has been undertaken to determine the technical requirements for the structural integration of the OSD with the station. This level of design work has informed the concept proposal for the OSD. It is noted that ongoing design development of the works to be delivered under the CSSI Approval would continue with a view to developing an Interchange Access Plan (IAP) and Station Design Precinct Plan (SDPP) for Pitt Street Station to satisfy Conditions E92 and E101 of the CSSI Approval.

The public domain improvement works around the site would be delivered as part of the CSSI Approval.

1.4. The Site

The Pitt Street South OSD site is located near the corner of Pitt Street and Bathurst Street, comprising four individual allotments but excluding the Edinburgh Castle Hotel, above the southern portal of the future Pitt Street Station. The context of the site is demonstrated at Error! Reference source not found. below.

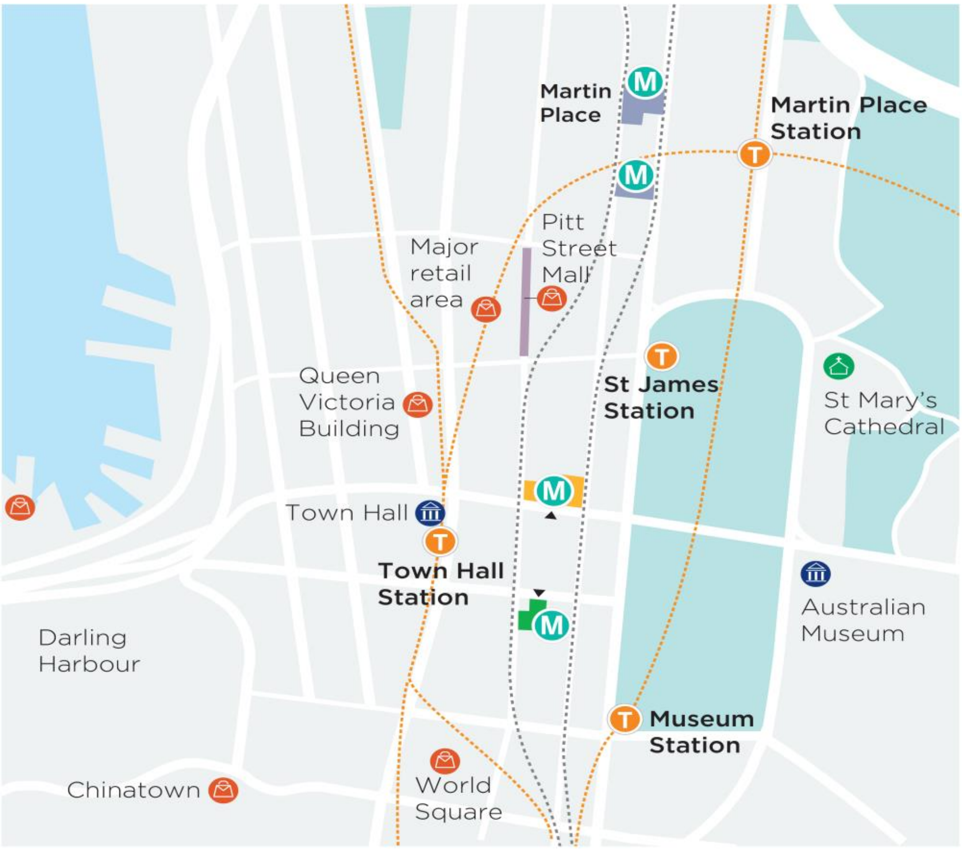


Figure 3: Pitt Street Station location plan

The site is located in the City of Sydney Local Government Area. The site (refer to **Figure 4** below) is irregular in shape, has a total area of approximately 1,708 square metres and has street frontages of approximately 32 metres to Pitt Street and 24 metres to Bathurst Street.

The Pitt Street South site comprises a number of individual properties which front Bathurst Street and Pitt Street. Specifically, the site comprises the following:

- 125-129 Bathurst Street, Sydney (Lot 1 in DP60293)
- 131-135 Bathurst Street, Sydney (Lot 1 in DP59101)
- 296-300 Pitt Street, Sydney (Lot 1 in DP436359)
- 302 Pitt Street, Sydney (Lot 1 in DP62668)

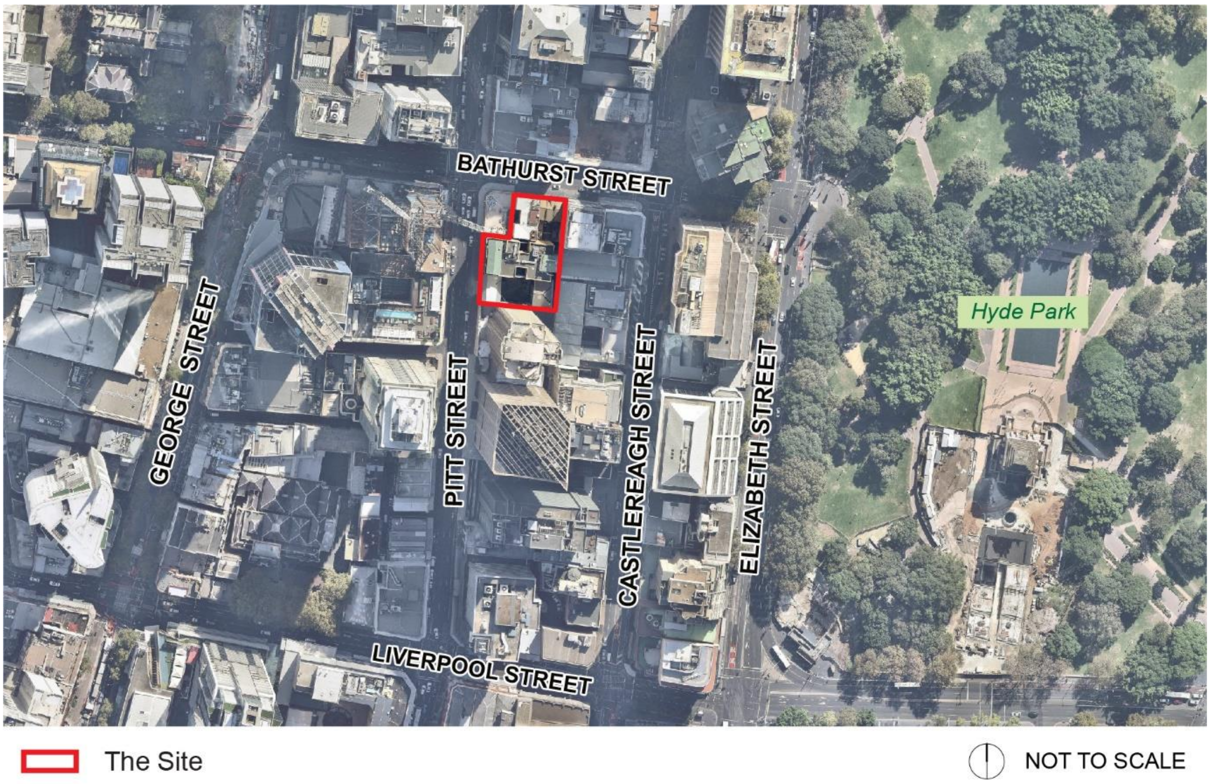


Figure 4: Aerial photo of Pitt Street South

1.5. Overview of the proposed development

This concept SSD Application comprises the first stage of the Pitt Street South OSD project. It will be followed by a detailed SSD Application for the design and construction of the OSD to be lodged by the successful contractor who is awarded the contract to deliver the integrated station development.

This concept SSD Application seeks approval for the planning and development framework and strategies to inform the future detailed design of the OSD. It specifically seeks approval for the following:

- a building envelope
- a maximum envelope height of Relative Level (RL 171.6) which equates to approximately 35 storeys, including the podium height of RL 71.0 which equates to approximately 8 storeys above ground
- use for the OSD component of the development for uses, subject to further detailed applications, which could include:
    - residential accommodation; or
    - commercial premises

- use of the conceptual OSD space provisioning within the footprint of the CSSI Approval (both above and below ground), including the OSD lobby areas, podium car parking, storage facilities, services and back-of-house facilities

- car parking for a maximum of 34 spaces located across three levels of the podium
- loading, vehicular and pedestrian access arrangements from Pitt Street
- strategies for utilities and service provision
- strategies for the management of stormwater and drainage
- a strategy for the achievement of ecologically sustainable development
- indicative future signage
- a strategy for public art
- a design excellence framework
- the future subdivision of parts of the OSD footprint (if required)

As this concept SSD Application is a staged development pursuant to section 4.22 of the EP&A Act, future approval would be sought for detailed design and construction of the OSD. Concept indicative designs showing potential residential and commercial building form outcomes at the site have been provided as part of this concept SSD Application at Appendix E and Appendix F, respectively.

Pitt Street Station is to be a key station on the future Sydney Metro network, providing access to the Sydney CBD. The proposal combines the metro station with an OSD component. The OSD would assist in strengthening the role of Central Sydney as the key centre of business in Australia and would contribute to the diversity, amenity and sustainability of the CBD.

It is noted that Pitt Street Station northern portal OSD is subject to a separate application, and does not form part of this concept SSD Application.

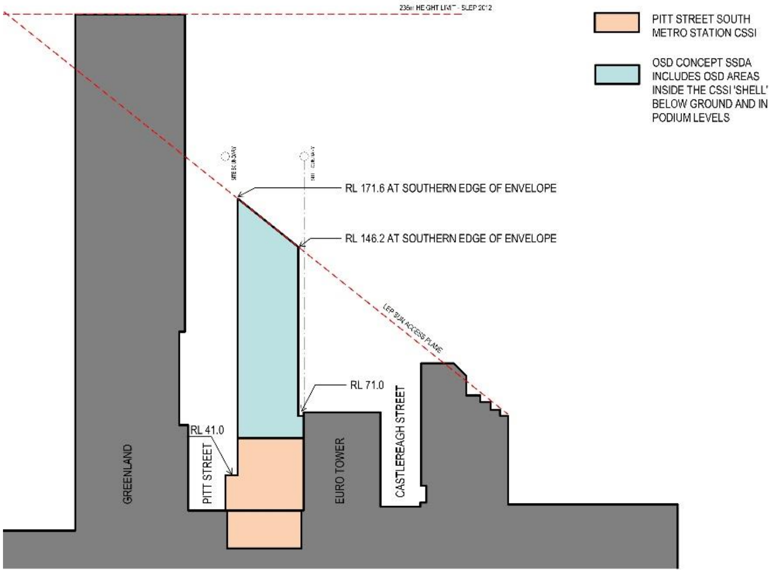


Figure 5: Pitt Street South OSD envelope, including OSD components (Blue) and station box (Orange)

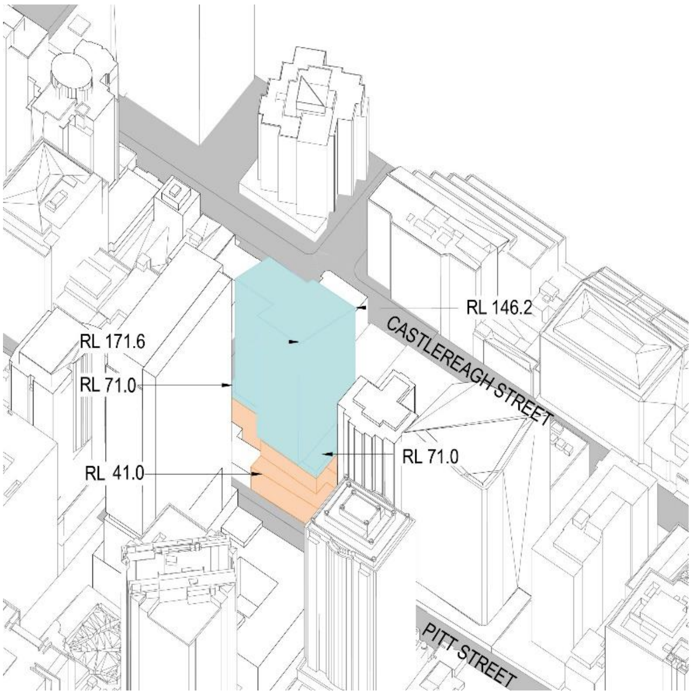


Figure 6: Pitt Street South OSD axonometric diagram, as seen from the south-west

1.6. Staging and framework for managing environmental impacts

Sydney Metro proposes to procure the delivery of the Pitt Street South integrated station development in one single package, which would entail the following works:

- station structure
- station fit-out, including mechanical and electrical
- OSD structure
- OSD fit-out, including mechanical and electrical.

Separate delivery packages are also proposed by Sydney Metro to deliver the excavation of the station boxes/shafts ahead of the integrated station development delivery package, and line-wide systems (e.g. track, power, ventilation) and operational readiness works prior to the Sydney Metro City & Southwest metro system being able to operate.

Three possible staging scenarios have been identified for delivery of the integrated station development:

1. Scenario 1 – the station and OSD are constructed concurrently by constructing the transfer slab first and then building in both directions. Both the station and OSD would be completed in 2024.
2. Scenario 2 – the station is constructed first and ready for operation in 2024. OSD construction may still be incomplete or soon ready to commence after station construction is completed. This means that some or all OSD construction is likely to still be underway upon opening of the station in 2024.
3. Scenario 3 – the station is constructed first and ready for operation in 2024. The OSD is built at a later stage, with timing yet to be determined. This creates two distinct construction periods for the station and OSD.

Scenario 1 represents Sydney Metro's preferred option as it would provide for completion of the full integrated station development and therefore the optimum public benefit at the site at the earliest date possible (i.e. on or near 2024 when the station is operational). However, given the delivery of the OSD could be influenced by property market forces, Scenarios 2 or 3 could also occur, where there is a lag between completion of the station component of the integrated station development (station open and operational), and a subsequent development.

The final staging for the delivery of the OSD would be resolved as part of the detailed SSD Application(s).

For the purposes of providing a high level assessment of the potential environmental impacts associated with construction, the following have been considered:

- Impacts directly associated with the OSD, the subject of this SSD Application

- Cumulative impacts of the construction of the OSD at the same time as the station works (subject of the CSSI Approval)

Given the integration of the delivery of the Sydney Metro City & Southwest metro station with an OSD development, Sydney Metro proposes the framework detailed in Error! Reference source not found. to manage the design and environmental impacts, consistent with the framework adopted for the CSSI Approval.

