WINDTECH

PEDESTRIAN WIND ENVIRONMENT STATEMENT

NORWEST MARKETOWN

WH317-01F02(REV4) - WS REPORT

SEPTEMBER 29, 2023

Prepared for:

Mulpha Australia Limited

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DOCUMENT CONTROL

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EXECUTIVE SUMMARY

This report presents an opinion on the likely impact of the Norwest Marketown development, located in Norwest, 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, south-easterly sector, 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 1 May 2023). 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 subject development is relatively exposed to the three prevailing wind directions. As a result, there is a potential for wind impacts on the wind comfort for pedestrian trafficable areas within and around the site. Future developments around this precinct could reduce prevailing wind exposure.

The general design of the reference scheme incorporates several beneficial features to reduce the effect of the prevailing wind impacts. These include the following:

- The provision for landscaping in the form of trees and shrubs throughout the Garden Terrace, Eat Street, Norwest Square, and other ground level areas within and around the site.
- Awnings over the ground level around the base of some of the tower forms.
- Chamfered or rounded building corners.
- Varied orientations of the building forms to avoid alignment with Westerly and South-Easterly winds.

Further specific treatment strategies can be developed at a later more detailed design stage to further improve wind conditions where required for longer duration stationary activities. Examples of these are summarised as follows:

- Additional densely foliating evergreen landscaping for areas where winds are expected to funnel or side stream, such as communal open spaces or through site links that are situated between two buildings. Where planting cannot be utilised, the inclusion of localised screening, placing awnings to deflect down-washing winds away from pedestrian trafficable areas to lessen this wind effect is recommended.
- The inclusion of densely foliating evergreen landscaping, permanent screening or operable screening where the prevailing winds are expected to interact with building corners.

- The inclusion of awnings, canopies, or densely foliating evergreen trees where winds are expected to downwash from facades onto footpaths or communal open spaces.
- The inclusion of high impermeable balustrades or densely foliating evergreen landscaping for areas that are exposed to directly impacting winds.

With the inclusion of these considerations in the detailed design of the development, wind conditions within outdoor trafficable areas of the development are expected to be suitable for their intended uses.

CONTENTS

1 INTRODUCTION

1.1 Overview

This report has been prepared, on behalf of Norwest City Trust (Mulpha Norwest), to support the submission and assessment of the Norwest Marketown Planning Proposal. The proposal seeks to amend *The Hills Local Environmental Plan 2019* (THLEP 2019) to insert revised planning controls for land situated at 4-6 Century Circuit, Norwest adjacent to the Norwest Metro Station and within the Norwest Strategic Centre.

The Norwest Marketown Planning Proposal aims to facilitate the long-planned transformation of 46,455m^2 of strategically important land presently containing the Norwest Marketown Shopping Centre and adjoining lands comprising the Carlile Swimming Centre. The site is situated along a major regional throughfare in Norwest Boulevarde, connecting to Old Windsor Road to the west.

This Planning Proposal will facilitate the appropriate planning controls to facilitate the site's future redevelopment for a contemporary transit-oriented and truly mixed-use precinct. The site has a capacity to deliver a range of employment generating uses in support of the surrounding Norwest Business Park, through commercial, retail, office, entertainment, tourist/visitor accommodation and community floorspace. These uses are further enhanced through the proposal's introduction of residential uses and the potential for a diversity of future emerging housing typologies. Mulpha's vision for sustainable development practices are at the heart of the concept for the site and a range of environmental sustainability initiatives and aspirations are sought, including renewable energy and building efficiencies.

Development planned for the site will be supported by a range of facilities that will benefit occupants of the site and the broader region, together with infrastructure improvements and upgrades and the delivery of generous plazas, public squares and open space, facilitating access to an enhanced Norwest Lake foreshore. Education and collaboration facilities are a primary focus of community life for Norwest Marketown.

1.2 Norwest Marketown Indicative Reference Scheme

Mulpha's vision for the site is a revitalised and vibrant mixed-use precinct that increases the productivity of employment generating land, provides essential services and increases the provision of housing close to transport. The precinct will provide essential services and a range of new community facilities and open space areas that will benefit the broader community. This will enable the creation of a vibrant and rejuvenated centre that fosters an attractive place to live, work and play.

The Norwest Marketown Indicative Reference Scheme, as prepared by FJC Studio, represents an optimised and refined reference scheme, to guide best practice design and the preparation of detailed planning controls to achieve an attractive transit-oriented development precinct with high amenity.

Key features of the Norwest Marketown Indicative Reference Scheme are:

- A masterplanned urban design of new building blocks, public streets, squares and open spaces.
- A total development density of up to 232,375m^2 Gross Floor Area (GFA) comprising a Floor Space Ratio of 5.0:1. This includes the following components:
    - 117,330m^2 of employment generating floorspace comprising commercial, retail and hotel accommodation;
    - 102,523m^2 of residential floorspace comprising approximately 854 apartments; and
    - 12,523m^2 of community, indoor recreation, civic, entertainment and education floorspace.
- Building heights above ground ranging from 5 storeys to 36 storeys.
- A Lower Ground level providing a direct connection to Norwest Metro through to Norwest Lake at grade with retail and food and beverage opportunities.
- Basement parking, loading and servicing across 5 subterranean levels, with spaces for some 2,600 cars, which are intended to be allocated by way of a parking management system.
- Substantial open space provisions including:
    - Lake Avenue – pedestrian linkage connecting Norwest Boulevarde to Norwest Lake
    - Garden Terrace – cascading open space, providing an enhanced Norwest Lake Foreshore
    - Norwest Public Square – local passive open space and alfresco dining.
- Community and civic buildings such as the Glass House.
- Significant enhancements to the existing Century Circuit, including intersections with Norwest Boulevarde, the provision of internalised local streets within a pedestrian priority environment and opportunity for a future connection to Fairway Drive.
- Complementary on and off-site infrastructure to be delivered by way of a future Planning Agreement.

