WINDTECH

# WIND ENVIRONMENT ASSESSMENT

## THE STAR KEY SITE MASTERPLAN

WA531-21F02(REV2)- WS REPORT

SEPTEMBER 13, 2021

Prepared for:

Star Entertainment Group

80 Pyrmont Street,
Pyrmont, NSW 2009

# DOCUMENT CONTROL

| Date | Revision History | Issued Revision | Prepared By (initials) | Instructed By (initials) | Reviewed & Authorised by (initials) |
|---|---|---|---|---|---|
| 23 August 2021 | Initial. | 0 | HK | TR | TR |
| 1 September, 2021 | Updated Introduction text and addressed comments | 1 | HK | TR | TR |
| 13 September, 2021 | Updated cover image | 2 | HK | TR | TR |
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# EXECUTIVE SUMMARY

This report presents an opinion on the likely impact of The Star Key Site Masterplan, located in Pyrmont, on the local wind environment at the critical outdoor areas within and around the subject site. The effect of wind activity has been examined for the three predominant wind directions for the region, namely the north-easterly, southerly, and westerly winds. The analysis of the wind effects relating to the proposed development have been carried out in the context of the local wind climate, building morphology and land topography.

The conclusions of this report are drawn from our extensive experience in this field and are based on an examination of the latest architectural drawings. No wind tunnel testing has been undertaken for the subject development, and hence this report addresses only the general wind effects and any localised effects that are identifiable by visual inspection of the architectural drawings provided (received 18 August 2021). Any recommendations in this report are made only in-principle and are based on our extensive experience in the study of wind environment effects.

The results of this assessment indicate that the development has incorporated several important design features that aid in mitigating potential wind environment impacts at the street level. These include significant tower setbacks from the podium, particularly from the southern aspect of the South Tower and the northern tip of the North Tower. The proposed strategic placement of awnings along Union St and around the northern section of the North Tower podium together with the proposed retention of street trees along Union St and Pyrmont Bridge Road as well as strategic planting of trees along Pirrama Road will all assist in achieving the level of pedestrian comfort needed to activate the Union St and Pirrama Rd aspects of the site as well as maintain pedestrian comfort in the surrounding streetscapes.

Wind tunnel testing is recommended to be undertaken to quantitatively assess the wind conditions around the site at a more detailed design stage.

# CONTENTS

# 1 INTRODUCTION

This report has been prepared on behalf of The Star Entertainment Group (The Star) in support of its Key Site Master Plan under the Pyrmont Place Strategy.

The Master Plan is developed under the framework established under the Pyrmont Peninsula Place Strategy (PPPS), where The Star has been identified as one of four 'key sites'. The PPPS creates a 20-year vision and planning framework to support the NSW Government's vision to transform the Pyrmont Peninsula to "be an innovative, creative and cultural precinct and an engine room of the Eastern Harbour CBD" while meeting the aspirations of the business, industry, visitors, local and future residents.

The Master Plan ultimately seeks to inform updated planning controls related to 20-80 Pyrmont Street and 37-69 Union Street, Pyrmont to facilitate redevelopment of both sites and enable the Star's contribution to the Precinct as "a renowned and treasured cultural and entertainment precinct".

In particular, this report provides an opinion on the likely impact of the proposed design on the local wind environment affecting pedestrians within the critical outdoor areas within and around the subject development is presented in this report. The analysis of wind effects relating to the proposed development has been carried out in the context of the predominant wind directions for the region, building morphology of the development and nearby buildings, and local land topography. The conclusions of this report are drawn from our extensive experience in the field of wind engineering and studies of wind environment effects.

No wind tunnel testing has been undertaken for this assessment. Hence this report addresses only the general wind effects and any localised effects that are identifiable by visual inspection, and any recommendations in this report are made only in-principle.

It should be acknowledged this report has been prepared based on the provided information in the PPPS and the technical consultant reports that accompany the document. Assumptions have had to be made in order to make a reasonable assessment of the precinct-wide matters related to the pedestrian wind environment effects.

## 1.1 Pyrmont Peninsula Place Strategy

The PPPS provides a 20-year framework that identifies areas that can accommodate growth in Darling Island, Blackwattle Bay, Tumbalong Park and Ultimo sub-precincts, while enabling more growth in the Pyrmont Village and Wentworth Park sub-precincts. The PPPS is implemented in the statutory planning system by a Ministerial Direction that requires all land use and planning proposals to be consistent with the Place Strategy.

The first phase in implementing the PPPS is the preparation of master plans for each of the seven sub-precincts that make up the Peninsula (Figure 1). As a 'Key Site' located in the Darling Island sub-precinct, The Star has been identified to progress its own Master Plan for its 'Key Site' alongside the broader Precinct-wide master planning being undertaken by the Department, in consultation with the City of Sydney.