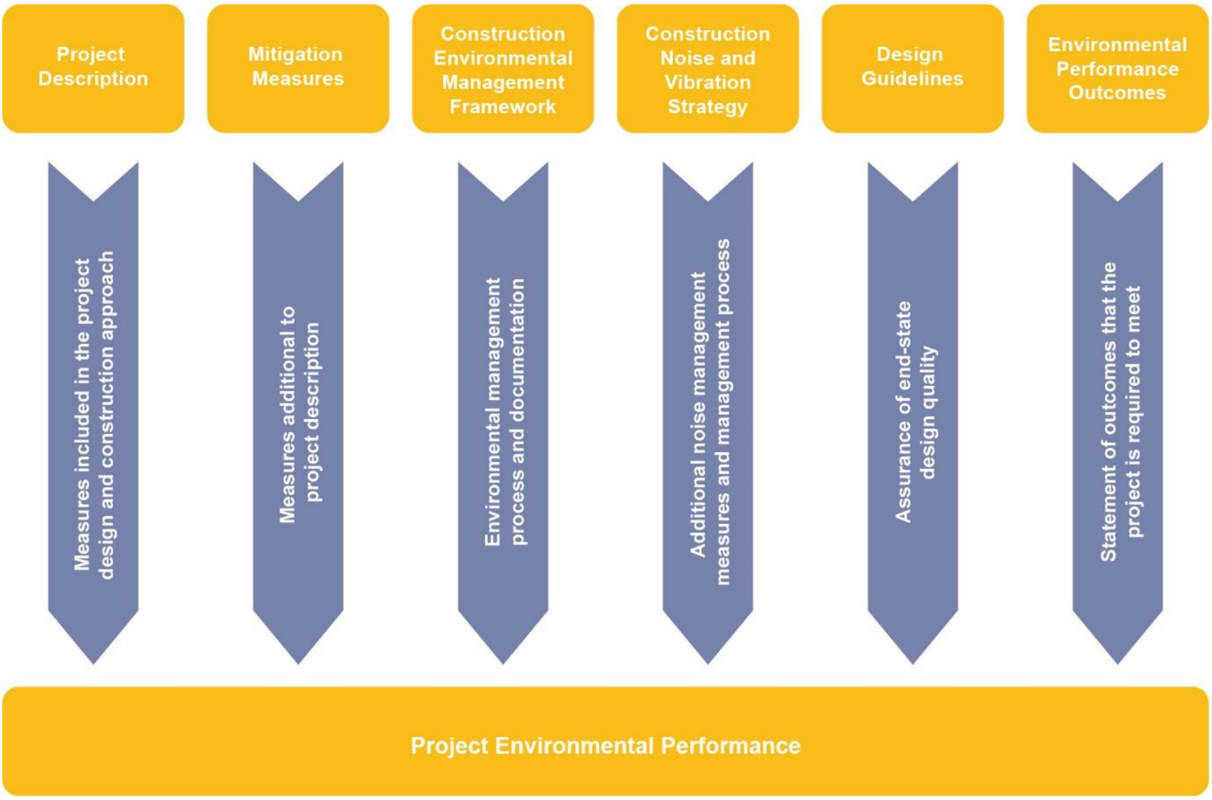


Figure 7: Project approach to environmental mitigation and management

Sydney Metro proposes to implement a similar environmental management framework where the integrated delivery of the CSSI station works and the OSD occur concurrently. This would ensure a consistent approach to management of design interface and construction-related issues.

Sydney Metro proposes this environmental management framework would apply to the OSD until completion of the station and public domain components of the integrated station development delivery contract (i.e. those works under the CSSI Approval). Should the OSD be constructed beyond the practical completion and opening of the station, standard practices for managing construction related environmental impacts would apply in accordance with the relevant guidelines and Conditions of Approval for the detailed SSD Application(s).

2.0 Desktop Wind Assessment

2.1. Introduction

Cermak Peterka Petersen Pty. Ltd. has been engaged by Sydney Metro to provide an opinion-based assessment of the impact of the proposed Sydney Metro OSD on the pedestrian level local wind environment in and around the site.

Whereas the current proposal is for a building envelope of up to 35 storeys, this assessment was based on the initial indicative design of the over station development (dated August 2017) and comprised a multi-residential development with approximately 269 apartments over 54 floor levels to be located above the Sydney Metro Underground Railway Station. The addendum in Section 5 of this report addresses the impacts of the reduction in height of the current proposal.

The apartments will begin about 50 m above street level, above the Railway Station public concourse and plant rooms, and were to reach a height of 235 m above street level, **Figure 8**. It is noted that the wind assessment contained herein is an assessment of the indicative design only, to demonstrate the expected performance of a residential development of the proposed size and massing illustrated in **Figure 8**.

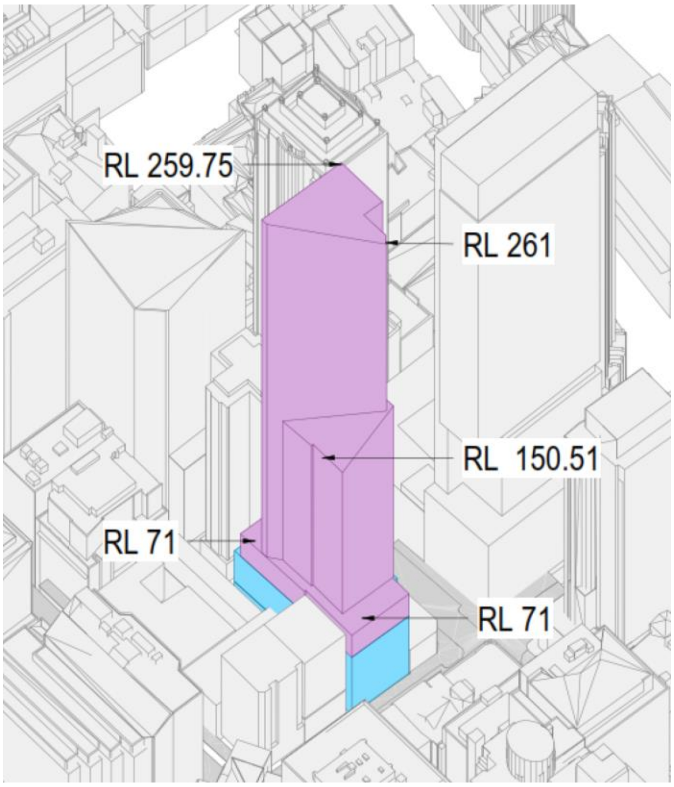


Figure 8: Perspective view of August 2017 OSD indicative design

2.2. Sydney Wind Climate

To enable a qualitative assessment of the wind environment, the wind frequency and direction information measured by the Bureau of Meteorology at a standard height of 10 m at Sydney Airport from 1995 to 2016 have been used in this analysis, **Figure 9**. The anemometer is located about 9 km to the south of the site and is considered representative of the wind conditions at the site. It is noted from Figure 9 that strong prevailing winds are organised into three main groups which centre at about north-east, south, and west. This wind assessment is focused on these prevailing strong wind directions.

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

Winter and early spring winds typically occur from the south and west quadrants. West quadrant winds provide the strongest winds affecting the area throughout the year and are large scale synoptic events that can be hot or cold depending on inland conditions.

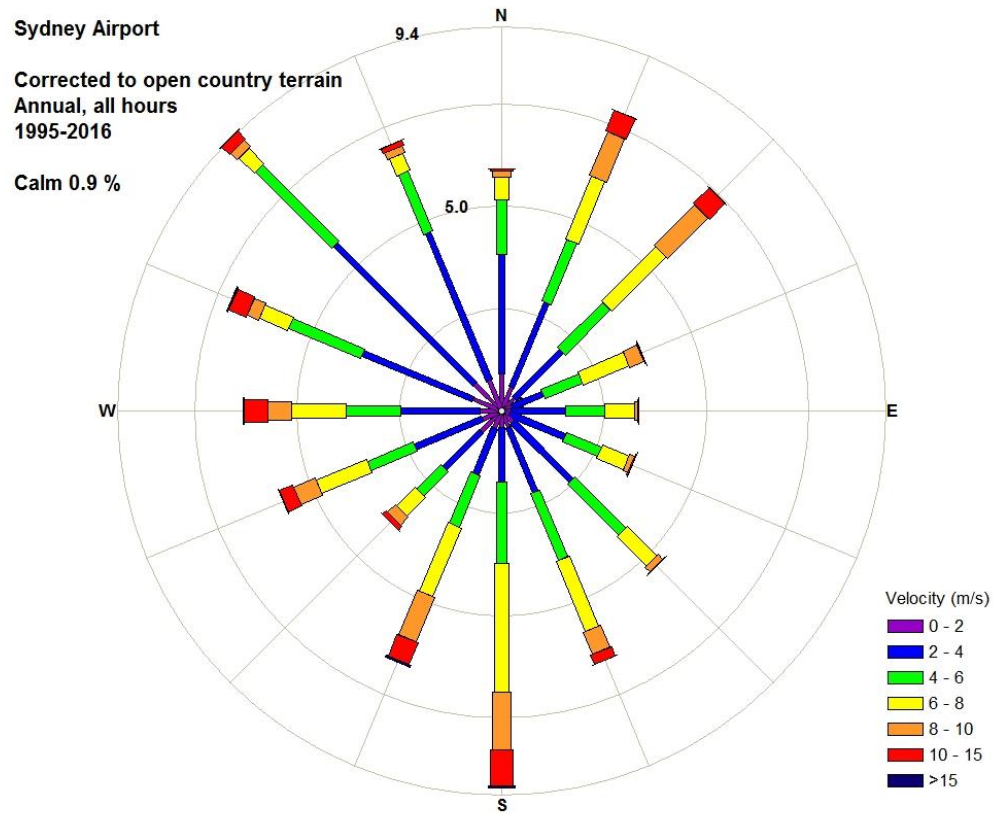


Figure 9: Wind rose showing probability of time of wind direction and speed for Sydney Airport.

2.3. 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 and sides of the building. Downwash will occur on buildings of all heights, but the vertical component is dictated by the height to width ratio 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 one third height in the centre of the face.

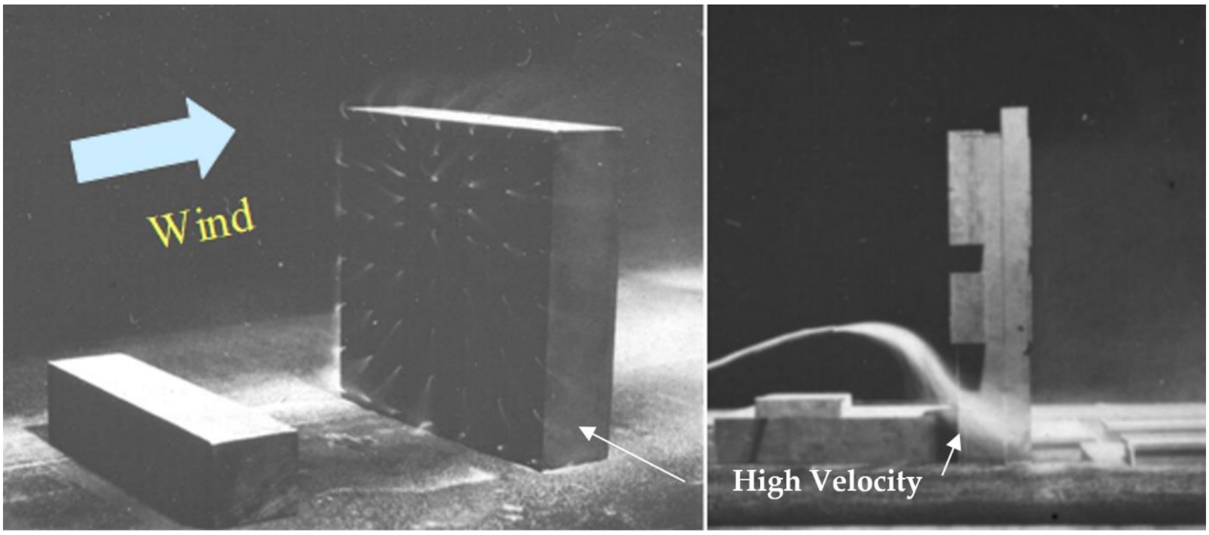


Figure 10: Flow visualisation around a tall building.

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 deeper the horizontal element generally 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. For long buildings relative to their height the flow around the corners will generally be horizontal.

2.4. Environmental Wind Speed 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. Over the years, a number of researchers have added to the knowledge of wind effects on pedestrians by suggesting criteria for comfort and safety. 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.

This study is based upon the criteria of Lawson (1990), which are described in **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.

From ongoing findings using the criteria, and clients who have issues with strong wind, a more stringent criterion is required for outdoor dining style activities and a value of 2 m/s for 5% of the time is recommended for such intended use. As the 5% of the time wind speed recorded at the airport is about 9 m/s, and even with the benefits of shielding from suburban buildings compared with the airport, most locations in the Sydney region require some level of shielding to meet the criterion.

Assessment using the Lawson criteria provides a similar classification as using the once per annum gust, however also provides information regarding the serviceability wind climate.

Table 1: – Pedestrian comfort criteria for various activities.

Comfort (maximum of mean or gust equivalent mean (GEM†.) wind speed exceeded 5% of the time)	
< 4 m/s	Pedestrian Sitting (considered to be of long duration)
4 - 6 m/s	Pedestrian Standing (or sitting for a short time or exposure)
6 - 8 m/s	Pedestrian Walking
8 - 10 m/s	Business Walking (objective walking from A to B or for cycling)
> 10 m/s	Uncomfortable
Distress (maximum of mean or GEM wind speed exceeded 0.022% of the time)	
<15 m/s	not to be exceeded more than two times per year (or one time per season) for general access
<20 m/s	not to be exceeded more than two times per year (or one time per season) where only able-bodied people would be expected; frail or cyclists would not be expected

The 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 1.85.

2.5. Environmental Wind Assessment

The over station development is located to the west of Hyde Park at the corner of Bathurst and Pitt Streets, **Figure 11**. The site is surrounded by medium to high-rise buildings; neighbouring high-rise buildings include Greenland Tower under construction, Princeton Apartments, 110 Bathurst Street under construction, and Meriton Serviced Apartments. Topography immediately surrounding the site is relatively flat.

Figure 11: Location of the proposed development (Google Earth, 2017).

Winds in such a complex cityscape tend to be channelled along the streets with local effects being dictated by exposed large buildings and local topography. In this area of the city prevailing winds are brought to ground level in the form of downwash by large exposed towers, and the downwash from these buildings is channelled along the streets. The nested location of the over station development site within the surrounding cityscape greatly reduces the potential for downwash from the tower, as tall buildings in the immediate vicinity would considerably shield the site from prevailing winds. The following sections will discuss in detail the effects of winds from each prevailing wind direction in and around the proposed development.

2.5.1. Winds from the North-East

For winds from the north-east, the proposed building would receive some shielding from the approved 110 Bathurst Street high-rise building and the 201 Elizabeth Street Tower to the north east. These upwind buildings will promote some of the wind to flow around the proposed development. Elevated wind flow reaching the upper levels of the proposed tower will strike the north-east face, encouraging wind to flow horizontally around the building. A small quantity of downwash would be expected to result from winds from the north-east, however the transition to the square planform of the lower levels, and podium setback would assist in keeping this flow elevated as it accelerates around the south-east and north-west corners of the tower. It is expected the addition of the proposed development will not significantly impact the wind conditions during wind events from the north-east.