Norwest Marketown, Indicative Landscape Masterplan – Source: Realm

Norwest Marketown, Indicative Built Form Vision – Source: FJC

Norwest Marketown, Indicative Lake Interface – Source: FJC

1.3 Proposed Planning Controls

The Planning Proposal Justification Report, as prepared by Ethos Urban, details the intention to insert new planning provisions covering Norwest Marketown, through the amendment of the THLEP 2019. Specifically, the Planning Proposal will:

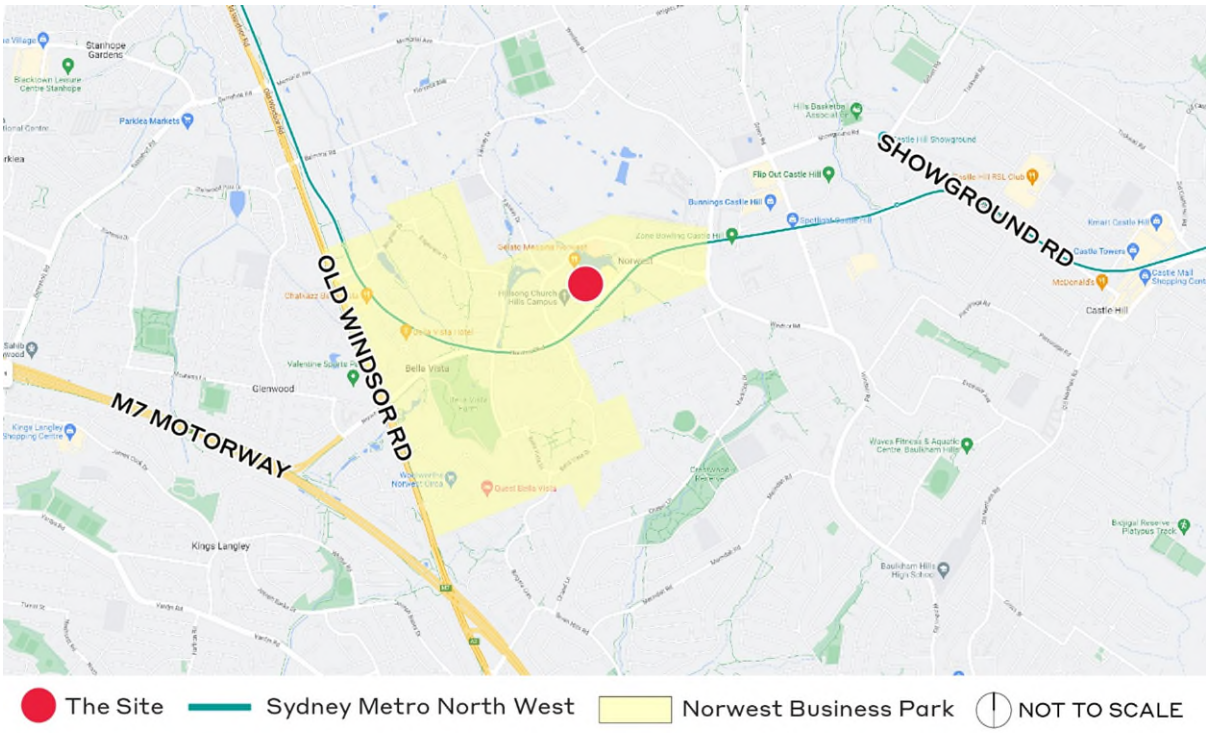
- Seek a rezoning of the site from E1 Local Centre to MU1 Mixed Use.
- Seek an increase in overall height within the site from RL116 to RL216.
- Seek an increase to Floor Space Ratio from 1.49:1 to 5.0:1, comprising a minimum 'commercial premises' and 'entertainment facility' FSR of 2.5:1 and a maximum 'residential flat buildings', 'shop top housing' and 'boarding houses' FSR of 2.21:1 and 854 dwellings.
- Dwelling size and mix requirements consistent with THLEP 2019 and Council's strategic goals for housing.
- Car parking provisions in relation to dwellings, dwelling visitors, retail and commercial uses.
- Additional Permitted Uses (Schedule 1) to allow for the land uses of: recreation area, retail premises, recreation facility (outdoor), water recreation structure, waterbody (artificial) and wharf/boating facilities, within the land zoned SP2 Infrastructure within the site.
- Corresponding site-specific DCP which will address provisions such as:
    - Relationship to other Hills Shire DCP provisions
    - Urban Context
    - Desired Future Character and Principles
    - Public Domain and Open Space
    - Built Form
    - Active Frontages
    - Solar Access and Overshadowing
    - Vehicular Access and Connectivity
    - Landscape
    - Design Excellence
    - Sustainability
    - Wind
    - Staging and Implementation

The proposal is in response to the Draft Norwest Precinct Plan which was on exhibition from 2 May 2023 until 31 July 2023. According to the Draft Plan, Norwest Marketown is identified within 'Focus Area 2' was earmarked as being subject to 'market driven' change and that changes to the planning framework would be driven by landowner-initiated planning proposals, along with associated amendments to the DCP, Public Domain Plan and appropriate infrastructure contribution mechanisms.