Figure 1: Pyrmont Peninsula Sub-Precincts

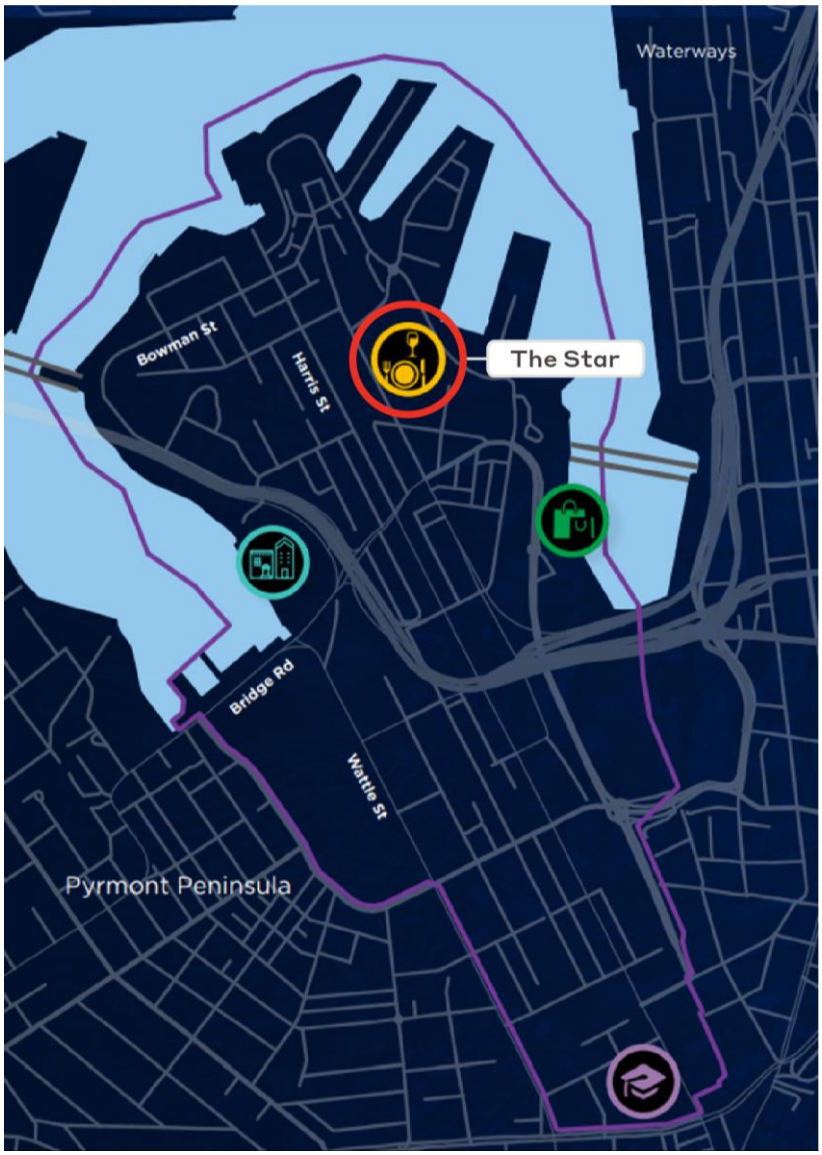


Figure 2: The Star Key Site

## 1.2 The Star

The Star is an ASX 100 listed company that owns and operates The Star Sydney, Treasury Brisbane and The Star Gold Coast.

The Star Sydney is Sydney's leading entertainment, dining and tourism destination. More than 11 million people, including locals, domestic visitors and international tourists visit The Star annually, facilitated by a workforce of approximately 4,500 people (pre-COVID). As Sydney's only integrated resort, The Star Sydney focuses on the development of tourism and entertainment products across four key segments – accommodation, F&B, gaming and entertainment.

## 1.3 The Proposal

The Star Key Site Master Plan is proposing to rezone 20-80 Pyrmont Street and 37-69 Union Street, Pyrmont to establish new planning controls to enable redevelopment on the site to accommodate future mixed uses including retail, commercial uses, hotel and residential. The site is outlined in Figure 3.


Figure 3: Site Aerial (Source: Nearmap/Ethos Urban)

The rezoning and proposed planning controls have been informed by detailed site planning considerations as well as existing and future local context analysis. The proposed new controls that comprise amendments to the Sydney Local Environmental Plan 2012 (Sydney LEP 2012) and a Design Guide, respond to the objectives for The Star site Master Plan as listed in the PPPS as well as the Strategy's directions, big moves and place priorities.

It should be noted that subsequent development applications will be required in line with the relevant provisions of the *Environmental Planning & Assessment Act 1979* to deliver the proposed developments.

The key development outcomes sought to be achieved for The Star site from the proposed Master Plan include:

### Northern Site (20-80 Pyrmont Street)

- A new 27 storey six star hotel (capped at RL 110) on Pirrama Road (North Tower) comprising;
  - 6 storey podium that retains the existing ground level setback on The Star site
  - 21 storey tower with 1.5m street setback from podium and increased minimum 7m street setback to the north in line with wind advice and view sharing principles
  - Total gross floor area of 26,000m$^2$ (excluding through-site link)
  - New porte-cochere drop off servicing hotel
- Additional built form to Level 5 rooftop of the main Star site comprising:

- A collection of indoor and outdoor spaces with complementary functions such as indoor/outdoor dining opportunities, recreational spaces, wellness spaces and hotel amenities, including an existing hotel pool
- Total of approximately 3,000m$^2$ (additional to existing)

- Opening up of Pirrama Road frontage to reveal light rail and to provide improved connectivity to public realm and waterfront including:
  - Active uses such as retail, food and beverage and wellness uses at street level; and
  - Total GFA of approximately 200m$^2$ (additional to existing).
- New through-site link connecting Jones Bay Road and Pirrama Road
- Re-configured and expanded entry to the Lyric Theatre
- Façade upgrades to existing Astral Towers

### Southern Site (37-69 Union Street)

- A new 37 storey mixed use building (capped at RL 140) on Union Street (South Tower) comprising:
  - 5 storey podium mixed use podium with a 3m ground level setback along the Pyrmont Bridge Road boundary to increase footpath width, comprising uses such as retail, residential and hotel amenities and/or dedicated hotel levels
  - 32 storey tower generally setback 5-7m from the podium, comprising uses such as retail, residential and hotel amenities and/or dedicated hotel levels and 2 plant levels
  - Total GFA of approximately 32,000m$^2$

### Public Realm

- Upgrades to corner of Edward Street and Union Street
- Upgrades to corner of Union Street and Pyrmont Street
- Improvements to public domain along Edward Street
- Improvements to public domain along Pirrama Road
- Upgrades to Union Street with potential for shared zone, including upgrades to walkway and cycleway

Once new planning controls are adopted, The Star will progress with the detailed design and planning of the future development on the site, including progressing with a design competition and securing development approval for the winning design.

