ARUP

University of New South Wales

UNSW G25 Education Building

Environmental Wind Assessment Report

Reference: Wind Report

Rev. 04 | 17 February 2025

Job number 304141-00

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Consultant Declaration Form

CONSULTANT DECLARATION

PROJECT DETAILS	
PROJECT NAME	
Application number	SSD-74670005
Address of subject land	8 High Street, Kensington, NSW, 2033
Lot / DP	Lot 5 DP 1264171
APPLICANT DETAILS	
Applicant name	University of NSW
Applicant address	8 High Street, Kensington, NSW 2033
REPORT DETAILS	
Name of report this declaration relates	Environmental Wind Assessment Report
Report reference no.	
Report date	28 November 2024
Company name (inc. ABN / ACN)	Arup
Author name	Lauren Boysen
Author qualifications	MIEAust CPEng NER | BAeroEng(Hons) BA
Author address	Sky Park, One Melbourne Quarter, 699 Collins St, Docklands VIC 3008
DECLARATION BY CONSULTANT	
Name	Lauren Boysen
Registration no.	N/A
Organisation registered with	N/A
Declaration	The undersigned declares that the Environmental Wind Assessment Report: • has been prepared in accordance with the following policy, guidelines, or legislative requirements: - Randwick City Development Control Plan 2013 • contains all available information relevant to the environmental assessment of the development, activity or infrastructure to which the Environmental Wind Assessment Report relates; • does not contain information that is false or misleading; • identifies and addresses the relevant Planning Secretary's environmental assessment requirements (SEARs) for the project; • identifies and addresses the relevant statutory requirements for the project, including any relevant matters for consideration in environmental planning instruments to which the Environmental Wind Assessment Report relates; • contains a consolidated summary of the proposed or necessary mitigation measures
Signature	
Date	28/11/2024

Executive Summary

Arup have been commissioned by University of New South Wales (UNSW) to provide an experienced-based impact assessment of the proposed G25 Education Building at UNSW Kensington campus, on the pedestrian level wind conditions for comfort and safety in and around the site.

The site is located in an area of similar height buildings at the north-eastern corner of the campus and is therefore only partially exposed to prevailing winds, mainly from the south.

Given its size and form, the proposed building would be expected to have an impact on the pedestrian level wind conditions. It is expected that the wind speed would be increased at the corners of the site, depending on the prevailing wind direction.

Qualitatively, integrating the expected directional wind conditions around the site with the wind climate, it is considered that from a comfort perspective, the wind conditions at the majority of locations around the site would be classified as suitable for pedestrian sitting or standing type activities at ground level, increasing to pedestrian walking around the corners of the site and through the ground level through-site link. The alignment of the through-site link with Chancellery Walk and its placement towards the middle of the building is expected to create windy conditions within the passageway, particularly for prevailing winds from the south and, to a lesser extent, winds from the north quadrant. If the through-site link is intended for purposes beyond transient walking, mitigation measures would be required to improve comfort.

Additionally, the café located in the north-eastern corner is likely to experience increased wind exposure especially for winds from the west quadrant. Introducing more mature trees around the corner perimeter as proposed in the landscaping package would be beneficial in providing wind shielding for this area.

All areas around the development would be expected to meet the pedestrian safety criterion.

To quantify the qualitative advice provided in this report, numerical or physical modelling of the development would be required, which is best conducted during detailed design.

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Disclaimer

This assessment of the site environmental wind conditions is presented based on engineering judgement. In addition, experience from more detailed simulations have been used to refine recommendations. No detailed simulation, physical or computational study has been made to develop the recommendations presented in this report.

1. Introduction

This Environmental Wind Assessment Report has been prepared by Arup on behalf of the University of New South Wales (UNSW) for construction and operation of a teaching and learning facility (the **Proposa**l) to be known as the UNSW G25 Education Building, on land at 8 High Street, Kensington (the **Site)**.

This report has been prepared to provide an experienced-based impact assessment of the proposed G25 Building at UNSW Kensington campus, on the pedestrian level wind conditions for comfort and safety in and around the site. This report outlines the assessment and subsequent recommendations for wind engineering services related to pedestrian wind comfort and safety on the ground level.