1.4 Site Location, Description and Context

The site is located at 4-6 Century Circuit, Norwest within The Hills LGA. Norwest is approximately 12km north of the Parramatta CBD, and 35km northwest of the Sydney CBD. The site is strategically located within the north eastern portion of Norwest Business Park. The Park accommodates an extensive amount of employment land such as office and business premises and contains a range of facilities and amenities, including childcare centres, medical facilities, supermarkets, and a range of smaller retail tenants. It also incorporates recreational areas as well as pedestrian and bicycle linkages.

The site is also directly adjacent to the Norwest Metro railway station. Following its opening in 2019, surrounding each Metro station is an identified precinct that contributes to the Sydney Norwest Urban Renewal Corridor. In the context of this corridor, the site is situated within the Norwest Precinct.



Location of the site in its surrounding context Source: Google Maps, edits by Ethos Urban

The worker population within Norwest Business Park includes around 30,000 workers, being one of Greater Sydney's major employment areas. The workforce includes a large portion of professionals and clerical/service workers. Health care and social assistance, retail trade, professional, scientific, and technical services are the largest employing industries in the locality.

The site is situated on the northern side of Norwest Boulevarde, between Brookhollow Avenue and Century Circuit. It comprises two allotments which are legally described as Lot 2 in DP 1213272 (4 Century Circuit) and Lot 5080 in DP1008602 (6 Century Circuit). Both allotments are owned by Mulpha. The site has a frontage of approximately 185m to Norwest Boulevard and incorporates Century Circuit which extends eastward within the southern portion of the site. This site was formerly part of the North Sydney Brick and Tile Company's Brick Works Holding and as noted previously now forms part of the Norwest Business Park. An aerial view of the site, the relevant allotments and the immediate locality is provided below.

Site aerial photograph, showing extent of the site. Source: Nearmap, edits by Ethos Urban

1.5 Wind Environment

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.

2 DESCRIPTION OF DEVELOPMENT AND SURROUNDINGS

In the context of the wind environment, the Norwest Market site is bounded by Norwest Boulevard and Norwest Station to the south-east, and Hillsong Church Epi Centre and Hill Campus to the west/south-west. The buildings surrounding the subject development are predominately low-rise residential and commercial buildings, with two mid-rise apartment buildings to the north-west.

A survey of the land topography indicates that the proposed development sits within a natural dip in elevation with the land height increasing gradually as you move further from the site, however, there are no major elevation changes in the area immediately surrounding the site.

The proposed reference scheme comprises of nine buildings that range from 5 to 36 stories in height. An aerial image of the subject site and the local surroundings is shown in Figure 1, with the frequency and magnitude of the prevailing winds is superimposed for each wind direction.

The critical outdoor trafficable areas associated with the proposed development, which are the focus of this assessment with regards to wind effects, are listed as follows:

- The various pedestrian footpaths and thoroughfares within and around the site.
- The outdoor Garden Terrace area to the north of the site.
- The various outdoor eating areas along Lane Avenue, particularly those located at the base of buildings B4 and B7 that overlook the Garden Terrace area.
- Open air dining precinct along Eat Street
- Communal meeting area at Norwest Square
- Specialty retail precinct and casual cafes located at Boutique Lane

For the purposes of this assessment, the main building forms discussed are referred to as per Figure 2