2.5.2. Winds from the South

The majority of the proposed development will be shielded by high-rise developments, and general massing of the city, to the south. Some wind flow from the south will strike the exposed upper levels of the proposed building and generate some downwash that will generally be deflected by the podium and away from ground level. The compound mass created by the Telstra Plaza Building, Century Tower and HSBC building in particular will encourage wind to flow horizontally around them, and away from the development site. It is expected the wind conditions along the adjacent roadways of Pitt and Bathurst Streets will experience minimal incremental impact after the addition of the proposed development due to pre-existing shielding of adjacent high-rise buildings.

2.5.3. Winds from the West

During wind events from the west the proposed development will be situated within the wake behind the compound mass created by the Meriton Apartments, Greenland Tower (once completed) and HSBC Building. A large quantity of wind will flow around these buildings and away from the development site. This will help reduce potential downwash and channelling flow caused by the proposed building. Some high-level flow will be directed toward ground as downwash, but would be expected to be diverted away from ground level by the setbacks at the lower levels. Ground level wind conditions along the adjacent roadways are not expected to experience significant incremental impacts with the addition of the proposed building.

2.5.4. Terrace and Balcony conditions

On the proposed tower, balconies are flush with the façade and include operable elements to seal the majority of the balcony, **Figure 12**. This configuration is considered a good design from a wind perspective, as the operable elements will allow patrons to control the wind conditions within the balcony. In the closed configuration it would be expected that wind conditions would be classified as suitable for pedestrian sitting from a Lawson comfort perspective.

The upper level terrace will be subject to downwash generated by winds from the north-east, to assist in dispersing this flow horizontal elements, such as an awning, would be suggested. The inclusion of 3 m high vertical screens would be expected to provide local shielding from horizontal flow to patrons close to the screens.

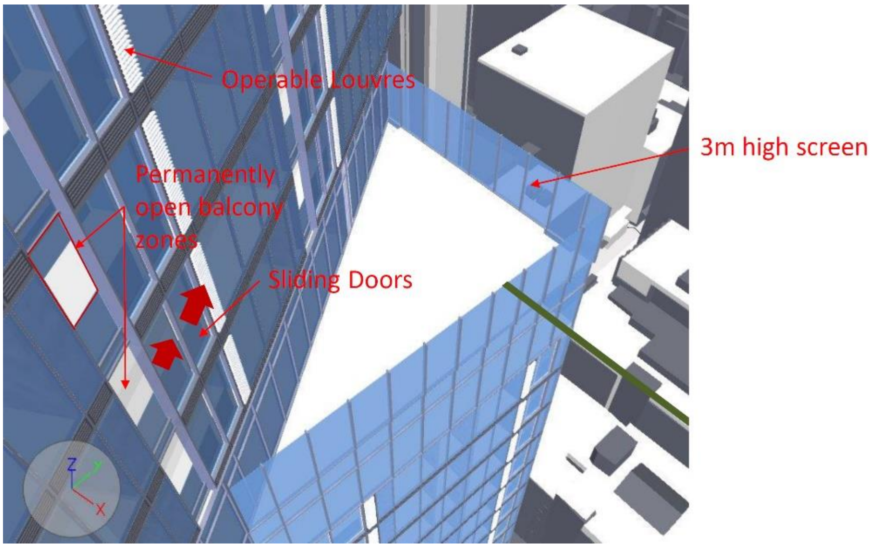


Figure 12: Perspective view of typical balcony configuration and upper level terrace.

The lower terrace and pool deck will each be impacted by downwash from the tower façade. Provision of horizontal elements adjacent to the tower façade over the lower terrace would be expected to improve wind conditions in this space. Continuation of the glazed roof, **Figure 13**, above the pool deck along the tower façade would be recommended to assist in dispersing downwash.

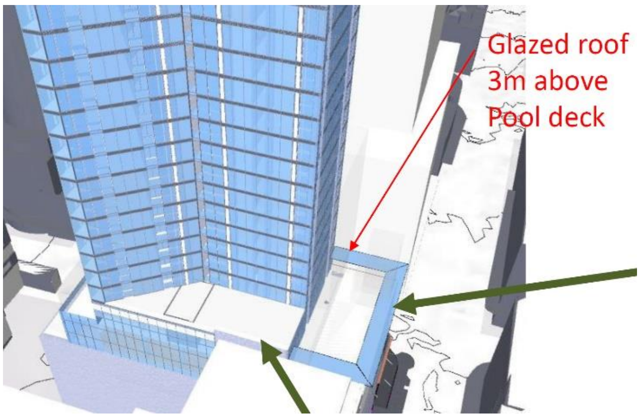


Figure 13: Perspective view of lower terrace and pool deck.

3.0 Conclusions

Cermak Peterka Petersen Pty. Ltd. has provided an opinion-based assessment of the impact of the proposed Sydney Metro over station development on the local wind environment.

Wind conditions at ground level around the site are not expected to be altered significantly by the proposed Sydney Metro over station development due to considerable shielding offered by the neighbouring high-rise towers. On average, the wind conditions around the site would be expected to be similar to existing conditions, with the pedestrian level wind environment for most locations expected to be classified as suitable for pedestrian standing under the Lawson criterion, and all locations expected to pass the distress criterion.

Wind-tunnel testing for the proposed development, including the station box and building envelope, was conducted subsequent to this qualitative assessment. The testing allowed for quantification of the wind conditions around the site, and was prepared with regard to the relevant Secretary's Environmental Assessment Requirements as provided by the Department of Planning and Environment. The wind tunnel test report for the proposed development is considered to take precedence over the conclusions of this qualitative analysis and may be found in Section 4.0.

3.1. References

City of Sydney, (2011), "Central of Sydney Development Control Plan 1996".

City of Sydney, (2012), "Sydney Development Control Plan 2012".

Lawson, T.V., (1990), The Determination of the wind environment of a building complex before construction, Department of Aerospace Engineering, University of Bristol, Report Number TVL 9025.

Melbourne, W.H., (1978), Criteria for environmental wind conditions, J. Industrial Aerodynamics, 3, 241-249.

4.0 Environmental Wind Tunnel Tests

4.1. Executive Summary

A wind tunnel study of the then proposed 65 level Sydney Metro OSD to be located in Sydney, Australia, was conducted to assess pedestrian wind comfort. A model of the project was fabricated to a 1:400 scale and centred on a turntable in the wind tunnel. Replicas of surrounding buildings within a 570 m radius were constructed and placed on the turntable.

The wind tunnel testing was performed in the natural boundary layer wind tunnel of Cermak Peterka Petersen Pty. Ltd., St. Peters. Approach boundary layers, representative of the environment surrounding the proposed development, were established in the test section of the wind tunnel. The approach wind flow had appropriate turbulence characteristics corresponding to a Suburban approach as defined in Standards Australia (2011).

Measurements of winds likely to be experienced by pedestrians were made with a hot-film anemometer at 24 locations for 16 wind directions each. These points were tested around the development in the proposed and existing configurations, focusing on access routes, terraces, and outdoor seating areas. The measurements were combined with site specific wind statistics to produce results of wind speed versus the percentage of time that wind speed is exceeded for each location.

The wind environment around the ground plane of the development was found to be generally suitable for pedestrian standing activities from a comfort perspective with reference to the Lawson criteria. All locations on the ground plane passed the Lawson distress criteria.

Wind conditions on the podium and upper level terraces were also presented, and were found to be classified as suitable for pedestrian sitting and standing activities, on the podium terraces, and pedestrian walking and business walking for the upper level terraces, from a Lawson comfort perspective. All podium locations passed the distress criterion, with exceedances found on the upper levels due to the exposed nature of these locations.

4.2. Introduction

Pedestrian acceptability of footpaths, entrances, plazas, and terraces is an important design parameter of interest to the building owner and architect. Assessment of the acceptability of the pedestrian level wind environment is desirable during the project design phase so that modifications can be made, if necessary, to create wind conditions suitable for the intended use of the space.

Analytical methods such as computational fluid dynamics (CFD) are not capable, except in very simple geometries, to estimate wind pressures, frame loads, or windiness in pedestrian areas.

Techniques have been developed which permit boundary layer wind tunnel modelling of buildings to determine wind velocities in pedestrian areas. This report includes wind tunnel test procedures, test results, and discussion. **Table 2** summarises the model configurations, test methods, and data acquisition parameters used. All the data collection was performed in accordance with Australasian Wind Engineering Society (2001), and American Society of Civil Engineers (1999, 2010).

Table 2: Configurations for data acquisition.

General Information	
Model length scale	1:400
Surrounding model radius (full-scale)	570 m
Reference height (full-scale)	200 m AGL
Approach terrain category	Suburban approach (Terrain Category 3)
Testing Configuration(s)	
Existing Configuration (location results labelled X)	Existing site with approved surrounding buildings, as shown in **Figure 16**. Pedestrian winds measured at 11 locations for 16 wind directions at 22.5° increments from 0° (north).
Proposed Configuration (location results labelled X.1)	Proposed Sydney Metro – over station development with existing and approved surrounding buildings, as shown in **Figure 17** and **Figure 18**. Pedestrian winds measured at 13 locations for 16 wind directions at 22.5° increments from 0° (north).

4.3. The Wind Tunnel Test

Modelling of the aerodynamic flow around a structure requires special consideration of flow conditions to obtain similitude between the model and the prototype. A detailed discussion of the similarity requirements and their wind tunnel implementation can be found in Cermak (1971, 1975, 1976). In general, the requirements are that the model and prototype be geometrically similar, that the approach mean velocity and turbulence characteristics at the model building site have a vertical profile shape similar to the full-scale flow, and that the Reynolds number for the model and prototype be equal. Due to modelling constraints the Reynolds number cannot be made equal and Australasian Wind Engineering Society Quality Assurance Manual (2001) suggests a minimum Reynolds number of 50,000, based on characteristic model dimension and wind velocity at the top of the model; in this study the modelled Reynolds number was over 50,000.

The wind tunnel test was performed in the boundary layer wind tunnel shown in **Figure 14**. The wind tunnel test section is 3.0 m wide, by 2.4 m high with a porous slatted roof for passive blockage correction. This wind tunnel has a 21 m long test section, the floor of which is covered with roughness elements, preceded by a vorticity generating fence and spires. The spires, barrier, and roughness elements were designed to provide a modelled atmospheric boundary layer approximately 1.2 m thick with a mean velocity and turbulence intensity profile similar to that expected to occur in the region approaching the modelled area. The approach wind characteristics used for the model test are shown in **Figure 15**, and are explained more fully in Section 4.5.1.

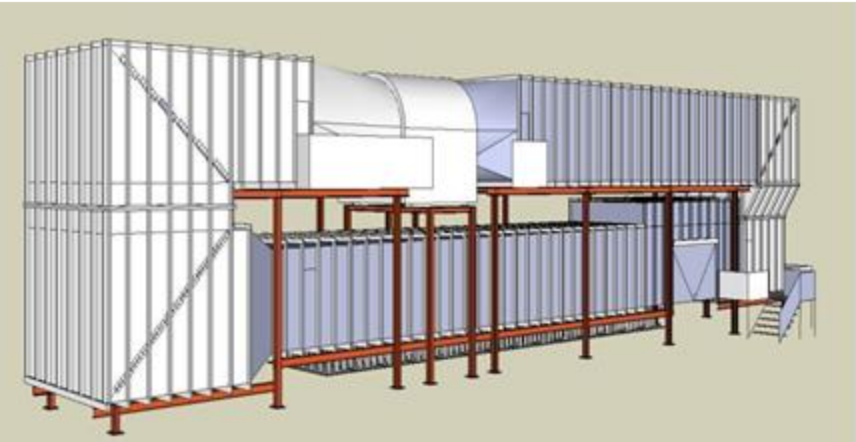


Figure 14: Schematic of the closed-circuit wind tunnel.

A model of the proposed development and surrounds to a radius of 570 m was constructed at a scale of 1:400, which was consistent with the modelled atmospheric flow, permitted a reasonable test model size with an adequate portion of the adjoining environment to be included in a proximity model, **Figure 17** and **Figure 18**, and was within wind tunnel blockage limitations.

Significant variations in the building surface were formed into the model. The models were mounted on the turntable located near the downstream end of the wind tunnel test section. The turntable permitted rotation of the modelled area for examination of velocities from any approach wind direction. Additional photos of the testing are included in Appendix 1.

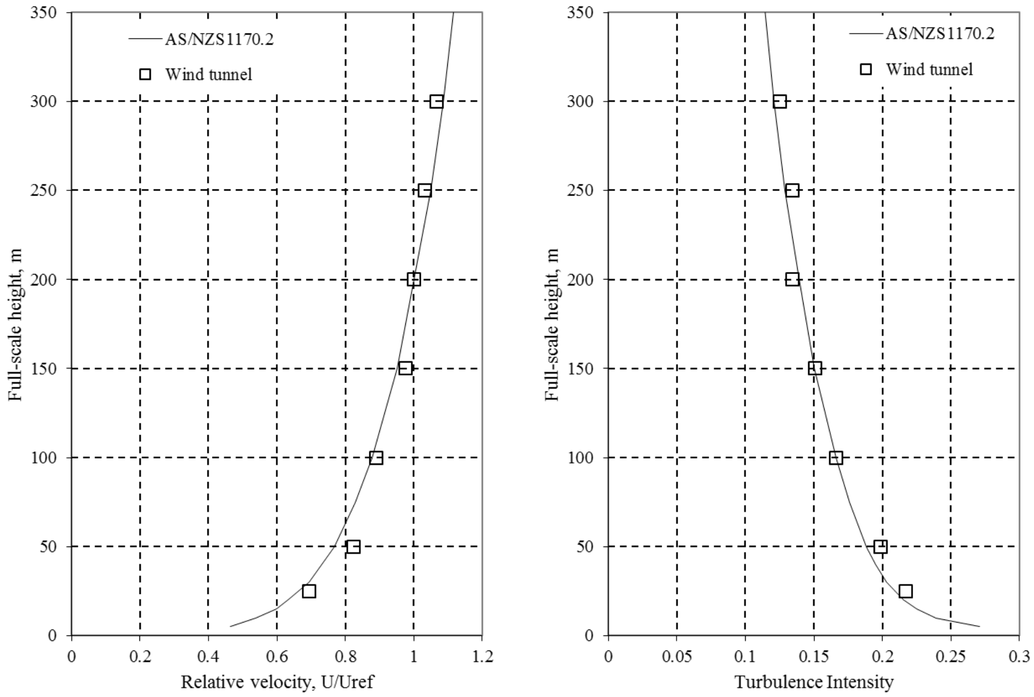


Figure 15: Mean velocity and turbulence profiles – suburban approach (terrain category 3).

Figure 16: Existing Pitt Street South site model in the wind tunnel viewed from the east.