## 1.4 General Requirements

This report has been prepared with reference to the *General Requirements for Preparing Key Site Master Plans under the Pyrmont Peninsula Place Strategy* and the alignment review prepared by the Department of Planning, Industry and Environment (DPIE) dated 26 April 2021.

# 2 DESCRIPTION OF DEVELOPMENT AND SURROUNDINGS

The proposed masterplan development site is located in Pyrmont, and is bounded by Pirrama Road, Edward Street, Union Street, Pyrmont Bridge Road, Pyrmont Street and Jones Bay Road. Immediately surrounding the site to the north-east is Pyrmont Bay and Pyrmont Bay Park to the east, and predominantly low to medium rise buildings to the north, south and west. The Pyrmont peninsula is bounded by water on the eastern, northern and western aspects. Further from the site, past the peninsula are the high rise building of the Sydney CBD to the east, and further low to medium rise buildings to the north, south and west.

A survey of the land topography indicates a gradual slope downwards from the Pyrmont peninsula down to the water, however, the wind effect this topography is expected to be relatively minor.

An aerial image of the subject site and the local surroundings is shown in Figure 4, with the frequency and magnitude of the prevailing winds is superimposed for each wind direction.

The critical wind impacts for the outdoor public areas are discussed under each of the following key elements of the masterplan.

- North Tower
- South Tower
- Pyrmont Bay Plaza
- Additional Built Forms on Level 5 and New Façade Treatment to Upper Storeys
- Pirrama Road
- Jones Bay Road
- Pyrmont Street
- Union Street
- Pyrmont Bridge Road
- Edward Street

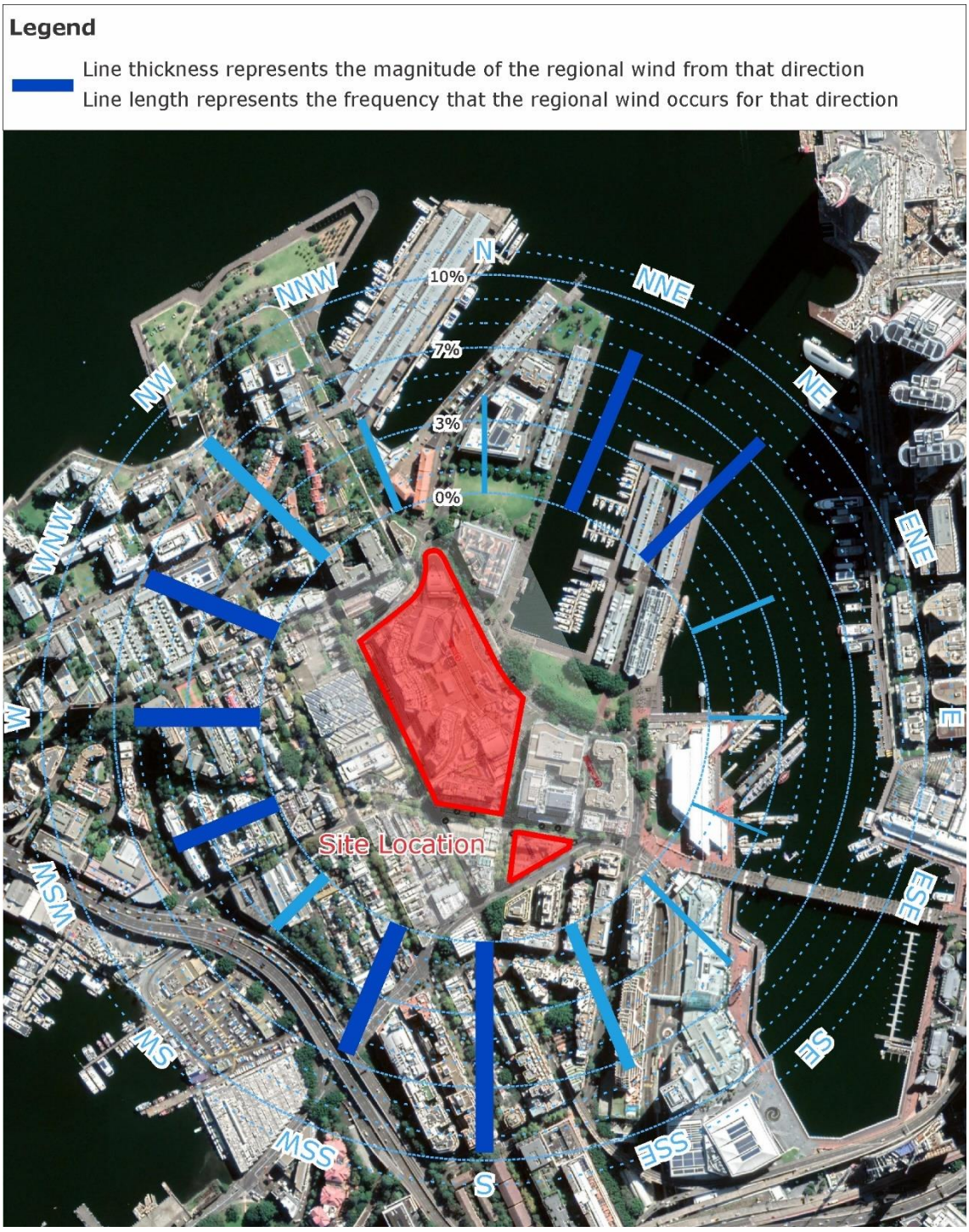


Figure 4: Aerial Image of the Site Location and Prevailing Wind Directions

# 3 REGIONAL WIND

The Sydney region is governed by three principal wind directions that can potentially affect the subject development. These winds prevail from the north-east, south, and west. These wind directions were determined from an analysis undertaken by Windtech Consultants of recorded directional wind speeds obtained from the meteorological station located at Kingsford Smith Airport by the Bureau of Meteorology (recorded from 1995 to 2016). The data has been corrected to represent winds over standard open terrain at a height of 10m above ground level. The results of this analysis are presented in Figure 5 in the form of a directional plot of the annual and 5% exceedance mean winds for the region. The frequency of occurrence of these winds is also shown in Figure 5.