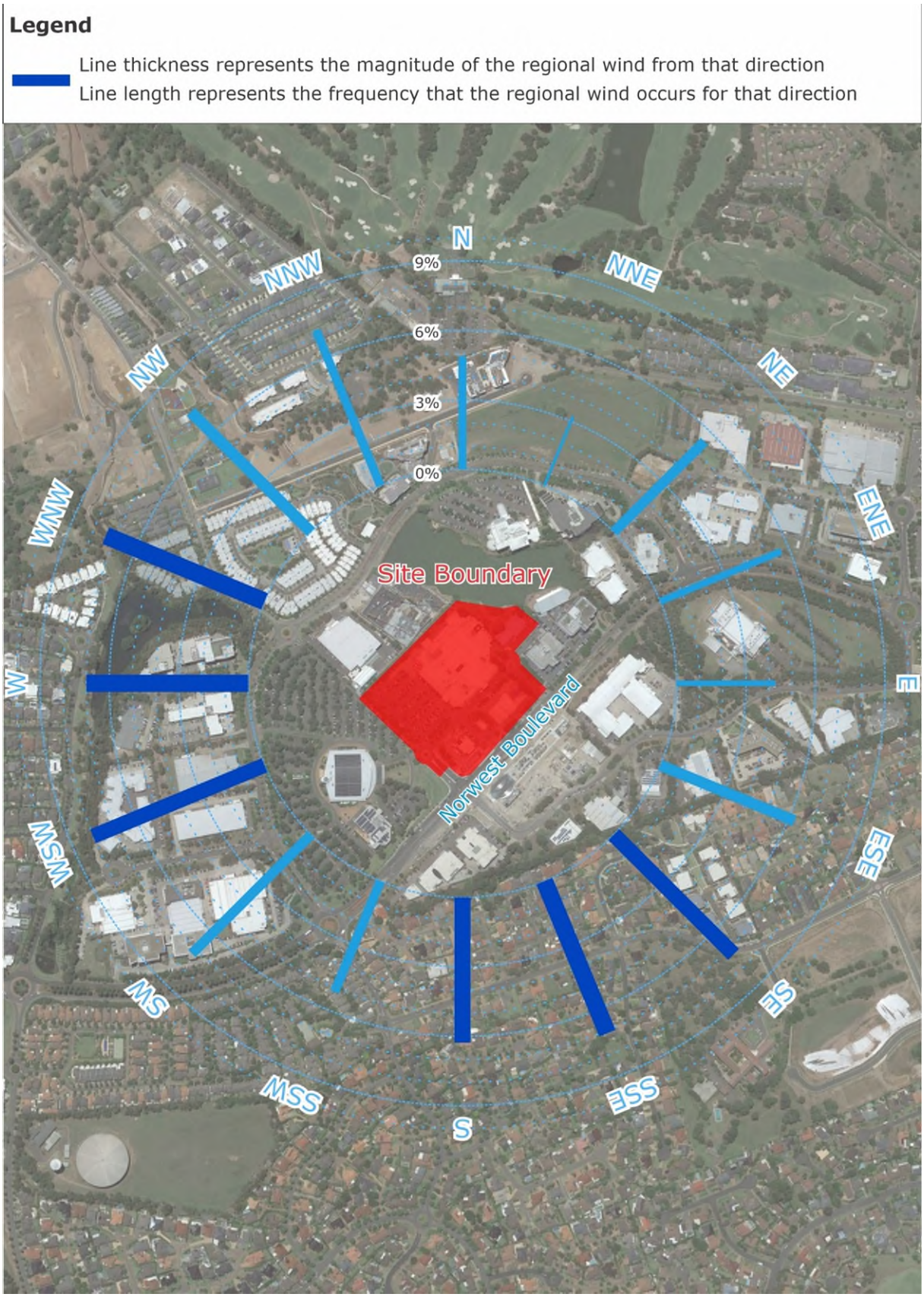


Figure 1: Aerial Image of the Site Location and Prevailing Wind Directions

Figure 2: Building Form Labels

3 REGIONAL WIND

The Hills region is governed by three principal wind directions that can potentially affect the subject development. These winds prevail from the north-east, south to south-east, 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 Bankstown Airport by the Bureau of Meteorology (1993 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 3 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 3.

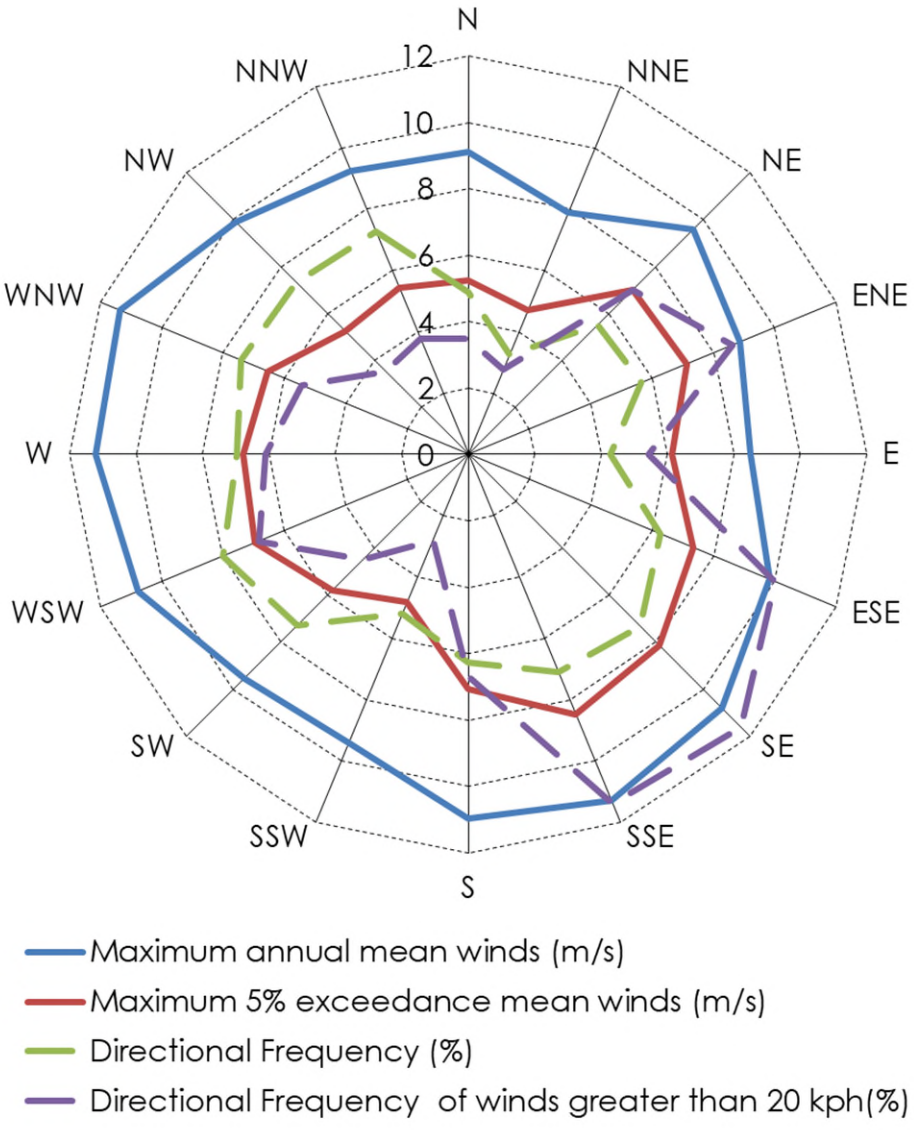


Figure 3: Directional Annual and 5% Exceedance Hourly Mean Wind Speeds (referenced to 10m height in standard open terrain), and Frequencies of Occurrence, for the Hills Region

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 development are discussed in the following sub-sections of this report for the various outdoor areas within and around the subject development. 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 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 (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 (Long Exposure) (4m/s with a 5% probability of exceedance)
  for stationary activities longer than an hour, e.g. outdoor cinemas, outdoor fine dining etc.