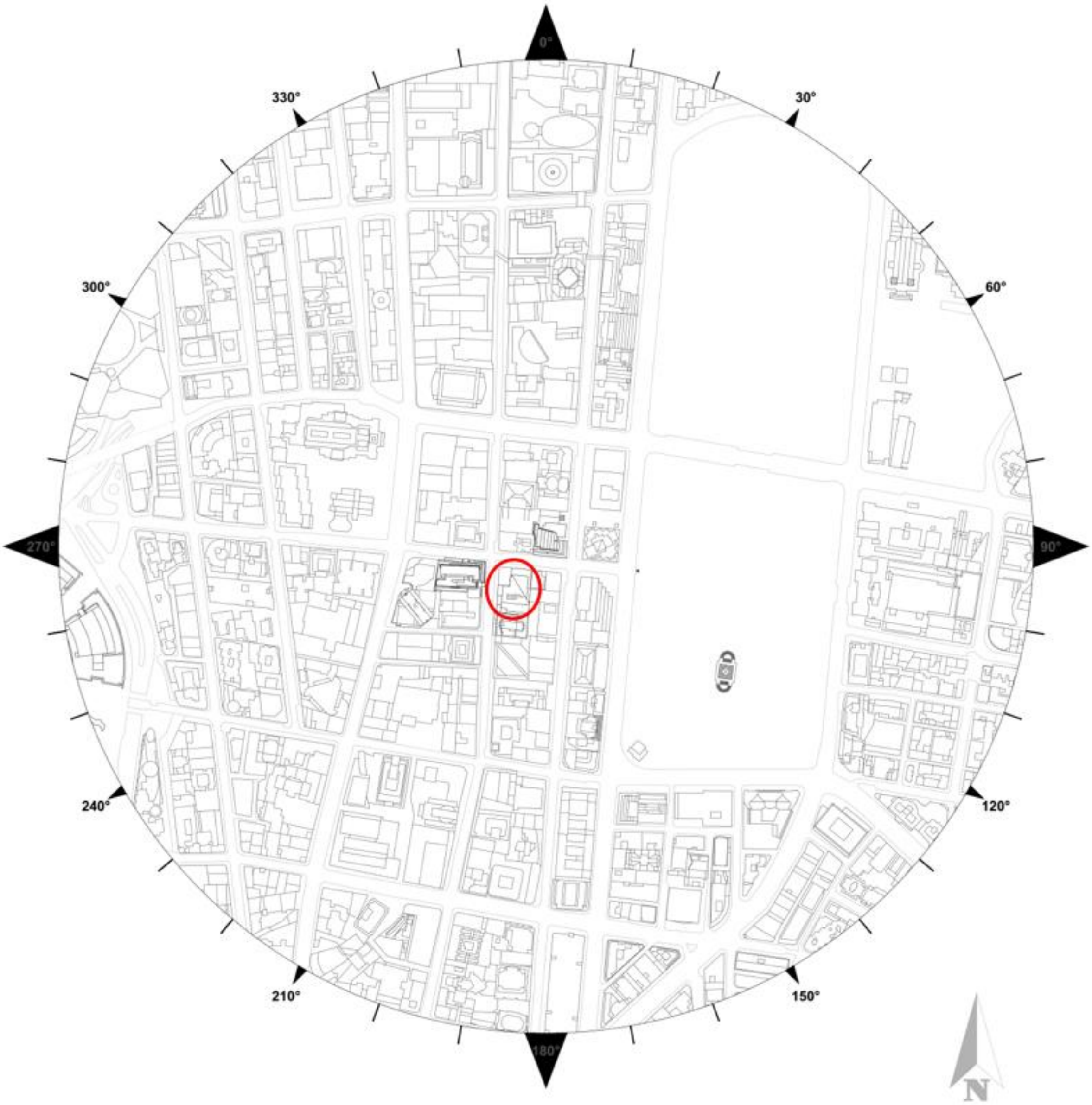


Figure 17: Project location and turntable layout – Proposed configuration.

Figure 18: Proposed Sydney Metro – over station development model in the wind tunnel viewed from the east.

4.4. Environmental Wind Criteria

Over the years, a number of researchers have added to the knowledge of wind effects on pedestrians by suggesting criteria for comfort and safety. 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. Also, a location can be evaluated for its intended use, such as for an outdoor café or a footpath. One of the most widely accepted set of criteria was developed by Lawson (1990), which is described in **Table 3**.

Lawson's criteria have categories for comfort, based on wind speeds exceeded 5% of the time, allowing planners to judge the usability of locations for various intended purposes ranging from "Business Walking" to "Pedestrian sitting". The level and severity of these comfort categories can vary based on individual preference, so calibration to the local wind environment is recommended when evaluating the Lawson ratings. The criteria also include a distress rating, for safety assessment, which is based on occasional (once or twice per year) wind speeds. In both cases, the wind speed used the larger of a mean or gust equivalent-mean (GEM) wind speed. The GEM is defined as the peak gust wind speed divided by 1.85; this is intended to account for locations where the gustiness is the dominant characteristic of the wind. However, assessment using the Lawson criteria provides a similar classification as using once per annum gust criteria, but also provides additional information regarding the serviceability wind climate.

Table 3: Summary of Lawson criteria.

Comfort (maximum of mean or gust equivalent mean (GEM†·) wind speed exceeded 5% of the time)	
< 4 m/s	Pedestrian Sitting (considered to be of long duration)
4 - 6 m/s	Pedestrian Standing (or sitting for a short time or exposure)
6 - 8 m/s	Pedestrian Walking
8 - 10 m/s	Business Walking (objective walking from A to B or for cycling)
> 10 m/s	Uncomfortable
Distress (maximum of mean or GEM wind speed exceeded 0.022% of the time)	
<15 m/s	not to be exceeded more than two times per year (or one time per season) for general access area
<20 m/s	not to be exceeded more than two times per year (or one time per season) where only able bodied people would be expected; frail or cyclists would not be expected

Note: †· The gust equivalent mean (GEM) is the peak 3 s gust wind speed divided by 1.85.

4.5. Data Acquisition and Results

Velocity profile measurements were taken to verify that appropriate boundary layer flow approaching the site was established and to determine the likely pedestrian level wind climate around the test site. Pedestrian wind measurements and analysis are described in Section 4.5.2. All velocity measurements were made with hot-film anemometers, which were calibrated against a Pitot-static tube in the wind tunnel. The calibration data were described by a King's Law relationship (King, 1914).

4.5.1. Velocity Profiles

Mean velocity and turbulence intensity profiles for the boundary layer flow approaching the model are shown in **Figure 15**. Turbulence intensities are related to the local mean wind speed. These profiles have the form as defined in Standards Australia (2011) and are appropriate for the approach conditions.

4.5.2. Pedestrian Winds

The proposed development is located in the heart of the Sydney CBD. The site is located on the south-west corner of Bathurst and Pitt St, **Figure 17**. The development is surrounded by medium to high-rise buildings. Topography surrounding the site is essentially flat from a wind perspective.

For this report wind speed measurements were recorded at 24 locations to evaluate pedestrian comfort in and around the project site, **Figure 20** and **Figure 21**. Testing was conducted for the configurations described in **Table 2**. Wind speed measurements were made at the model scale equivalent of 1.5 to 2.1 m above the surface for 16 wind directions at 22.5° intervals. Locations were chosen to determine the degree of pedestrian comfort on adjacent pavements with pedestrian traffic including near building corners where relatively severe conditions are frequently found, near building entrances, and on site outdoor recreational areas.

The hot-film signal was sampled for a period corresponding to one hour in prototype. All wind speed data were digitally filtered to obtain the two to three second running mean wind speed at each point; this is the minimum size of a gust affecting a pedestrian and is the basis for the various acceptability criteria.

These local wind speeds, U, were normalised by the tunnel reference velocity Uref. Mean and turbulence statistics were measured and used to calculate the normalised effective peak gust using:

$$\frac{U_{pk}}{U_{ref}} = \frac{U + 3U_{rms}}{U_{ref}}$$

The mean and gust equivalent mean velocities relative to the free stream wind tunnel reference velocity at a full-scale elevation of 200 m are plotted in polar form in Appendix 2.

The graphs show wind speed ratio and the approach wind direction for which that measurement was taken. The polar plots aid in visualisation of the effects of the nearby structures or topography, the relative significance of various wind azimuths, and whether the mean or gust wind speed is of greater importance.

To enable a quantitative assessment of the wind environment, the wind tunnel data were combined with wind frequency and direction information measured by the Bureau of Meteorology at a standard height of 10 m at Sydney Airport from 1995 to 2015, **Figure 19**. From these data, directional criterion lines for the Lawson rating wind speeds have been calculated and included on the polar plots in Appendix 2; this gives additional information regarding directional sensitivity at each location.

The criteria of Lawson consider the integration of the velocity measurements with local wind climate statistical data summarised in **Figure 19** to rate each location. From the cumulative wind speed distributions for each location, the percentage of time each of the Lawson comfort rating wind speeds are exceeded are presented in tabular form under the polar plots in Appendix 2. In addition to the rating wind speeds, the percentage of time that 2 m/s is exceeded is also reported. This has been provided as it has been found that the limiting wind speed for long-term stationary activities such as fine outdoor dining should be about 2 to 2.5 m/s rather than 4 m/s.

Interpretation of these wind levels can be aided by the description of the effects of wind of various magnitudes on people. The earliest quantitative description of wind effects was established by Sir Francis Beaufort in 1806, for use at sea; the Beaufort scale is reproduced in **Table 4** including qualitative descriptions of wind effects.

The tables in Appendix 2 additionally provide the wind speed exceeded 5% and 0.022% of the time for direct comparison with the Lawson comfort and distress criteria and the associated Lawson ratings for both mean and GEM wind speeds. A colour coded summary assessment of pedestrian comfort and safety with respect to the Lawson criteria is presented in **Figure 20** and **Figure 21**, for each test location. The implications of the results are discussed in Section 4.6.

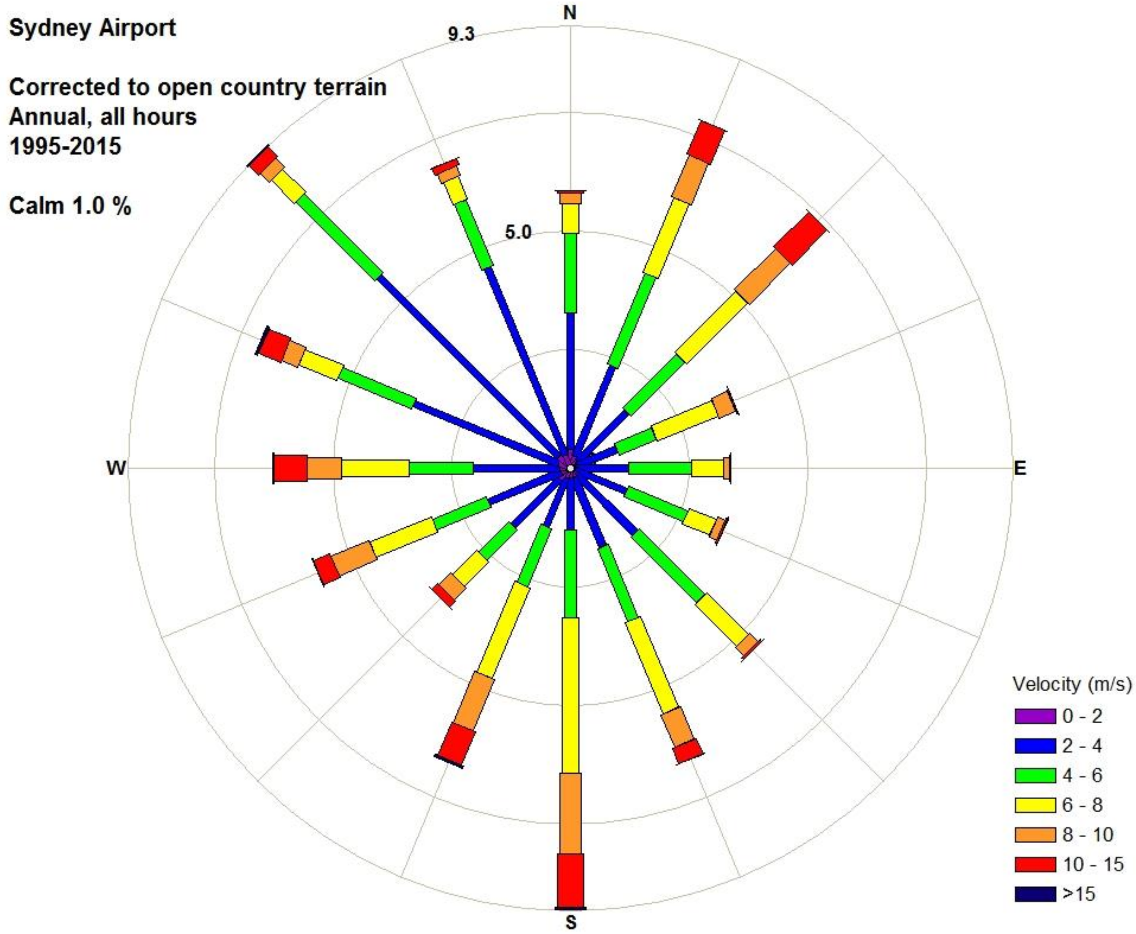


Figure 19: Wind rose of direction and speed for Sydney Airport.

Table 4: Summary of wind effects on people, Penwarden (1973).

Description	Beaufort Number	Speed (m/s)	Effects
Calm, light air	0, 1	0–2	Calm, no noticeable wind.
Light breeze	2	2–3	Wind felt on face.
Gentle breeze	3	3–5	Wind extends light flag. Hair is disturbed. Clothing flaps
Moderate breeze	4	5–8	Raises dust, dry soil, and loose paper. Hair disarranged.
Fresh breeze	5	8–11	Force of wind felt on body. Drifting snow becomes airborne. Limit of agreeable wind on land.
Strong breeze	6	11–14	Umbrellas used with difficulty. Hair blown straight. Difficult to walk steadily. Wind noise on ears unpleasant. Windborne snow above head height (blizzard).
Near gale	7	14–17	Inconvenience felt when walking.
Gale	8	17–21	Generally impedes progress. Great difficulty with balance in gusts.
Strong gale	9	21–24	People blown over by gusts.

4.6. Discussion

The wind climatology chart of **Figure 19** indicates that the most frequent strong winds are from the south, and to a lesser extent from the west and north-east quadrants. The locations tested around the development site are susceptible to winds from the different directions, depending on the relative location of the point tested to the geometry of the proposed development and surrounds. The influence of wind direction on the suitability of a location for an intended purpose can be ascertained from the graphs in Appendix 2.