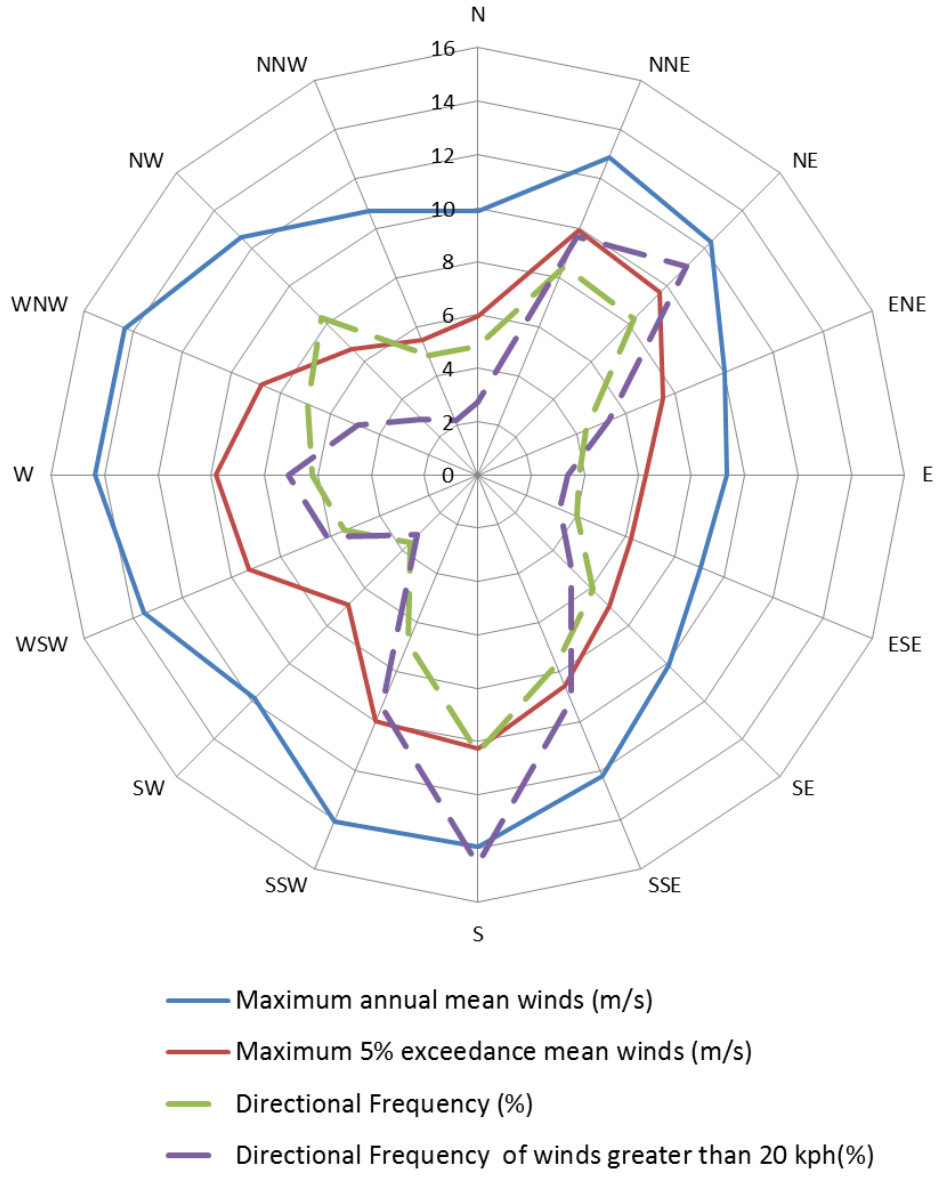


Figure 5: Directional Annual and 5% Exceedance Hourly Mean Wind Speeds (referenced to 10m height in standard open terrain), and Frequencies of Occurrence, for the Sydney Region

# 4 WIND EFFECTS ON PEOPLE

The acceptability of wind in any area is dependent upon its use. For example, people walking, or window-shopping will tolerate higher wind speeds than those seated at an outdoor restaurant. Various other researchers, such as A.G. Davenport, T.V. Lawson, W.H. Melbourne, and A.D. Penwarden, have published criteria for pedestrian comfort for pedestrians in outdoor spaces for various types of activities. Some Councils and Local Government Authorities have adopted elements of some of these into their planning control requirements.

For example, A.D. Penwarden (1973) developed a modified version of the Beaufort scale which describes the effects of various wind intensities on people. Table 1 presents the modified Beaufort scale. Note that the effects listed in this table refers to wind conditions occurring frequently over the averaging time (a probability of occurrence exceeding 5%). Higher ranges of wind speeds can be tolerated for rarer events.