This report accompanies a State Significant Development Application (SSD) that seeks approval for the construction and operation of a teaching and learning facility at the G25 site, within the Upper Campus of UNSW.

Specifically, the SSDA seeks consent for the following:

- Site preparation works including demolition of the existing at-grade car park, tree removal, and excavation works.
- Construction of an eleven (11) storey (plus roof plant) teaching and learning building with approximately 20,200m^2 of gross floor area. The building will comprise the following:
  - Basement including plant/services, Bike Storage, End of Trip facilities and staff amenities, ancillary service areas such as Mail and Print rooms.
  - Ground level Food and Beverage space and informal education spaces
  - Teaching and Learning spaces and workspaces for UNSW Faculties for other levels
  - (The internal fit-out will be subject to separate approval)
  - Rooftop level including landscaped outdoor terrace, multifunction space, mechanical plant and services
- Associated landscaping, replacement trees and public domain embellishment works in and around the proposed building
- Extension and augmentation of infrastructure and services as required
- New lift core in the adjacent building, H25 Botany Street Carpark and associated access improvements.

The Proposal will seek to deliver improvements including:

- Providing new, purpose built learning and teaching spaces to support the University activities and strategic goals such as the development of the Randwick Health and Education Precinct
- Delivering an enhanced ground plane connection
- Providing flexible and adaptable teaching and learning spaces
- Creating a healthy, green, and welcoming place for students, staff and visitors
- Creating an experience that is an open, permeable, and connected public realm
- Creating pedestrian priority and inclusive shared public space

For a detailed project description refer to the Environmental Impact Statement prepared by Ethos Urban.

2. Site Analysis

1.1 Site Context

The site is situated within the UNSW Kensington upper campus, within the Randwick Local Government Area (LGA). The site address is 8 High Street, Kensington, which applies to the whole of the UNSW Kensington campus.

The UNSW campus forms part of the wider Randwick Health and Education Precinct, which has been strategically identified to provide a world-class coalition of education, research, innovation and healthcare organisations and to attract growth, investment and employment opportunities. This Precinct has been identified in the Greater Sydney Region Plan – A Metropolis of Three Cities and the Eastern City District Plan, for its strategic importance as a specialised centre providing for health and education research, innovation, teaching and learning.

The UNSW campus is located approximately 6km southeast of the Sydney CBD, immediately adjacent to the east is the Randwick Hospitals Complex which also forms part of the Randwick Health and Education Precinct. The UNSW site is within 600m of the Randwick Shopping Centre to the east and adjacent to Royal Randwick Racecourse to the north (refer Figure 1 below).