A summary of the target criteria based on the intended use of the space for the pedestrian level measurement locations and the wind tunnel results including the Lawson comfort and safety ratings is provided in **Table 5**. It is evident from **Table 5** that from a Lawson comfort perspective the majority of locations tested on and around the proposed development met or improved upon the expected target criteria.

The primary conclusions of the pedestrian study can be understood by reviewing the colour coded images of **Figure 20** and **Figure 21**, which depict the locations selected for investigation of pedestrian wind comfort along with the Lawson criteria rating for both comfort and distress. The central colour indicates the comfort rating for the location, and the colour of the outer ring indicates whether the location passes the distress criterion. Mitigation measures are likely to be required for red locations, and may be necessary for other locations depending on the intended use of the space. Although conditions may be classified as acceptable there may be certain wind directions that cause regular strong events, these can be determined by an inspection of the plots in Appendix 2.

Note that testing was performed without planned trees, or other plantings to provide a worst case assessment; heavy landscape planting typically reduces the wind speeds by less than 10%. The wind assessment contained herein is an assessment of the indicative design only, to demonstrate the expected performance of a residential development of the proposed size and massing illustrated in **Figure 18**.

Table 5: Summary of target criteria and wind tunnel results.

Description / Location			Target	Wind Tunnel Results			Notes
				Base case Configuration			
			Comfort rating, 5% exceedance wind speed (m/s)	Comfort rating, 5% exceedance wind speed (m/s)	Meets target Y(es)/N(o)	Safety rating, 0.022% exceedance wind speed (m/s)	
Ground Plane	Remote	1	>6 to 8	4.0	Y	8.5	
Ground Plane	Remote	2	>6 to 8	5.3	Y	9.9	
Ground Plane	Existing	3	>4 to 6	3.8	Y	7.8	
Ground Plane	Existing	4	>4 to 6	4.6	Y	9.3	
Ground Plane	Existing	5	>4 to 6	4.6	Y	10.9	
Ground Plane	Existing	6	>4 to 6	4.2	Y	9.7	
Ground Plane	Existing	7	>6 to 8	4.8	Y	9.3	
Ground Plane	Existing	8	>6 to 8	6.3	Y	12.4	
Ground Plane	Existing	9	>6 to 8	5.6	Y	11.0	
Ground Plane	Existing	10	>4 to 6	3.3	Y	7.2	
Ground Plane	Existing	11	>4 to 6	4.3	Y	8.4	
Ground Plane	Proposed	3.1	>4 to 6	4.2	Y	8.1	
Ground Plane	Proposed	4.1	>4 to 6	4.0	Y	7.7	
Ground Plane	Proposed	5.1	>4 to 6	5.1	Y	10.4	
Ground Plane	Proposed	6.1	>4 to 6	4.5	Y	9.7	
Ground Plane	Proposed	7.1	>6 to 8	4.8	Y	9.3	
Ground Plane	Proposed	8.1	>6 to 8	7.1	Y	13.3	
Ground Plane	Proposed	9.1	>6 to 8	5.6	Y	12.8	
Ground Plane	Proposed	10.1	>4 to 6	2.0	Y	3.7	
Ground Plane	Proposed	11.1	>4 to 6	2.9	Y	7.7	
Terraces	Podium	12.1	>4 to 6	5.8	Y	13.5	
Terraces	Podium	13.1	>4 to 6	3.5	Y	6.8	
Terraces	Upper levels	14.1	>4 to 6	7.4	N	15.3	Implementation of balustrades at least 1.8m high would assist in improving wind conditions
Terraces	Upper levels	15.1	>4 to 6	9.2	N	18.9	Significant shielding in the form of balustrades and vertical screening would be required to improve wind conditions

LEGEND			
Comfort Criteria		**Safety Criteria**	
(magenta)	Outdoor Dining	(green)	Passes safety criteria
(blue)	Pedestrian Sitting	(orange)	Able bodied
(green)	Pedestrian Standing	(red)	Fails safety criteria
(yellow)	Pedestrian Walking		
(orange)	Business Walking		
(red)	Uncomfortable		

The wind conditions at locations remote to the site are presented in **Figure 20**. Wind conditions at Locations 1 and 2 are a representative of general wind conditions in the Sydney CBD for locations nested within the CBD, and in the absence of shielding respectively. These locations are classified as suitable for pedestrian sitting and standing respectively, and give a general indication of the surrounding wind environment and can be used for comparison to the wind conditions in and around the proposed development site.

Figure 20: Pedestrian wind speed measurement locations with comfort/distress ratings – Remote locations.

In the vicinity of the proposed development site the wind conditions at pedestrian level in the existing configuration are generally classified as suitable for pedestrian sitting or standing from a Lawson comfort perspective, **Figure 21**. Wind conditions experienced at Location 8 are rated as pedestrian walking, with downwash from neighbouring buildings for winds from the north-east generating strong channelling flow along Bathurst Street. All locations passed the Lawson distress criterion.

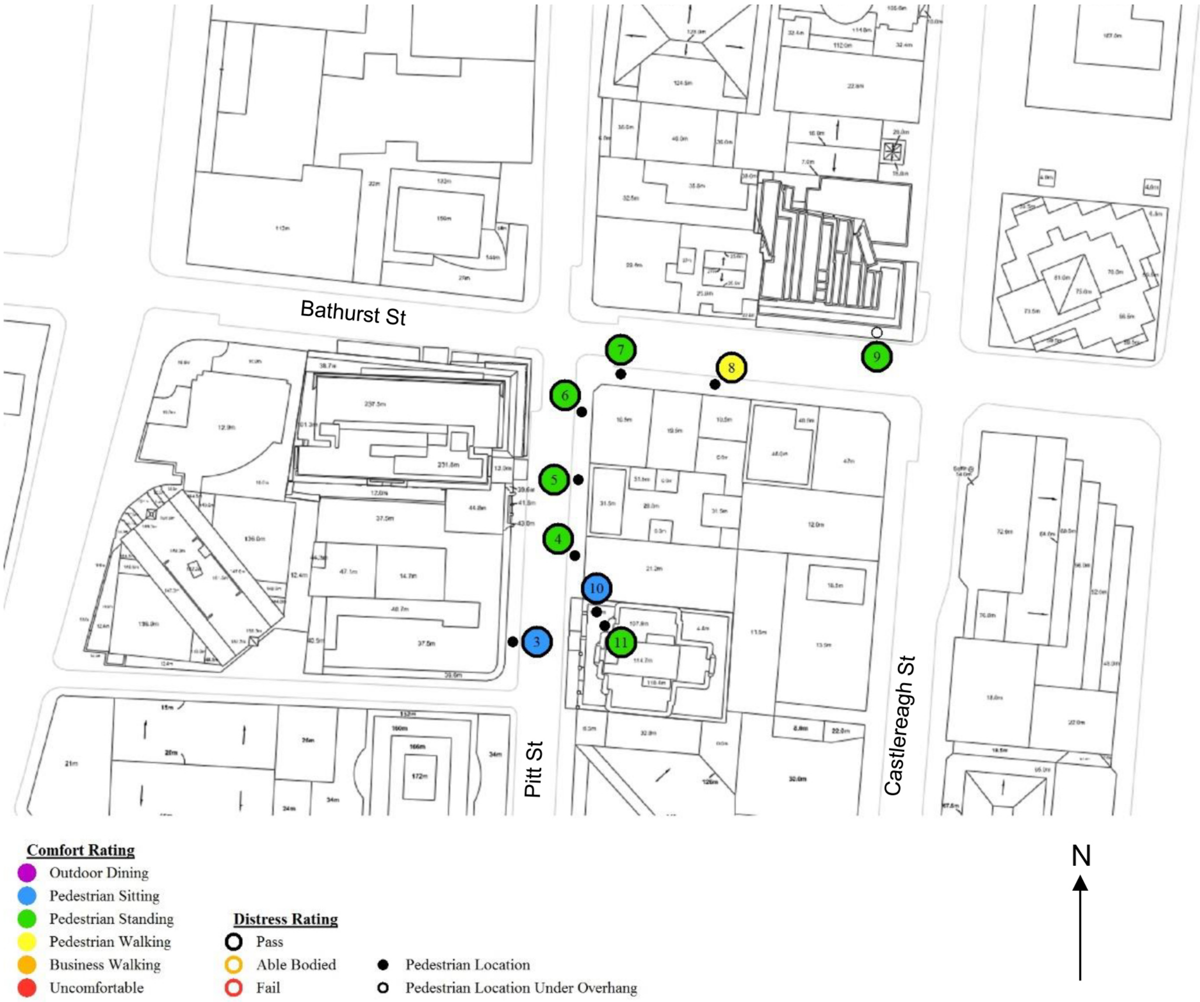


Figure 21: Pedestrian wind speed measurement locations with comfort/distress ratings – Existing configuration.

Wind conditions in the proposed configuration are presented in **Figure 22**, and were found to be very similar to the existing configuration. Location 3.1 was the only location to experience an increase in criterion rating, from pedestrian sitting to standing. Reference to the polar plots presented in Appendix 2 indicates that the wind conditions at Location 3 were only marginally within the pedestrian sitting criterion, and that the increase observed in Location 3.1 is slight. Further, it may be noted that the Location 3.1 meets the upper wind speed associated with the pedestrian sitting criterion more than 90% of the time. Wind conditions on a mid-level balcony on the adjacent Princeton apartment tower, represented by Location 11.1, were found to improve in the proposed configuration, with the proposed tower generating backpressure which assists in diverting approaching flow from the south-west quadrant away from the façade.

Location 12.1 and 13.1 represent wind conditions on the podium terraces, and indicate that wind conditions at these locations are amiable, and pass the Lawson distress criterion. It would be expected that wind conditions at these locations could be improved with the provision of awning elements to assist in shielding these locations from downwash for winds from the north-west and north-east. Due to the exposed nature of the upper level terraces Locations 14.1 and 15.1 are classified as suitable for pedestrian walking and business walking respectively, with both locations exceeding the distress criterion. Location 14.1 is exposed to winds from the north-west and south-east, implementation of a high, greater than 1.8 m, balustrade would be expected to assist in improving conditions over the upper terrace. Given the height of the tower Location 15.1 is subjected to strong unimpeded winds from most directions which accelerate over the roof edge; high balustrades and vertical screening to create localised areas of calm would be required if this space were to be activated.

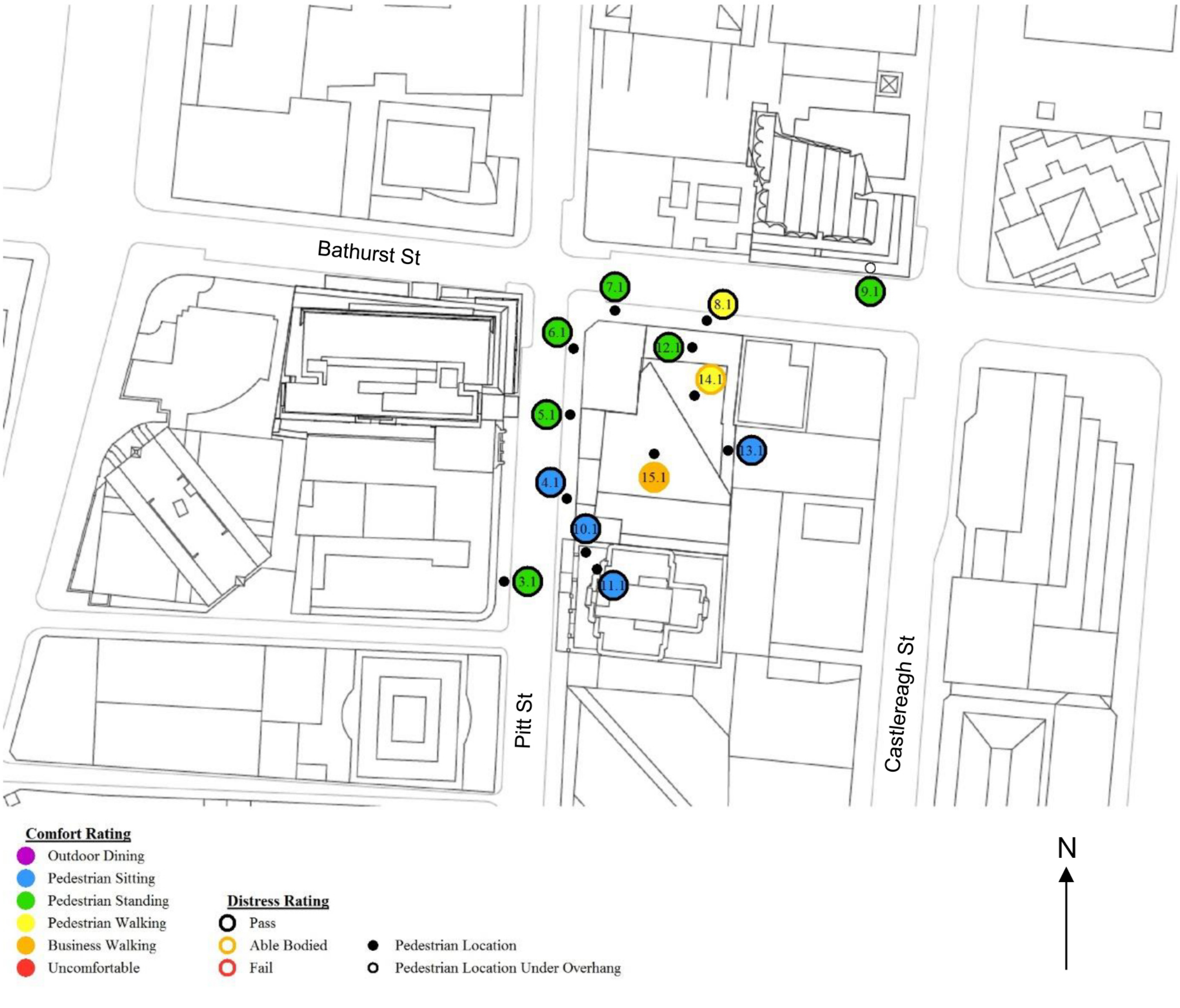


Figure 22: Pedestrian wind speed measurement locations with comfort/distress ratings – Proposed configuration.