Table 1: Summary of Wind Effects on People (A.D. Penwarden, 1973)

| Type of Winds | Beaufort Number | Mean Wind Speed (m/s) | Effects |
|---|---|---|---|
| Calm | 0 | Less than 0.3 | Negligible. |
| Calm, light air | 1 | 0.3 – 1.6 | No noticeable wind. |
| Light breeze | 2 | 1.6 – 3.4 | Wind felt on face. |
| Gentle breeze | 3 | 3.4 – 5.5 | Hair is disturbed, clothing flaps, newspapers difficult to read. |
| Moderate breeze | 4 | 5.5 – 8.0 | Raises dust, dry soil and loose paper, hair disarranged. |
| Fresh breeze | 5 | 8.0 – 10.8 | Force of wind felt on body, danger of stumbling |
| Strong breeze | 6 | 10.8 – 13.9 | Umbrellas used with difficulty, hair blown straight, difficult to walk steadily, wind noise on ears unpleasant. |
| Near gale | 7 | 13.9 – 17.2 | Inconvenience felt when walking. |
| Gale | 8 | 17.2 – 20.8 | Generally impedes progress, difficulty balancing in gusts. |
| Strong gale | 9 | Greater than 20.8 | People blown over. |

It should be noted that wind speeds affecting this particular development can only be accurately quantified with a wind tunnel study. This assessment addresses only the general wind effects and any localised effects that are identifiable by visual inspection and the acceptability of the conditions for outdoor areas are determined based on their intended use. Any recommendations in this report are made only in-principle and are based on our extensive experience in the study of wind environment effects.

# 5 RESULTS AND DISCUSSION

The expected wind conditions affecting the various key areas of the development are discussed in the following sub-sections of this report. The interaction between the wind and the building morphology in the area is considered, and important features taken into account including the distances between the surrounding buildings and the proposed building form, as well as the surrounding landform. Note that only the potentially critical wind effects are discussed in this report. A glossary of the different wind effects described in this report included in Appendix A.

For this assessment, the wind speed criteria for pedestrian comfort that are considered are listed as follows:

- Walking or Comfortable Walking Criterion (8m/s with a 5% probability of exceedance) for general circulation and pedestrian thoroughfares, e.g. footpaths, private balconies/terraces, through-site links etc.

- Standing or Short Exposure Criterion (6m/s with a 5% probability of exceedance) for stationary activities generally less than an hour, e.g. waiting areas, communal terraces, main entries, café seating etc.

- Sitting or Long Exposure Criterion (4m/s with a 5% probability of exceedance) for stationary activities longer than an hour, e.g. outdoor cinemas, outdoor fine dining etc.

Furthermore, all areas are also assessed with consideration to the pedestrian safety criterion of 24m/s for the annual maximum gust.

Note that these criteria reflect the modified Lawson (1975) criteria and the Draft Sydney Development Control Plan 2012 - Central Sydney Planning Review Amendment. Although this assessment is qualitative in nature, the abovementioned criteria for pedestrian comfort and safety are considered when assessing the wind environment impacts. The detailed DA scheme can be quantitatively assessed through wind tunnel testing. The above criteria should be adopted for the wind tunnel model study in the more detailed design stages.

## 5.1 North Tower

The proposed North Tower is situated at the corner of Pirrama Road and Jones Bay Road is expected to be approximately 110m in height. The ground level areas along Jones Bay Road are expected to benefit from some shielding from the direct impacts of the prevailing westerly winds by the buildings to the west, the north-easterly winds by the building to the north-east and the southerly winds by the development itself. However, these are limited to low level direct winds. Other wind effects such as downwash, corner acceleration and side-streaming are also expected to occur around this element of the development.

Past wind tunnel studies undertaken by Windtech Consultants indicate that the north-easterly winds are the most critical as they have the potential to downwash from the tower and podium façade onto the ground level below, due to the height and exposure of the North Tower above the surrounding buildings, accentuated by the lack of shielding further from the site. Furthermore, these downwashing winds are expected lead to corner acceleration around the Pirrama Road and Jones Bay Road corner, as well as funnel through the through site link. The westerly and winds also have a similar effect. The southerly winds also impact the tower form, but the podium form is shielded by the rest of the development.

The proposed development massing incorporates several design features to mitigate these wind effects. The tower form has a significant setback from the edge of the podium on the southern aspect, which is expected to mitigate adverse downwashing winds from the tower from impacting the ground level from this direction. An increased setback for the first floor above the podium at the northern corner is also beneficial in reducing the impact of downwash from the tower form. The proposed densely foliating tree planting around the base of the tower is expected to further improve conditions by reducing the effect the winds already funnelling along Pirrama Road and Jones Bay Rd, as well as provide additional protection from downwash for the pedestrians below.

Furthermore, the development incorporates a horizontal wind screen in the form of an awning over the porte-cochere and a separate around the northern corner of the podium form. However, there is still the potential for the downwash to impact the ground floor between these two discrete screening elements. It is therefore recommended that the awnings overlap (northern awning to go over the eastern awning), with the awning width protruding at least 2m from the façade, as shown in Figure 6. The awning is recommended to continue along the entire western aspect to mitigate any adverse downwash winds from the westerly prevailing wind.

The through site link is along the southern aspect of the tower podium. This has the potential to be open to air, and would be expected to suitable for pedestrian activities, with the inclusion of the surrounding landscaping and a horizontal canopy across the western entry. Shielding from the surrounding buildings also aids in the reduction of wind driven funnelling effects through this link.

Wind tunnel testing is recommended to be undertaken in order quantitatively assess the wind effects described. The layout of the elevated areas enables adequate levels of comfort with minor mitigations which can be developed at a more detailed design stage.