Note that the above wind comfort levels are derived from the Lawson (1975) criteria. Although this assessment is qualitative in nature, the abovementioned criteria for pedestrian comfort are considered when assessing the wind environment impacts. However, all areas are also assessed with consideration to a pedestrian safety criterion of 23m/s for the annual maximum gust.

5.1 North-Easterly Winds

The north-easterly prevailing winds are expected to impact the site directly, due to the lack of significant upstream shielding.

The Boutique Lane and Norwest Square sections of the development are significantly shielded by the proposed reference scheme's massing, primarily by buildings B1 and B2. Building B4 also provides some shielding for the Glasshouse and retail area located at the base of building B3.

However, there are some hot spots that have been identified in Figure 4 which are expected to be impacted by the prevailing winds. These effects include corner acceleration around the indicated areas, as well as funnelling between each of the built forms. Due to the alignment of Century Circuit and Eat Street with the north-easterly winds, some funnelling and side-streaming effects are expected to be experiences along these pathways.

In order to further improve conditions at the corner hot spots, treatments such as screens or landscaping to trip the wind as it accelerates around the corners of the built form are recommended to be considered. Wind sensitive uses can also be relocated away from the corners of building forms. Furthermore, to reduce the effect of funnelling, staggered vegetation can be implemented to break up the flow within the through-site links between the various buildings. Similarly, street trees and other similar forms of landscaping along the footpath are beneficial in mitigating adverse side-streaming winds.

Short duration stationary activities are anticipated along the building façades of buildings B4 and B7, facing onto the Garden Terrace area, with uses such as café seating, window shopping, retail entries etc. Additional localised screening, planting or operator-controlled screens are recommended to be implemented for any area that is expected to be used for these purposes. The other pedestrian trafficable areas such as the Garden Terrace expected to be similar to or better than the existing site conditions.

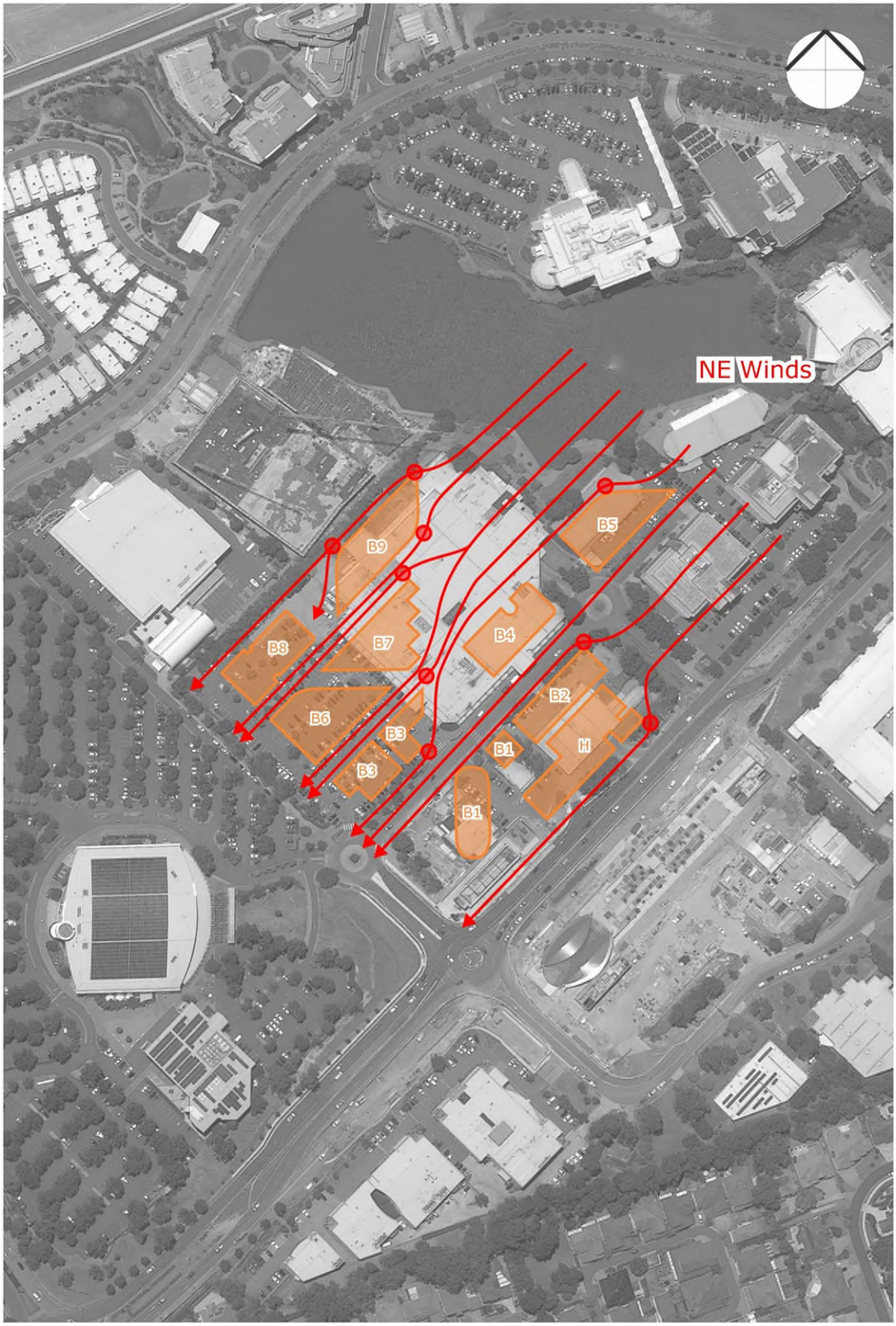


Figure 4: North-Easterly Wind Flow and Hotspots

5.2 South-Easterly Sector Winds

The south-easterly sector winds are the most frequent for the region, and impacts the site from a range of directions, mainly from the east-south-east to south-south-east.