4.7. References

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Appendix 1: Additional photographs of the CPP wind tunnel model

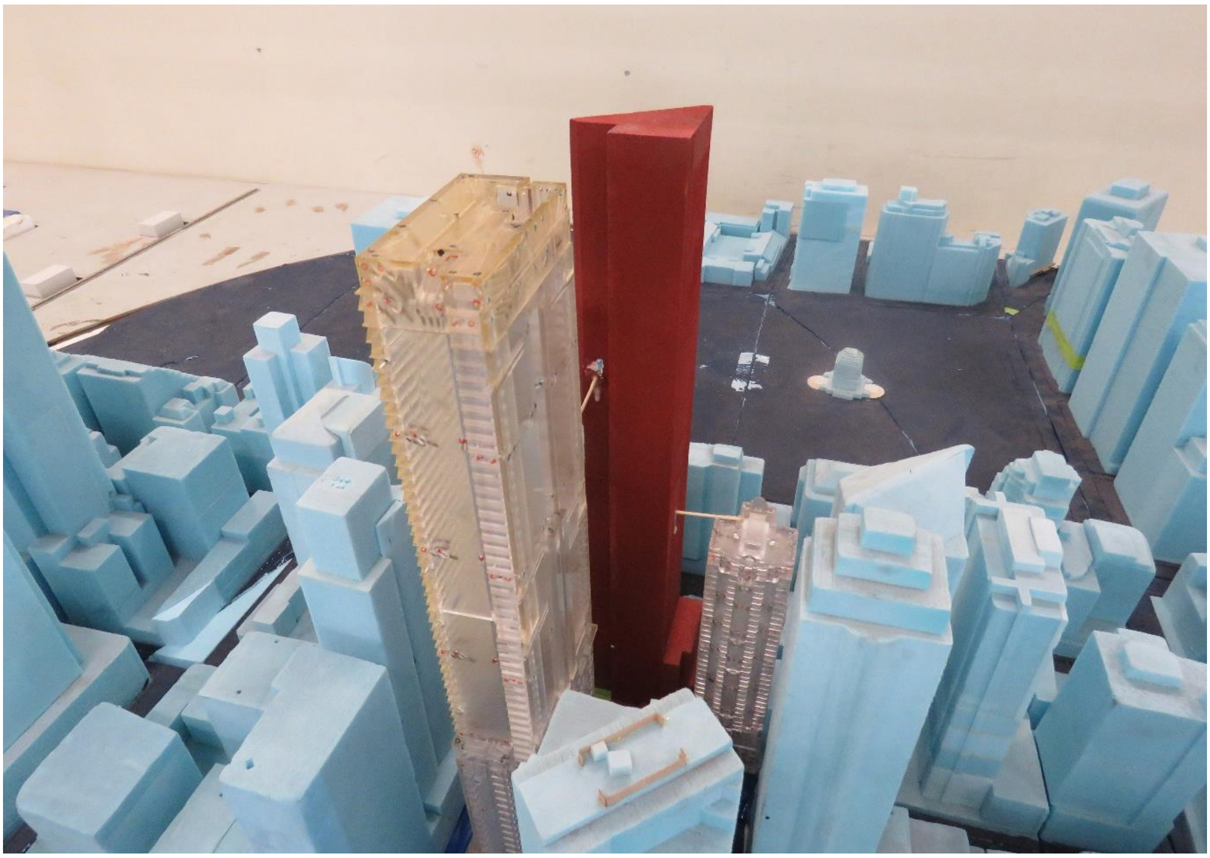
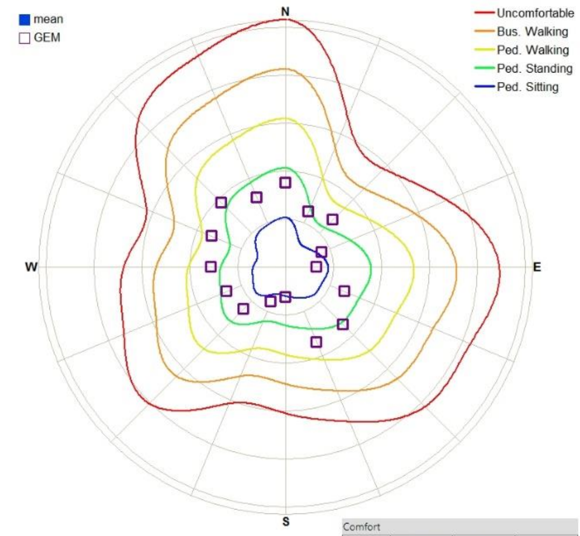


Figure 23: Close-up of the proposed Sydney Metro – over station development model viewed from the west.

Appendix 2: Directional Wind Results

Existing configuration

LOCATION 1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	14.90	37.38	37.38
4	0.58	4.98	4.98
6	0.03	0.51	0.51
8	0.00	0.05	0.05
10	0.00	0.00	0.00

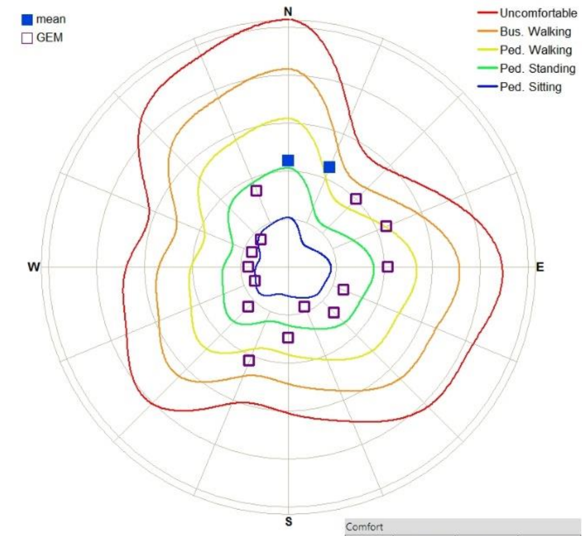
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	2.6	4.0	4.0
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	6.2	8.5	8.5
Rating	Pass	Pass	Pass

LOCATION 2



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	28.22	41.47	42.45
4	10.09	13.21	14.11
6	1.73	2.23	2.74
8	0.13	0.24	0.28
10	0.00	0.02	0.02

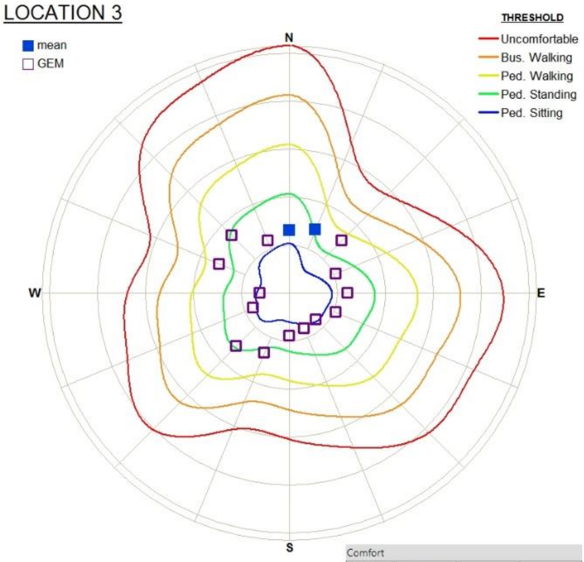
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.9	5.2	5.3
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.0	9.8	9.9
Rating	Pass	Pass	Pass

LOCATION 3



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	19.09	30.06	30.38
4	2.64	4.11	4.24
6	0.16	0.39	0.40
8	0.00	0.02	0.02
10	0.00	0.00	0.00

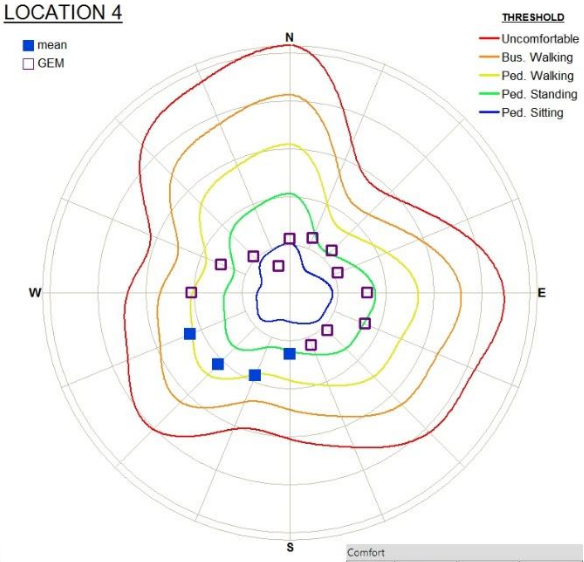
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.4	3.8	3.8
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.0	7.8	7.8
Rating	Pass	Pass	Pass

LOCATION 4



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	28.38	43.11	44.11
4	6.10	7.11	8.65
6	0.90	0.85	1.29
8	0.09	0.08	0.14
10	0.01	0.01	0.01

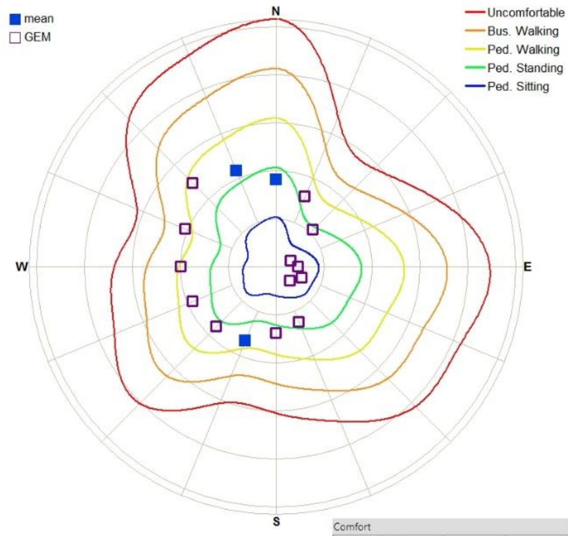
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.2	4.3	4.6
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.1	8.8	9.3
Rating	Pass	Pass	Pass

LOCATION 5



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	30.49	47.21	47.55
4	4.60	9.05	9.62
6	0.37	1.51	1.62
8	0.03	0.30	0.31
10	0.00	0.06	0.06

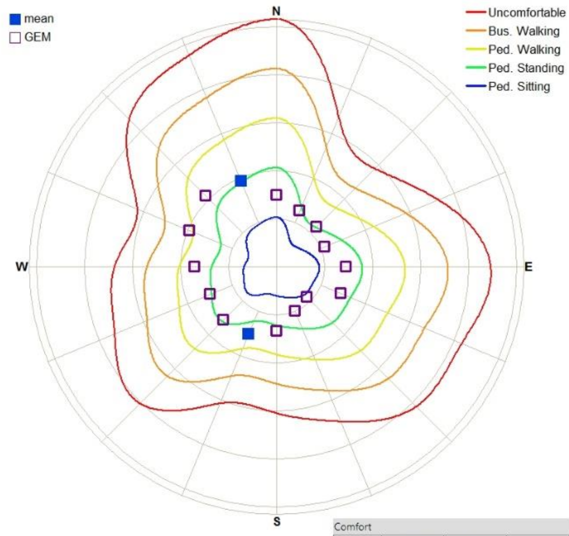
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.9	4.6	4.6
Rating	Ped Sitting	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.1	10.9	10.9
Rating	Pass	Pass	Pass

LOCATION 6



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	30.89	46.45	47.08
4	3.76	5.87	6.37
6	0.41	0.89	0.94
8	0.03	0.16	0.17
10	0.00	0.01	0.02

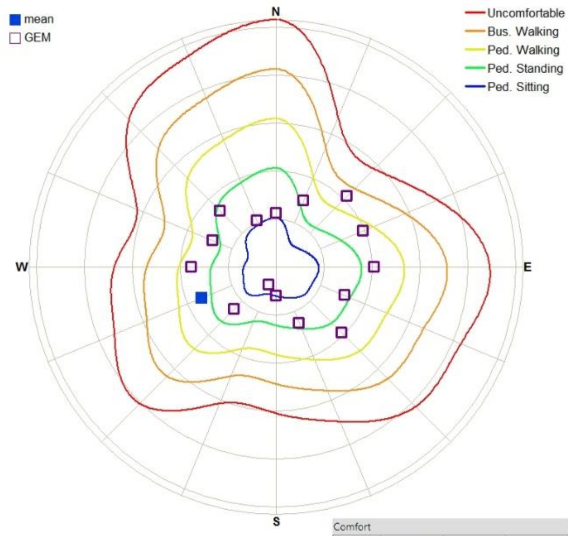
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.7	4.1	4.2
Rating	Ped Sitting	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.1	9.7	9.7
Rating	Pass	Pass	Pass

LOCATION 7



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	30.01	40.24	40.24
4	5.57	9.79	9.79
6	0.66	1.51	1.51
8	0.04	0.18	0.18
10	0.00	0.01	0.01

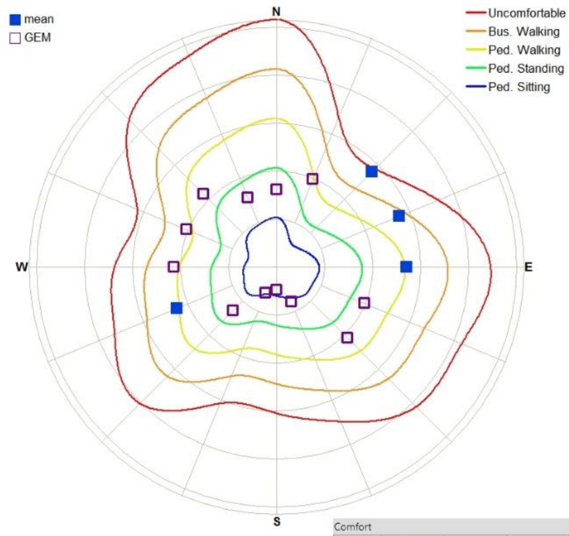
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.1	4.8	4.8
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	8.3	9.3	9.3
Rating	Pass	Pass	Pass

LOCATION 8



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	43.17	47.13	47.63
4	17.08	17.39	18.46
6	5.96	5.00	6.21
8	1.49	0.88	1.52
10	0.34	0.12	0.35

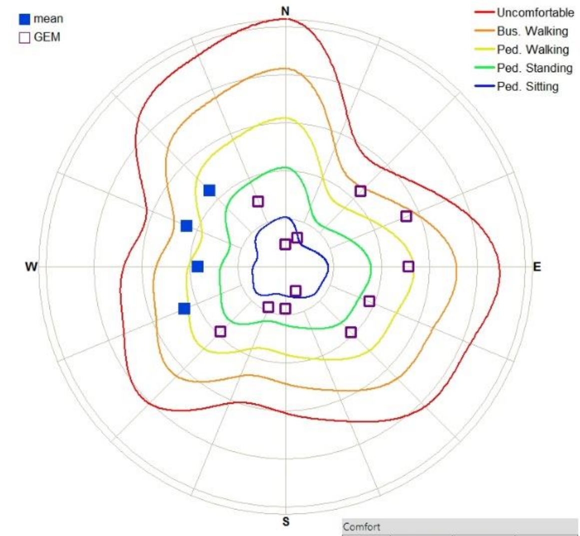
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	6.2	5.9	6.3
Rating	Ped Walking	Ped Standing	Ped Walking

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	12.4	11.3	12.4
Rating	Pass	Pass	Pass

LOCATION 9



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	35.69	42.68	44.69
4	9.07	13.20	14.65
6	1.63	3.42	3.99
8	0.33	0.53	0.71
10	0.06	0.03	0.09