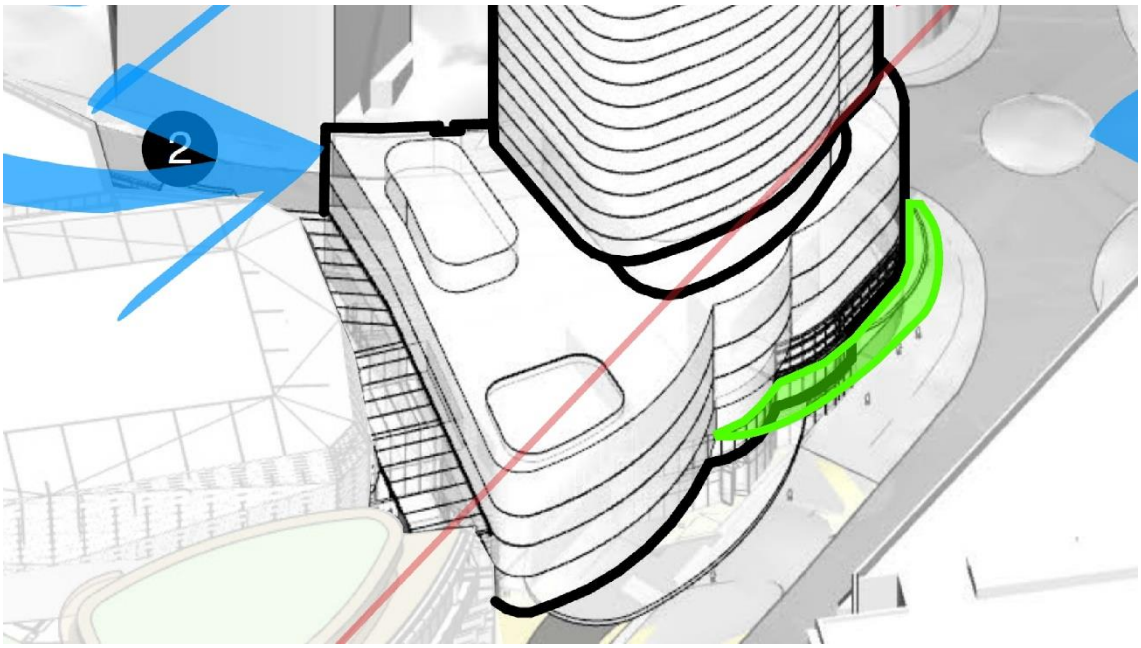


Figure 6: Example of Continuous Awning Recommended for Northern Tower

## 5.2 South Tower

The proposed south tower is bound by Pyrmont Bridge Road, Union Street and Edward Street and is expected to be approximately 140m in height. The nearby medium rise buildings aid in shielding the ground level from direct wind effects from the prevailing winds. However, due to the height and exposure of the proposed tower, other wind effects are expected to occur due to the interaction of the winds with the building form.

Past wind tunnel studies undertaken by Windtech Consultants indicate that the wind conditions at this end of the site are dominated by the southerly winds. Downwash is expected to occur due to the interaction of the tower with the southerly winds in particular as well as the north-easterly and westerly winds. The sharp corner at the intersection of Union Street and Pyrmont Bridge Road can result in corner acceleration of wind flows.

The development incorporates design features such as a relatively short podium (to be confirmed as per the final Masterplan), which would maximise the shielding by the surrounding buildings, and tower setbacks approximately 5m from the edge of the podium on the north-eastern and western aspects in order to reduce the impact of these wind effects on the ground level for these wind directions.

The proposed horizontal screening element in the form of an awning combined with densely foliating trees, preferably with interlocking canopies along the southern aspect of the South Tower is expected to ameliorate the effect of downwash and ensuing corner acceleration due to the prevailing southerly winds. The horizontal screening should wrap around the south-eastern and south-western corners to ensure these winds remain above the pedestrian level. Furthermore, the corner acceleration at the corner of Union Street and Pyrmont Bridge Road can be reduced by creating a deeper, straight chamfer at the corner.

Wind tunnel testing is recommended to be undertaken in order quantitatively assess the wind effects described. The layout of the elevated areas enables adequate levels of comfort with minor mitigations which can be developed at a more detailed design stage.

## 5.3 Additional Built Forms on Level 5 and New Façade Treatment to Upper Storeys

The additional built forms on Level 5 and the new façade treatment to the upper storeys of the existing building forms are relatively minor in terms of wind and are not expected to significantly alter the wind conditions on the ground level around the site. Wind tunnel testing is recommended to be undertaken in order quantitatively assess the wind conditions on the terrace. The layout of the elevated areas enables adequate levels of comfort to be achieved with minor mitigations which can be developed at a more detailed design stage.

## 5.4 Pyrmont Bay Plaza

The proposed Pyrmont Bay Plaza is primarily exposed to the prevailing north-easterly and southerly winds, and is shielded from the westerly prevailing winds by the development itself. Significant activation of the Pirrama Street frontage is proposed for the development, with retail pods and outdoor dining anticipated. There is significant existing landscaping to the north and south of the waterfront plaza. However, the existing and proposed palm trees are ineffective for wind mitigation. It should be noted that since the north-easterly winds are more frequent during the warmer months, these winds would tend to benefit overall comfort rather than be a detriment to this space. Should it be needed to mitigate the effect of the north-easterly winds in this area we recommend one of the following measures to achieve suitable conditions for seating adjacent to the proposed retail pods:

- Use a denser foliating tree species to the north-east of the proposed seating area would be more effective in mitigating the effect of the direct ground level winds. OR

- Design the enclosed areas of the retail pods such that the seating areas recessed within the retail pods.

The retail pod extension eastwards will provide a podium-like effect and mitigate downwash wind effects from the north-easterly winds. Furthermore, the concave design stagnates the flow and reduces the effect of side streaming along the façade. The wind conditions are expected to be suitable for short duration stationary activities, such as café seating, or standing. However, due to the increased activation of these frontages, additional localised shielding is recommended for these areas. These can be in the form of localised screening or landscaping to reduce the effect of winds shearing along the façade, particularly if it is required to ensure suitable conditions for longer duration seating activities and maximise the use of the outdoor dining spaces. The greatly increased activation may also necessitate tenant managed outdoor spaces.