The development provides some shielding to the downstream buildings, as well as the pedestrian trafficable areas to the north of the site, such as the retail/café areas that face onto the Garden Terrace. Eat Street is also well shielded by the upstream building forms for winds in this sector.

The wind hot spots have been identified in Figure 5 which are expected to be affected by south-easterly sector prevailing winds (south-easterly winds shown in the figure). These effects include corner acceleration around the indicated areas, as well as funnelling between each of the built forms. This effect is expected to be less pronounced due to the orientation of the building forms for a large section of the development, particularly around buildings B3, B6, B7, B8 and B9. Some downwash is also expected on the windward faces of Building H, B1, B3 and B5. This effect is likely to be less pronounced on Building B1 due to the oblique orientation of its façade aspect. Some side-streaming south-easterly winds are also expected along Century Circuit and the road to the south-west of the site.

Landscaping is recommended to ameliorate the effects of funnelling and side streaming winds, such as along Century Circuit (along the facades of buildings H, B2 followed by funnelling between B4 and B5) as well as funnelling between buildings B1 and B2. Incorporating an awning can help with keeping the down-washing/side-streaming winds above the pedestrian level by deflecting the winds away from pedestrian trafficable areas, such as for B1 and Building H. For areas that will be used for short or long duration stationary activities such as cafes or seating areas, localised screening planting or operable screening can be utilised. Further away from the building forms such as the Garden Terrace, where picnic areas or other public use areas may be situated, staggered densely foliating trees and/or vegetation is expected to aid in reducing the impact of funnelling in this area.

Other areas are expected to be largely unaffected by the south-easterly winds or are expected to be better than the existing site conditions.

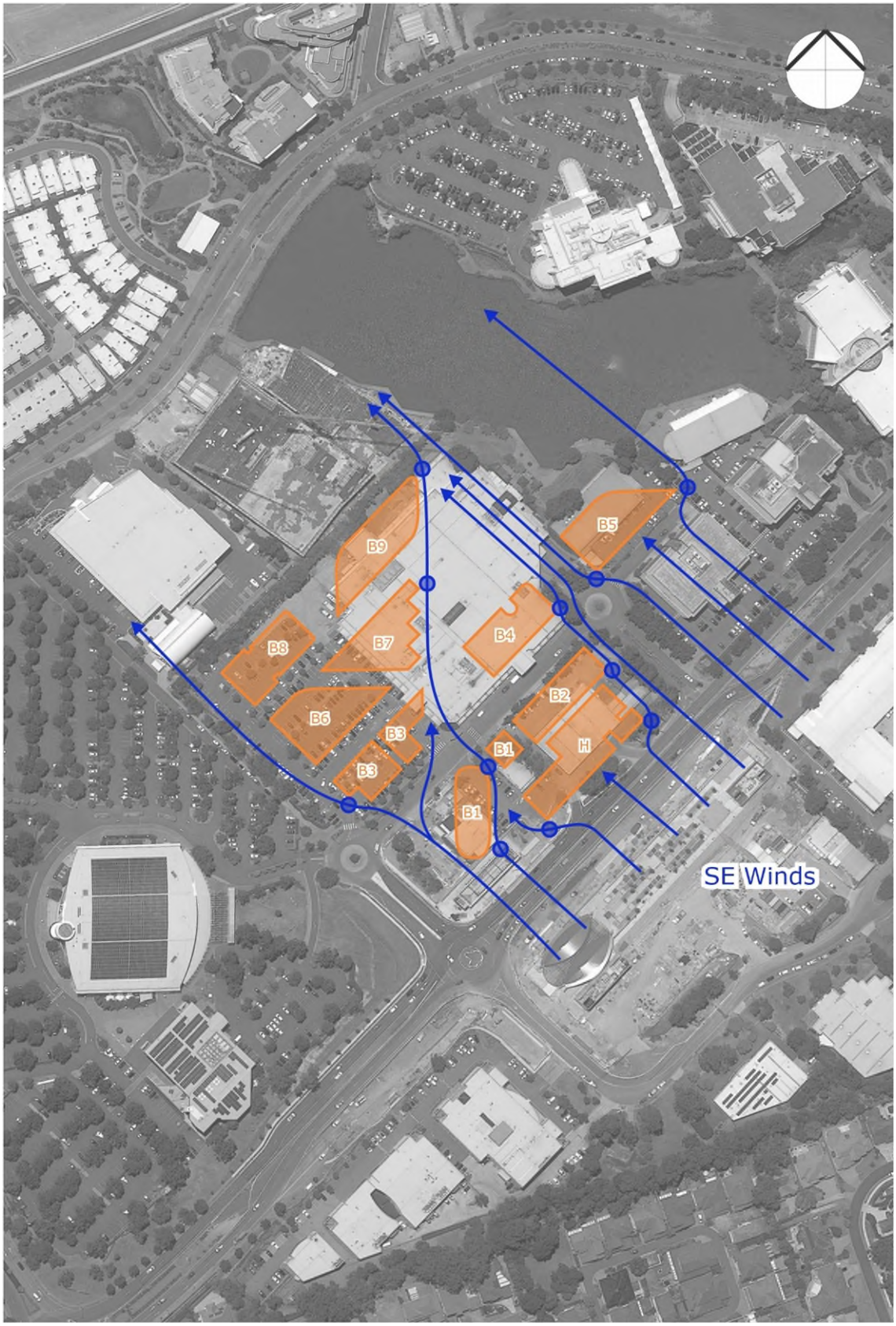


Figure 5: South-Easterly Wind Flow and Hotspots

5.3 Westerly Winds

The westerly winds, while still strong, are less frequent for the stronger winds than the south-easterly sector winds. However, they can still affect the site and cause undesirable wind conditions.