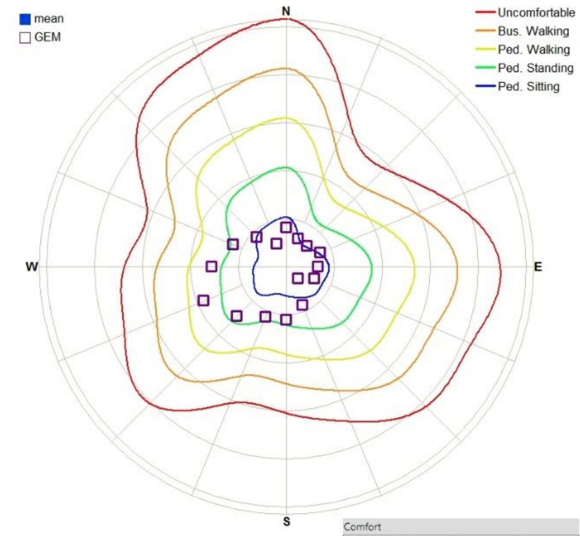
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.7	5.4	5.6
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	10.9	10.2	11.0
Rating	Pass	Pass	Pass

LOCATION 10



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	13.33	21.34	21.34
4	0.98	2.37	2.37
6	0.05	0.15	0.15
8	0.00	0.01	0.01
10	0.00	0.00	0.00

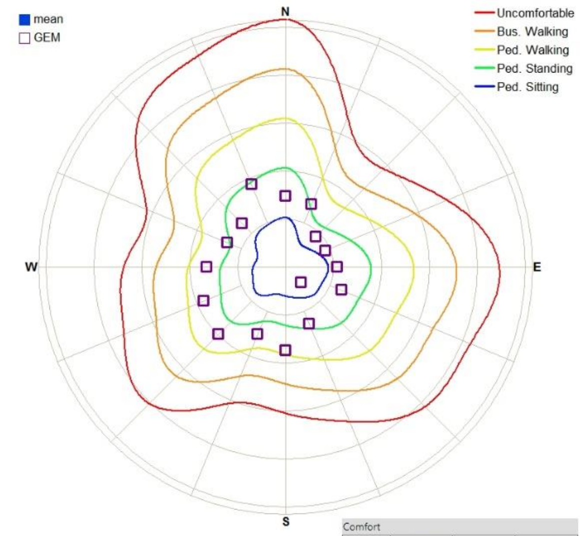
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	2.8	3.3	3.3
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	6.5	7.2	7.2
Rating	Pass	Pass	Pass

LOCATION 11



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	27.43	41.00	41.00
4	4.47	7.36	7.36
6	0.36	0.70	0.70
8	0.02	0.04	0.04
10	0.00	0.00	0.00

Comfort

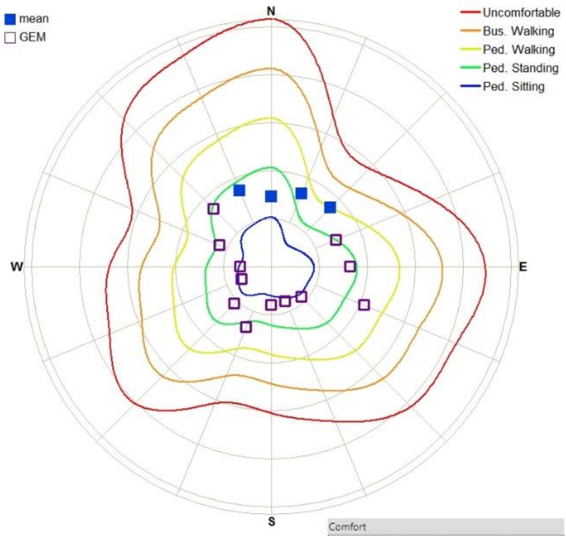
(5%)	MEAN	GEM	COMBINED
V (m/s)	3.8	4.3	4.3
Rating	Ped Sitting	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.9	8.4	8.4
Rating	Pass	Pass	Pass

Proposed configuration

LOCATION 3.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	22.39	32.42	33.45
4	4.58	5.71	6.48
6	0.46	0.51	0.62
8	0.01	0.02	0.03
10	0.00	0.00	0.00

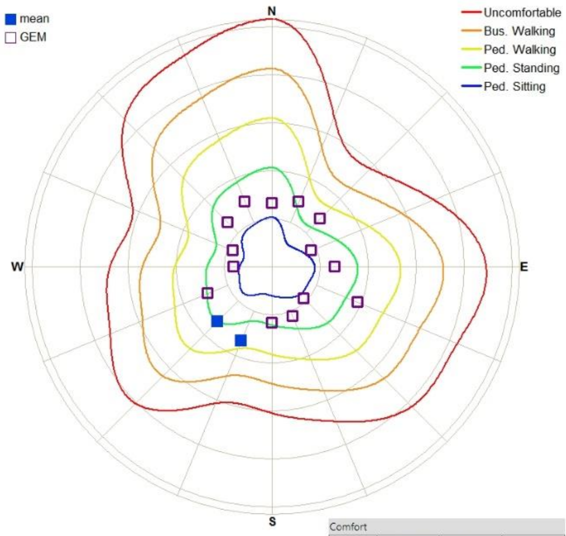
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.9	4.1	4.2
Rating	Ped Sitting	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.7	7.9	8.1
Rating	Pass	Pass	Pass

LOCATION 4.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	22.75	36.72	36.90
4	2.23	4.78	5.07
6	0.18	0.23	0.29
8	0.01	0.01	0.02
10	0.00	0.00	0.00

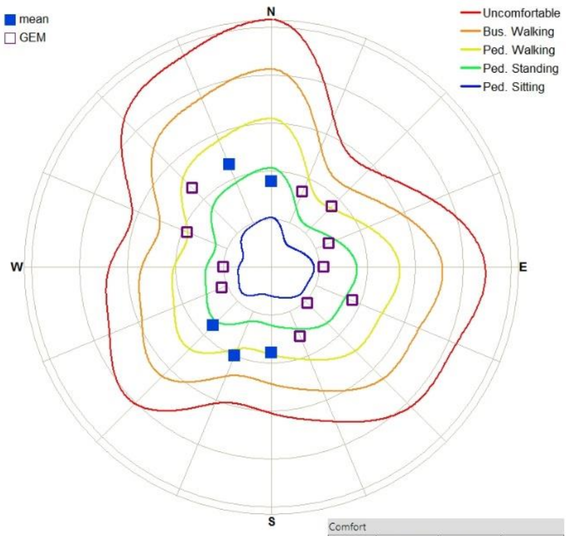
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.3	3.9	4.0
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	7.6	7.4	7.7
Rating	Pass	Pass	Pass

LOCATION 5.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	41.06	52.09	53.43
4	9.28	11.94	13.64
6	1.34	1.79	2.31
8	0.17	0.24	0.32
10	0.02	0.03	0.04

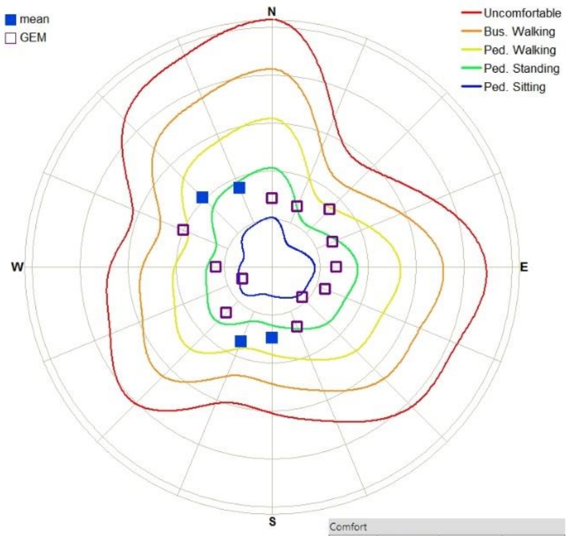
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.6	4.9	5.1
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.7	10.3	10.4
Rating	Pass	Pass	Pass

LOCATION 6.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	31.42	44.47	45.42
4	4.90	7.87	8.65
6	0.51	1.13	1.30
8	0.07	0.16	0.18
10	0.01	0.01	0.02

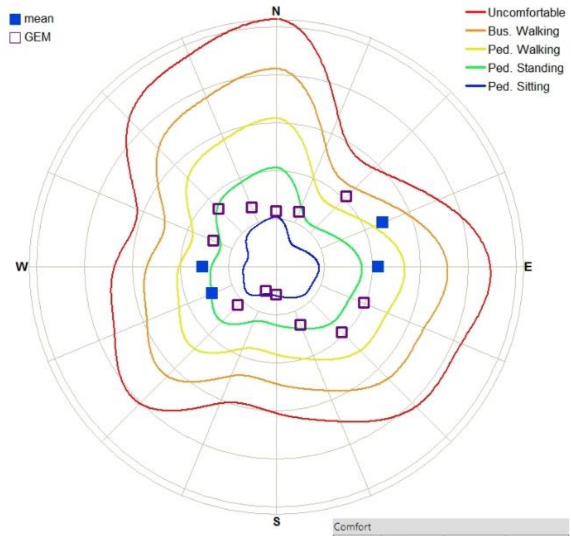
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	3.9	4.4	4.5
Rating	Ped Sitting	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	9.0	9.6	9.7
Rating	Pass	Pass	Pass

LOCATION 7.1

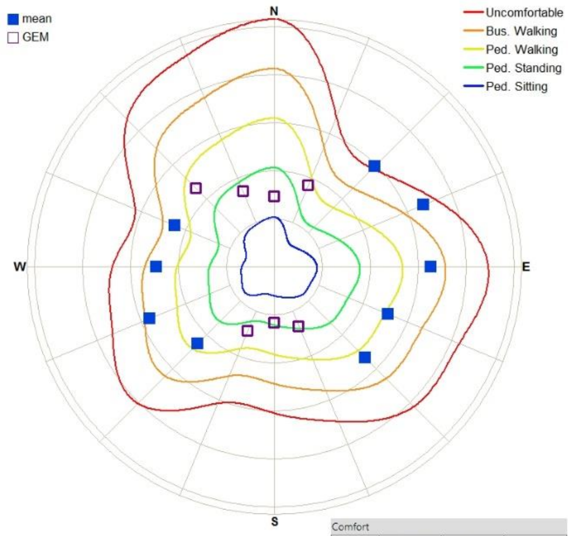


% of time in excess of wind speed V			
V (m/s)	**MEAN**	**GEM**	**COMBINED**
2	31.20	39.58	40.21
4	6.86	9.52	9.95
6	0.77	1.62	1.75
8	0.02	0.17	0.18
10	0.00	0.01	0.01

Comfort			
(5%)	**MEAN**	**GEM**	**COMBINED**
V (m/s)	4.3	4.8	4.8
Rating	Ped Standing	Ped Standing	Ped Standing

Safety			
(0.022%)	**MEAN**	**GEM**	**COMBINED**
V (m/s)	8.0	9.2	9.3
Rating	Pass	Pass	Pass

LOCATION 8.1

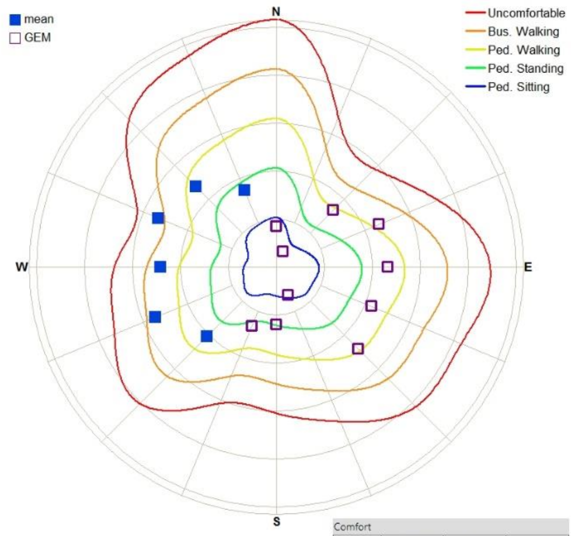


% of time in excess of wind speed V			
V (m/s)	**MEAN**	**GEM**	**COMBINED**
2	54.84	62.32	64.30
4	22.79	21.62	25.03
6	9.33	6.89	9.56
8	2.91	1.64	2.93
10	0.65	0.33	0.66

Comfort			
(5%)	**MEAN**	**GEM**	**COMBINED**
V (m/s)	7.1	6.4	7.1
Rating	Ped Walking	Ped Walking	Ped Walking

Safety			
(0.022%)	**MEAN**	**GEM**	**COMBINED**
V (m/s)	13.3	12.4	13.3
Rating	Pass	Pass	Pass

LOCATION 9.1

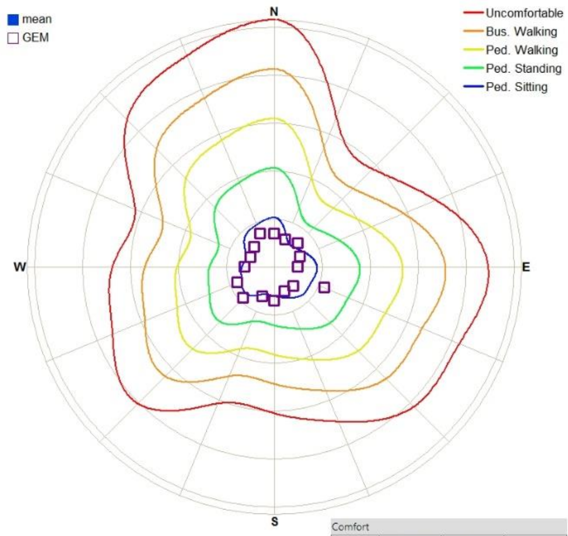


% of time in excess of wind speed V			
V (m/s)	**MEAN**	**GEM**	**COMBINED**
2	41.89	48.93	53.23
4	9.97	13.71	17.53
6	2.87	2.18	3.87
8	0.90	0.25	0.94
10	0.23	0.03	0.23

Comfort			
(5%)	**MEAN**	**GEM**	**COMBINED**
V (m/s)	5.0	5.1	5.6
Rating	Ped Standing	Ped Standing	Ped Standing

Safety			
(0.022%)	**MEAN**	**GEM**	**COMBINED**
V (m/s)	12.8	10.2	12.8
Rating	Pass	Pass	Pass