Seating areas are also proposed for the waterfront plaza area, which is intended for a mixture of walking, standing and occasional sitting. These seating areas, however, are likely to be used selectively only when wind conditions are conducive to sedentary activities, and the intent of these areas is not primarily targeting long duration stationary activities, typical of outdoor cinemas, amphitheatres or fine dining etc. This area is expected to be suitable for comfortable walking activities. When the weather presents windier conditions, the expectation of the users of this space will align with this as this is an area that is on the shore and thus would be exposed to the ambient wind conditions. It is recognised that certain pockets are proposed for seating within the waterfront plaza area, which should be assessed against the comfort criterion for short duration stationary activities or standing. In order to achieve this criterion, additional densely foliating vegetation such as shrubs, hedges and trees, or other forms of screening such as through furniture design or artwork, can be strategically included around areas where seating areas are desired to further improve wind conditions.

Wind tunnel testing is recommended to be undertaken in order quantitatively assess the wind effects described, for both the existing and proposed scenarios to ensure safe and comfortable wind conditions for pedestrians and users of the proposed Pyrmont Bay Plaza and active frontages.

## 5.5 Pirrama Road

Pirrama Road is expected to experience the same wind effects as Pyrmont Bay Plaza, primarily exposed to the north-easterly and southerly winds sidestreaming along the building form, as downwashing from the North Tower. Due to the existing landscaping, and recommendations for the North Tower, conditions suitable for walking can be achieved. It is recommended that wind tunnel testing is undertaken to verify the outcomes of this assessment and provide quantify these wind effects.

## 5.6 Jones Bay Road

Jones Bay Road is primarily exposed to the north-easterly and westerly winds. The north-easterly winds are expected to flow through Metcalfe Park and funnel through Jones Bay Road. The westerly winds are also expected to funnel along Jones Bay Road. However, with the existing landscaping around the site and along the facade, and with consideration of the abovementioned recommendations for the North Tower, it is expected that the wind conditions will be suitable for pedestrian activities/be similar to the existing wind conditions. The footpath widening on the northern side of Jones Bay Rd will allow for the inclusion of some additional vegetation which is expected to improve wind conditions further. Wind tunnel testing is

recommended to quantitatively assess the wind effects to ensure safe and comfortable conditions are achieved.

## 5.7 Pyrmont Street

Pyrmont Street runs along the west side of the site and is primarily affected by the southerly winds funnelling through due to the orientation of this road with the prevailing wind. The existing tree planting flanking this road is beneficial in reducing this funnelling effect. It is not expected that the proposed development building massings will have a significant impact on the wind conditions along this road. This road is shielded from the prevailing north-easterly winds by the development itself, as well as the westerly winds by the surrounding buildings. With the proposed widening of the footpath allowing for the introduction of pockets of landscape, wind conditions are expected to be further improved. It is expected that the wind conditions will be suitable for pedestrian activities/be similar to the existing wind conditions. Wind tunnel testing is recommended to quantitatively assess the wind effects to ensure safe and comfortable conditions are achieved.

## 5.8 Union Street

Union Street runs from Union Park to the west, and along the northern aspect of the South tower. It is shielded from the north-easterly and southerly prevailing winds by the existing and proposed development. It is primarily exposed to the westerly winds which funnel along the road due to its alignment with the prevailing wind. This is an existing wind effect. With the inclusion of the recommendations for the South tower, and the retention of the tower setback from the edge of the podium on the western aspect, the proposed design is expected to minimise the wind impact of the proposed development. The existing trees are deciduous and therefore are not an effective mitigation strategy for the westerly winds, which are more frequent during the winter months. Therefore, any activation along this street in conjunction with the footpath widening is recommended to include localised screening and awnings and/or canopies, or have tenant managed outdoor spaces. Wind tunnel testing is recommended to ensure that wind conditions will be suitable for the intended uses of the spaces along this street.

## 5.9 Pyrmont Bridge Road

Pyrmont Bridge Road runs along the southern aspect of the South Tower. It is shielded from the north-easterly prevailing winds by the existing buildings around the site. However, it is exposed to funnelling westerly winds along the road, and downwashing southerly winds from the South Tower. With the inclusion of the aforementioned recommendations for the South Tower, it is expected that the wind conditions on the ground level will be suitable for pedestrian activities, due to the awning proposed over the ground floor, the recessed ground floor, and the landscaping around the building form. Wind tunnel testing is recommended to ensure that wind conditions will be safe and comfortable for its intended uses.

## 5.10 Edward Street

Edward Street runs north-south and links the future potential Metro Station and South Tower development to the foreshore, light rail and the Pirrama Road entry to The Star building. The existing funnelling wind effect due to the north-easterly wind is expected to still occur. However, the proposed development is not expected to exacerbate this wind effect. The existing and proposed tree planting along this section of Edward St will assist in mitigating the funnelling effect of the southerly prevailing winds along this street.

The proposed South Tower design and the aforementioned recommendations are expected to result in suitable conditions for pedestrian activities. The existing trees have a beneficial effect in reducing the funnelling winds.

The proposed linear plaza design for Edward Street is expected to allow for additional landscaping in the form of shrubs and hedges, which will further improve conditions. Wind tunnel testing is recommended to ensure that wind conditions will be safe and comfortable for its intended uses.

## 5.11 Effect of Future Developments

Future development of the buildings to the south and east of the South Tower are expected to generally improve the wind conditions at the site through direct shielding.

The effect of future Blackwattle Bay developments to the south-west of the site and Barangaroo developments to the north-east is expected to be minimal due their distance from the site.

# 6 REFERENCES


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

Lawson, T.V., 1973, "The wind environment of buildings: a logical approach to the establishment of criteria". Bristol University, Department of Aeronautical Engineering.

Lawson, T.V., 1975, "The determination of the wind environment of a building complex before construction". Bristol University, Department of Aeronautical Engineering.

Lawson, T.V., 1980, "Wind Effects on Buildings - Volume 1, Design Applications". Applied Science Publishers Ltd, Ripple Road, Barking, Essex, England.

Melbourne, W.H., 1978, "Criteria for Environmental Wind Conditions". *Journal of Wind Engineering and Industrial Aerodynamics*, vol. 3, pp241-249.