The development provides some shielding to the pedestrian trafficable areas located centrally in the site, such as the retail/café areas at the bases of buildings B3 and B7.

The wind hot spots in Figure 6 are expected to be affected by westerly prevailing winds. These effects include corner acceleration around the indicated areas, as well as funnelling between each of the built forms. Some downwash is expected on the windward faces of B6, B8 and B9 however, this effect is likely to be less pronounced due to the oblique orientation of the façade aspects. Side-streaming south-easterly winds are also expected along roads to the north-west and south-west of the development.

The aforementioned adverse wind effects can be mitigated through the use of awnings that wrap around corners of the building form, extending from the façade over the ground floor (at least 2-3m to be effective). This is expected to protect areas below from any downwash effects and reduce the effect of the ensuing side-streaming winds.

In the event that the north-western and/or south-western aspects of buildings B3, B6, B8 and/or B9 are activated with café seating or other short duration stationary activities, it is recommended that additional localised screening, planting or operator-controlled screens along the façade be provided to further reduce the wind effect. The landscaping within and around the site is also expected to provide some further shielding throughout these areas.

The other pedestrian trafficable areas on the leeward side of the building forms are expected to be similar to or better than the existing conditions.

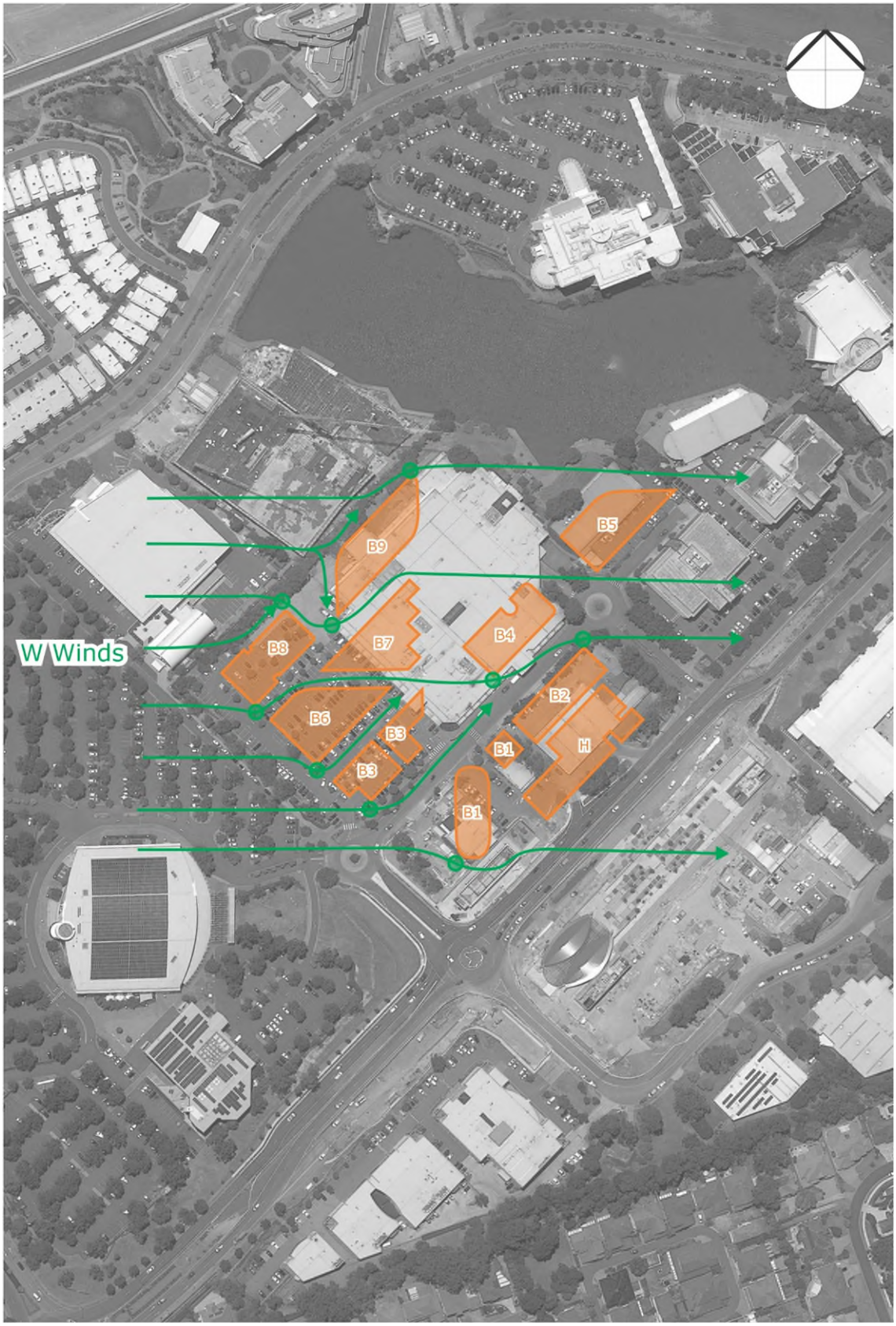


Figure 6: Westerly Wind Flow and Hotspots

5.4 Other General Design Considerations

For tree planting/landscaping to be effective as a wind mitigation device, the species should be of a densely foliating variety. If the area is affected by a winter wind (primarily the westerly winds for this region), it is recommended that an evergreen species be selected to ensure year-round effectiveness. Trees should also be planted in clusters with interlocking canopies to effectively absorb incident winds. In sensitive areas or hotspots where strong winds are expected, mature trees should be used as immature trees have difficulty establishing themselves in strong wind conditions. If immature trees are initially planted, the inclusion of porous screens around these tree plantings, or temporary wind screens is recommended to provide some wind mitigation while the trees develop and provide some protection as the trees establish. Conditions can be further improved by low-level vegetation such as shrubs/hedges or planter boxes. When utilised below a tree canopy, they provide protection from low level winds, especially for more sensitive areas where longer duration activities are expected. In general, landscaping can help mitigate adverse wind effects caused by winds directly impacting an area, or side streaming winds by slowing the winds upstream.