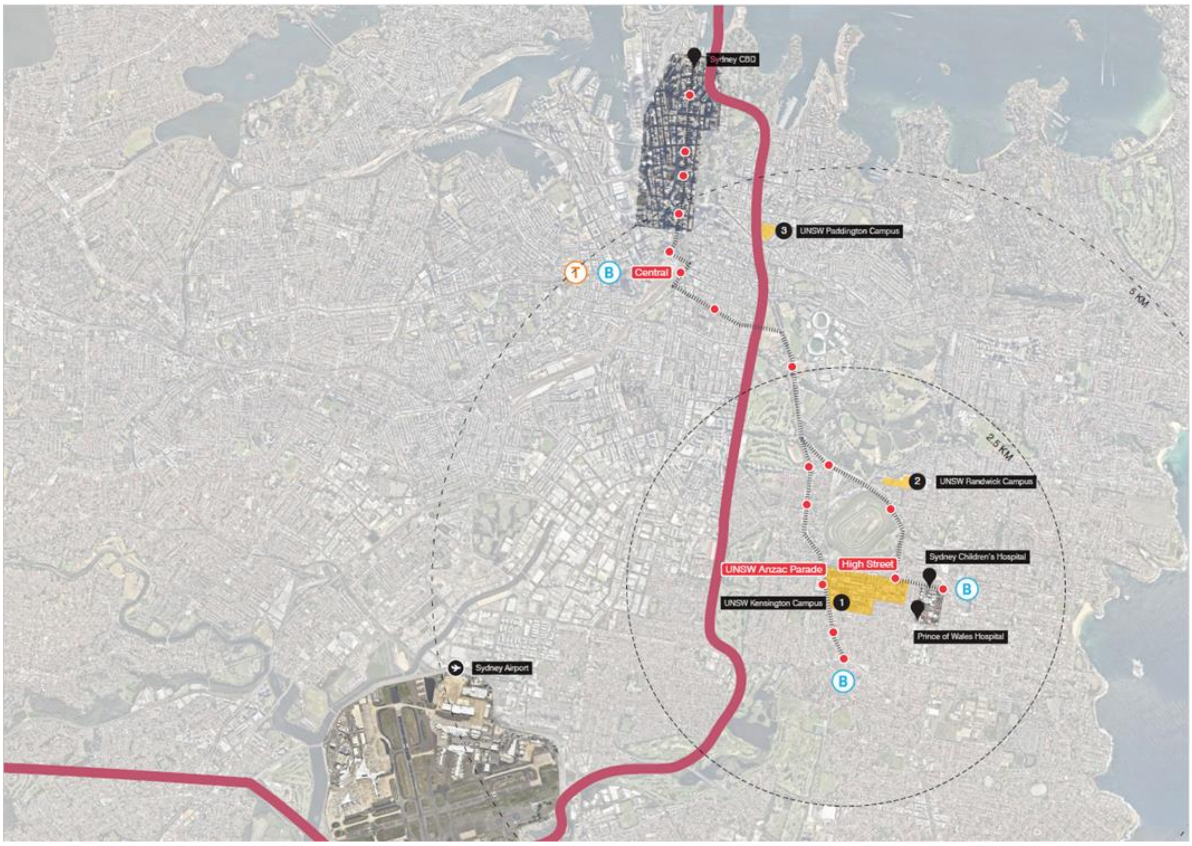

Figure 1: Site Context (source: Ethos Urban, Google Maps)

1.2 Site Description

The subject site known as the G25 site, is an existing on-grade carpark comprising of hardstand pavement with line-marked spaces, trees and landscaped areas. The site also includes the eastern portion of Library Walk and the loading dock area of the AGSM (Australian Graduate School of Management) Building (G27), with no other existing development on the site.

It is bounded to the north by the Samuels Building (F25) and Mathews Building (F23), to the west by the Solar Industrial Research Facility (SIRF) Building (G23), to the south by the multi-storey Botany Street Carpark Station (H25), and to the east by the Australian Graduate School of Management (AGSM) Building (G27) and the Gate 11 entrance to UNSW from Botany Street.

The broader UNSW Kensington Campus consists of five separate allotments. This site is situated within a single allotment legally described as Lot 5 DP 1264171. The UNSW Kensington campus is bounded by Anzac Parade (to the west), High Street (to the north), Botany Street (to the east), and Barker Street (to the south). It also includes developments to the west of Anzac Parade and north of Day Avenue, such as NIDA, the University Regiment, and the New College Post-Graduate Village. The campus currently has approximately 60,000 student enrolments.

Figure 2 provides an aerial image of the site and its location relative to the UNSW upper campus boundaries.