Penwarden, A.D. (1973). "Acceptable Wind Speeds in Towns", Building Science, vol. 8: pp259–267.

Penwarden, A.D., Wise A.F.E., 1975, "Wind Environment Around Buildings". Building Research Establishment Report, London.

# APPENDIX A WIND EFFECTS GLOSSARY

## A.1 Downwash and Upwash Effects

The downwash wind effect occurs when wind is deflected down the windward face of a building, causing accelerated winds at pedestrian level. This can lead to other adverse effects as corner acceleration as the wind attempts to flow around the building, as seen in Figure A.1.

This can also lead to recirculating flow in the presence of a shorter upstream building, causing local ground level winds to move back into the prevailing wind.

The upwash effect occurs near upper level edge of a building form as the wind flows over the top of the building. This has the potential to cause acceleration of winds near the leading edge, as well as potentially reattaching onto the roof area. This effect causes wind issues particularly near the leading edges of tall building and on the rooftop areas if there is sufficient depth along the wind direction. Upwash is more apparent in taller towers and podia.

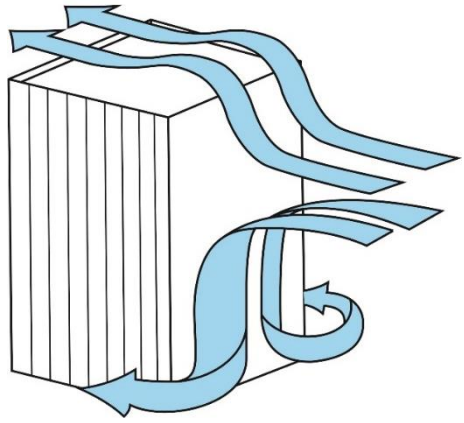

Figure A.1: Downwash Leading to Corner Wind Effect, and Upwash Effects

## A.2 Funnelling/Venturi Effect

Funnelling occurs when the wind interacts with two or more buildings which are located adjacent to each other, which results in a bottleneck, as shown in Figure A.2. This causes the wind to be accelerated through the gap between the buildings, resulting in adverse wind conditions and pedestrian discomfort within the constricted space. Funnelling effects are common along pedestrian links and thoroughfares generally located between neighbouring buildings that have moderate gaps between them.

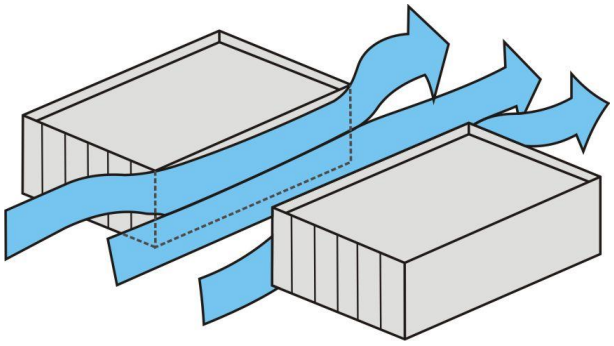

Figure A.2: Funnelling/Venturi Wind Effect

## A.3 Gap Effect

The gap effect occurs in small openings in the façade that are open to wind on opposite faces, as seen in Figure A.3. This can involve a combination of funnelling and downwash effects. Presenting a small gap in the façade on the windward aspect as the easiest means through which the wind can flow through can result in wind acceleration through this gap. The pressure difference between the windward façade and the leeward façade also tends to exacerbate the wind flow through this gap.

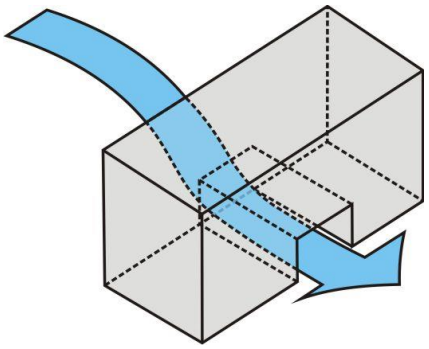

Figure A.3: Gap Wind Effect

## A.4 Sidestream and Corner Effects

The sidestream effect is due to a gradual accumulation of wind shearing along the building façade that eventuates in an acceleration corner effect. The flow is parallel to the façade and can be exacerbated by downwash effects as well, or due to corner effect winds reattaching on the façade.

This is shown in Figure A.4. The corner refers to the acceleration of wind at the exterior vertical edge of a building, caused by the interaction of a large building massing with the incident wind, with the flow at the corner being accelerated due to high pressure differentials sets up between the windward façade and the orthogonal aspects. It can be further exacerbated by downwash effects that build up as the flow shears down the façade.

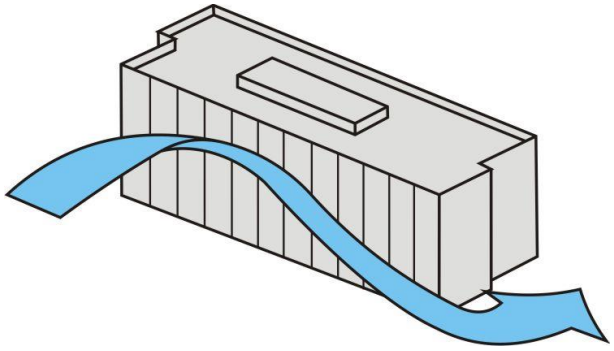

Figure A.4: Sidestream and Corner Wind Effect

## A.5 Stagnation

Stagnation in a region refers to an area where the wind velocity is significantly reduced due to the effect of the flow being impeded by the bluff body. For a particular prevailing wind direction, this is typically located near the middle of the windward face of the building form or over a short distance in front of the windward face of a screen or fence. Concave building shapes tend to create an area of stagnation within the cavity, and wind speeds are generally low in these areas.