In areas where stronger winds are expected, wind screens may be required as trees are generally not effective in particularly strong gusts. These can be in the form of impermeable screens, porous screens, signage, artwork etc. which are strategically located to mitigate winds at a particular location. In areas where longer duration stay is expected, such as café or restaurant seating areas, or communal recreation areas, additional localised screening, tenancy-operated screening deployable during windy conditions, or planting may be required. The location of these areas at the corners of buildings places them in an area where there is a high potential for adverse winds.

Downwash is most likely to occur at the base of tall buildings that present a flat façade to the prevailing winds. The proposed setback in the various towers of the development is expected to assist in breaking up the downwash flows, however, to be effective in downwash mitigation it is suggested the setback be at least 3m in length. In downwash affected areas, especially at the ground level, awnings and canopies can be used to deflect the winds away from pedestrian accessible areas. Generally, for these to be effective in achieving this, an awning of at least 3m would be required. This combined with tree planting alongside for the winds to be absorbed into would be particularly effective in mitigating this wind effect. Wrap-around awnings at the corners of buildings can also prevent the down washed winds from combining with winds side streaming around the corners of the development. To reduce the ability of winds to downwash along the tower facades, horizontal and vertical feature elements can also be included.

Through-site links and tower aspects should be oriented to avoid direct alignment with the prevailing winds, incorporate bends, planting, or screens in order to mitigate funnelling effects between buildings. The funnelling between buildings may be severe enough for further mitigation measures such as a baffle screen arrangement. This tends to reduce the severity of winds affecting a particular area by redirecting it around obstacles, and thus reducing the wind speed.

With respect to elevated areas such as balconies and terraces, wind conditions on recessed mid-wall balconies are expected to be suitable since they will benefit from the shielding provided by the building form which would effectively enclose those balconies on three sides. As for protruding and/or corner balconies, it is expected that the prevailing winds will cause adverse wind conditions due to corner accelerated flows and will therefore require wind mitigation measures, such as full height end screens, to be implemented.

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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.

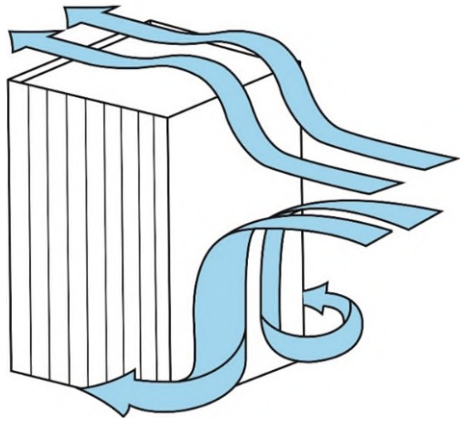

Figure A.1: Downwash Leading to Corner Wind Effect, and Upwash Effects

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.

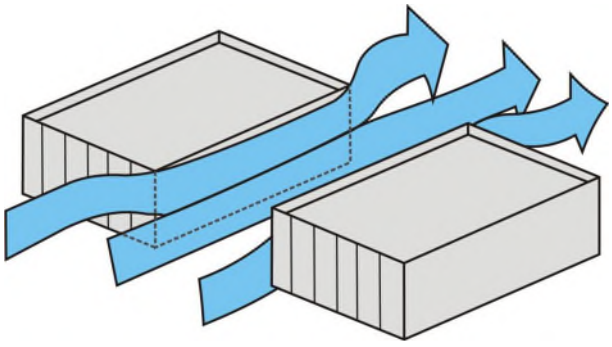

Figure A.2: Funnelling/Venturi Wind Effect

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.

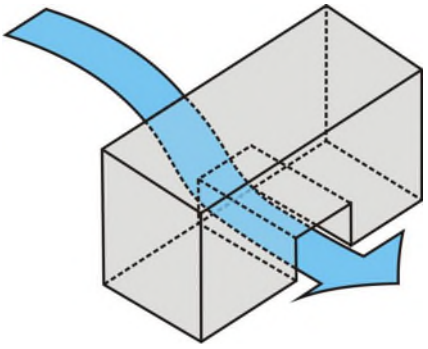

Figure A.3: Gap Wind Effect

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.

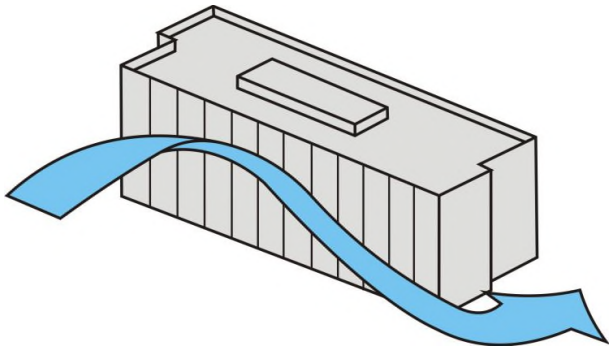

Figure A.4: Sidestream and Corner Wind Effect

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.