LOCATION 10.1

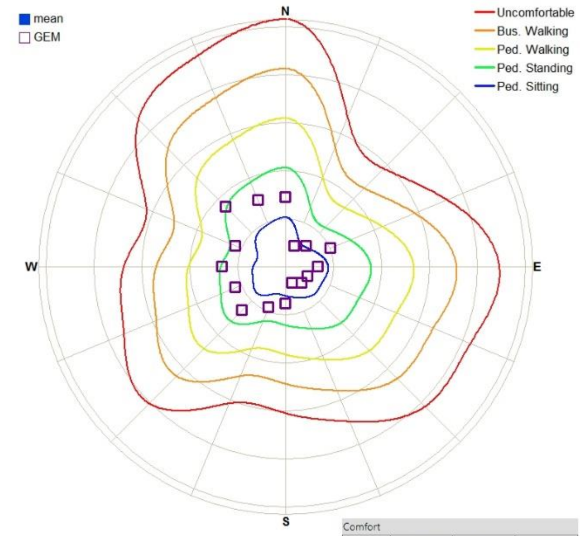


% of time in excess of wind speed V			
V (m/s)	**MEAN**	**GEM**	**COMBINED**
2	0.25	5.27	5.27
4	0.00	0.01	0.01
6	0.00	0.00	0.00
8	0.00	0.00	0.00
10	0.00	0.00	0.00

Comfort			
(5%)	**MEAN**	**GEM**	**COMBINED**
V (m/s)	1.3	2.0	2.0
Rating	Outdoor Dining	Ped Sitting	Ped Sitting

Safety			
(0.022%)	**MEAN**	**GEM**	**COMBINED**
V (m/s)	2.4	3.7	3.7
Rating	Pass	Pass	Pass

LOCATION 11.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	6.54	18.47	18.47
4	0.29	1.24	1.24
6	0.02	0.11	0.11
8	0.00	0.02	0.02
10	0.00	0.00	0.00

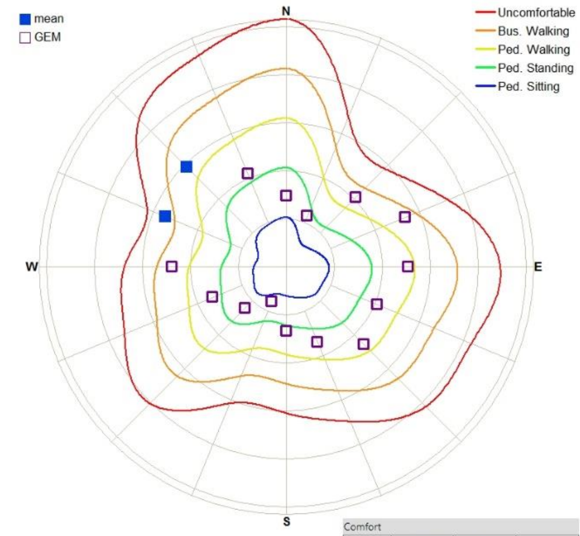
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	2.1	2.9	2.9
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	5.8	7.7	7.7
Rating	Pass	Pass	Pass

LOCATION 12.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	38.68	58.87	60.45
4	9.31	17.41	18.61
6	2.47	4.17	4.63
8	0.88	0.86	1.16
10	0.28	0.18	0.30

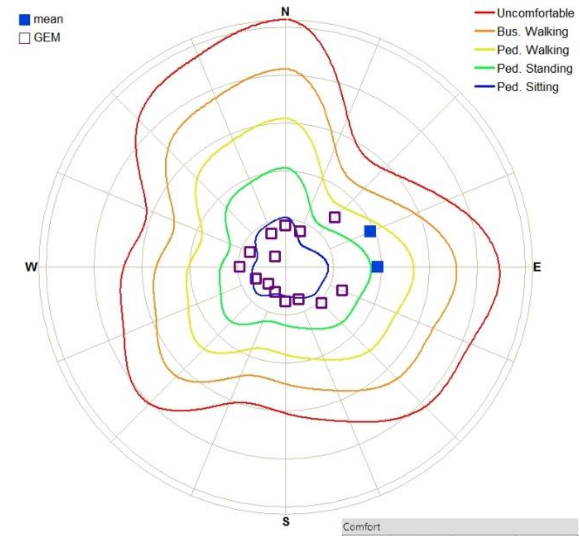
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	4.8	5.7	5.8
Rating	Ped Standing	Ped Standing	Ped Standing

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	13.5	12.1	13.5
Rating	Pass	Pass	Pass

LOCATION 13.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	10.07	17.80	17.89
4	1.65	2.67	2.86
6	0.05	0.10	0.11
8	0.00	0.00	0.00
10	0.00	0.00	0.00

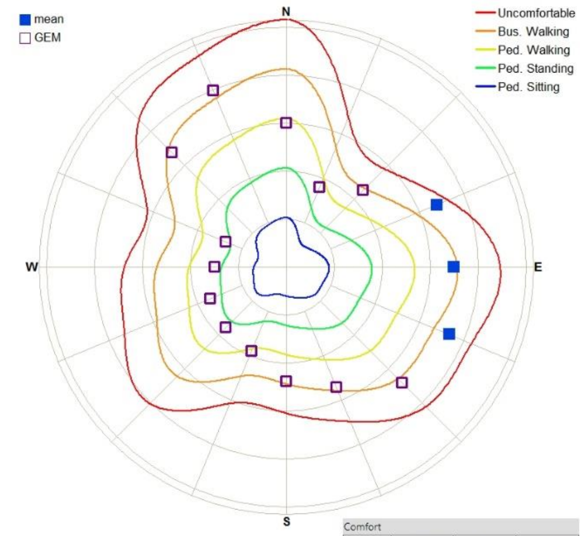
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	2.9	3.4	3.5
Rating	Ped Sitting	Ped Sitting	Ped Sitting

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	6.4	6.7	6.8
Rating	Pass	Pass	Pass

LOCATION 14.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	57.97	74.81	75.02
4	19.92	36.32	37.03
6	6.75	11.56	12.80
8	1.66	2.88	3.40
10	0.32	0.66	0.77

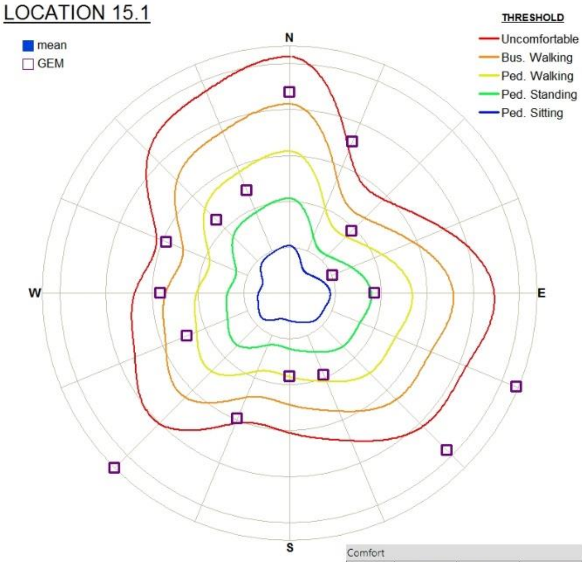
Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	6.4	7.1	7.4
Rating	Ped Walking	Ped Walking	Ped Walking

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	13.1	15.2	15.3
Rating	Pass	Able Body	Able Body

LOCATION 15.1



% of time in excess of wind speed V

V (m/s)	MEAN	GEM	COMBINED
2	60.21	76.74	76.74
4	23.68	39.96	39.96
6	9.05	18.68	18.68
8	3.69	8.74	8.74
10	1.45	3.56	3.56

Comfort

(5%)	MEAN	GEM	COMBINED
V (m/s)	7.2	9.2	9.2
Rating	Ped Walking	Bus Walking	Bus Walking

Safety

(0.022%)	MEAN	GEM	COMBINED
V (m/s)	17.8	18.9	18.9
Rating	Able Body	Able Body	Able Body

5.0 Wind Impact of 201 Elizabeth Street

Please find below a brief review of the recently approved development at 201 Elizabeth Street and its potential influence on the Pitt Street South site. The approved 201 Elizabeth Street development consists of a 50 story mixed use building, comprising a prismatic tower orientated in a roughly south-east to north-west direction, **Figure 24**.

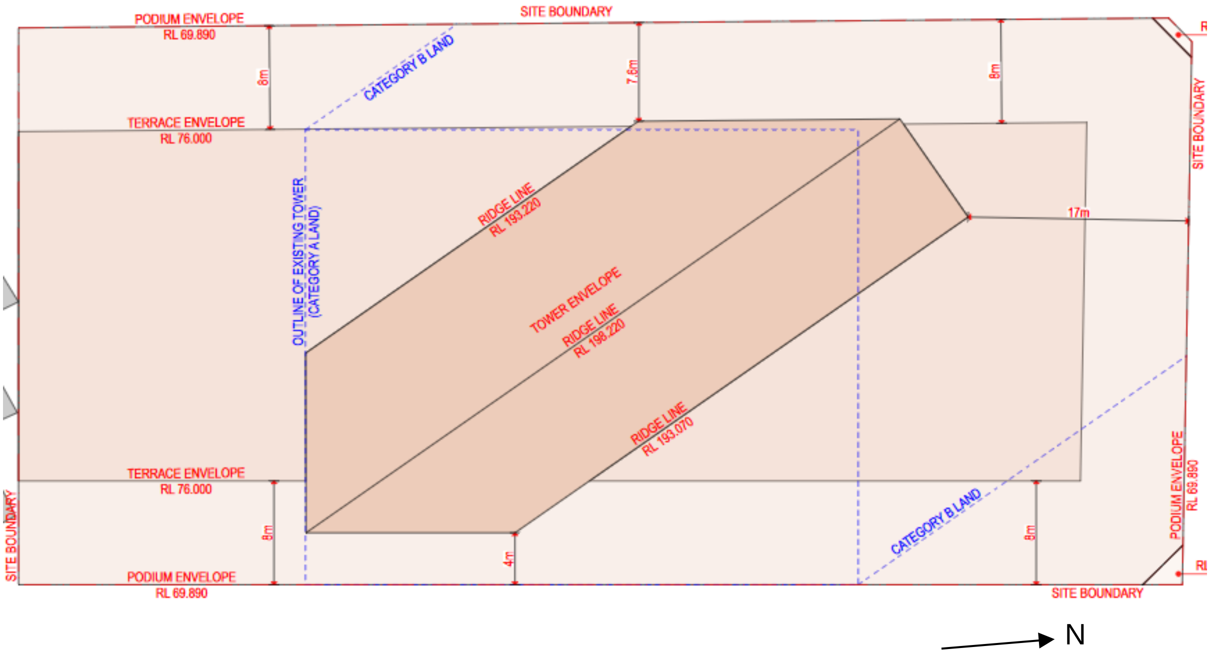


Figure 24: Plan view of approved 201 Elizabeth Street development

The 201 Elizabeth Street development is upwind of the Pitt Street South site for prevailing winds from the north-east. The orientation of the approved tower envelope within the Elizabeth Street site would be expected to provide a similar level of shielding to the Pitt Street South site as the existing 201 Elizabeth Street tower. Therefore, the results and conclusions of the wind assessments contained within Sections 2.0 and 4.0 are considered representative of the performance of the proposed Pitt Street South OSD from a wind comfort perspective.

6.0 Addendum – Letter dated 10 May 2018

CERMAK PETERKA PETERSEN

WIND ENGINEERING AND AIR QUALITY CONSULTANTS

10 May 2018 CPP Project 9272

GHD Woodhead
Level 15, 133 Castlereagh Street
Sydney
NSW 2000

Attn: Mr. Nicolas Beaulieu-Asselin
Project: Pitt Street South OSD

Dear Mr. Beaulieu-Asselin,

Please find herein a brief review of the updated Pitt Street South Over Station Development (OSD) design, and comment on the applicability of the results of previously conducted wind tunnel testing to the revised design.

The updated design includes a similar tower floorplate layout to the original, Figure 1, but incorporates a decrease in tower height of approximately 90 m, Figure 2. The articulation of the tower crown has also been altered, with a diagonal cut from east to west, Figure 2. It is noted that the podium design, Level 8 and below, remains unchanged from the original design, though the tower setback from the northern podium edge has been reduced from 8 m to 4 m.

From a wind perspective, the most significant of the design changes is the reduction in height of the tower. Wind conditions along the ground plane in this section of the Sydney CBD tend to be dictated by exposed large towers and local topography. Prevailing winds are brought to ground level in the form of downwash by large exposed towers, and the downwash is channelled along the streets by the general massing of the surrounding buildings. The significant reduction in height of the Pitt Street South OSD greatly reduces the potential for downwash from the tower, as tall buildings in the immediate vicinity would provide considerable shielding to the subject building from prevailing winds. With the reduction in downwash from the shorter tower, the decrease in setback of the tower from the north podium edge would not be expected to significantly affect ground level wind conditions. As a result, the pedestrian level wind tunnel study presented in CPP report "CPP9272_Over Station Development_REP_PW_R04" (2018) would be considered a worst-case assessment of the wind impact of the updated Pitt Street South OSD design, and therefore a conservative estimate of the expected ground level wind conditions.

CERMAK
PETERKA
PETERSEN

WIND ENGINEERING AND AIR QUALITY CONSULTANTS

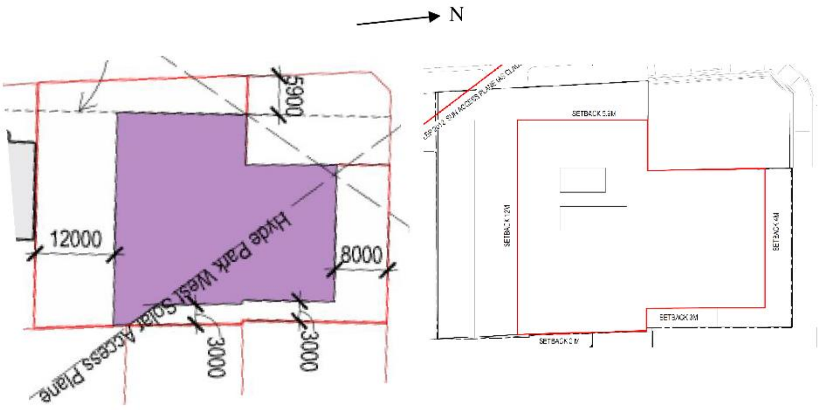


Figure 1: Typical tower floor plans for the original (L) and updated (R) designs

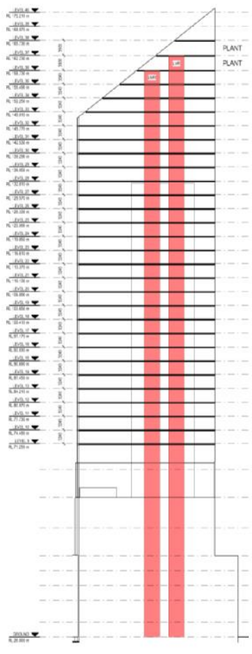


Figure 2: Section view of the updated tower design, viewed from the north

2

Please do not hesitate to contact me if you have any questions regarding any aspect of this letter.

Yours sincerely,

Adam Van Duijneveldt
Project Engineer

cc: Matthew Glanville, Managing Director

REFERENCES

CPP (2018), Pitt Street South Over Station Development: Pedestrian-level wind assessment, CPP Project 9272, March 2018.