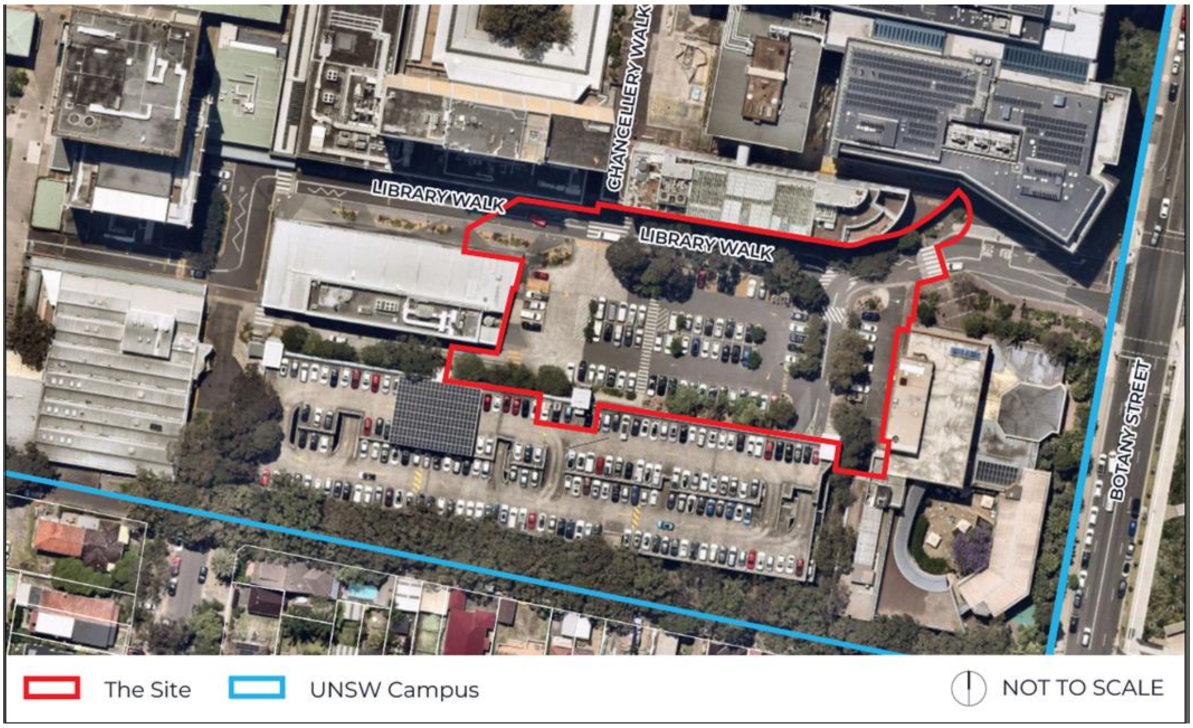

Figure 2: Site Aerial (approximate site area outlined in red; source: Nearmap, Ethos Urban)

1.3 Surrounding Development

The following development surrounds the site:

- North: To the north and directly adjacent to the site across from the Library Walk are the Samuels (F25) Building and Mathews (F23) Building, which comprise up to 16-storeys. Further north within the campus are additional education, administration and library buildings. The wider context includes the UNSW High Street Light Rail stop, as well as low to medium density residential development north of High Street.
- South: South of the site is the UNSW Botany Street Carpark Station (H25) (5 storeys), which is accessed internally within the UNSW campus. This location includes a pedestrian link from Oval Lane. The wider context includes low-medium density residential development south of Oval Lane.
- East: The site directly abuts the ASGM Building (G27) to the east (5 storeys), which fronts Botany Street. To the east and also fronting Botany Street is the Randwick Hospitals Complex including the Prince of Wales Hospital, the Sydney Children’s Hospital, and the Royal Hospital for Women, as well as low-medium density residential development to the south-east.

- West: The site directly adjoins the Solar Industrial Research Facility (SIRF) (G23) to the west, which also sits within the confines of Library Walk and Valentine Close. The western context of the subject site is primarily characterised by the wider UNSW campus (lower campus) as well as the Anzac Parade Light Rail stop.

3. Secretary's Environmental Assessment Requirements (SEARs)

The Department of Planning and Environment has issued Secretary's Environmental Assessment Requirements (SEARs) for the proposed development. This report has been prepared having regard to the relevant SEARs as referenced in Table 1.

Table 1: Applicable SEAR

Item	SEAR	Relevant section
5.2	Environmental Amenity: *Assess amenity impacts on the surrounding locality, including lighting impacts, solar access, visual privacy, visual amenity, view loss and view sharing, overshadowing and wind impacts. A high level of environmental amenity for any surrounding residential or other sensitive land uses must be demonstrated.*	This report, in particular Section 7, addresses the requirements to provide a wind impact assessment, which has been prepared by a suitably qualified person.

4. Site description relevant to the wind assessment

The proposed site is located in the south-east corner of the UNSW Kensington campus, to the south of Library Walk and one building in from Botany Street to the east, Figure 3. The site is surrounded by low-rise buildings to the south, and similar sized buildings to the north, east and west. Topography surrounding the site is mostly flat from a wind perspective, with a slight drop to the east/south-east, and slight rise to the south-west. There are pedestrian zones all around the site.

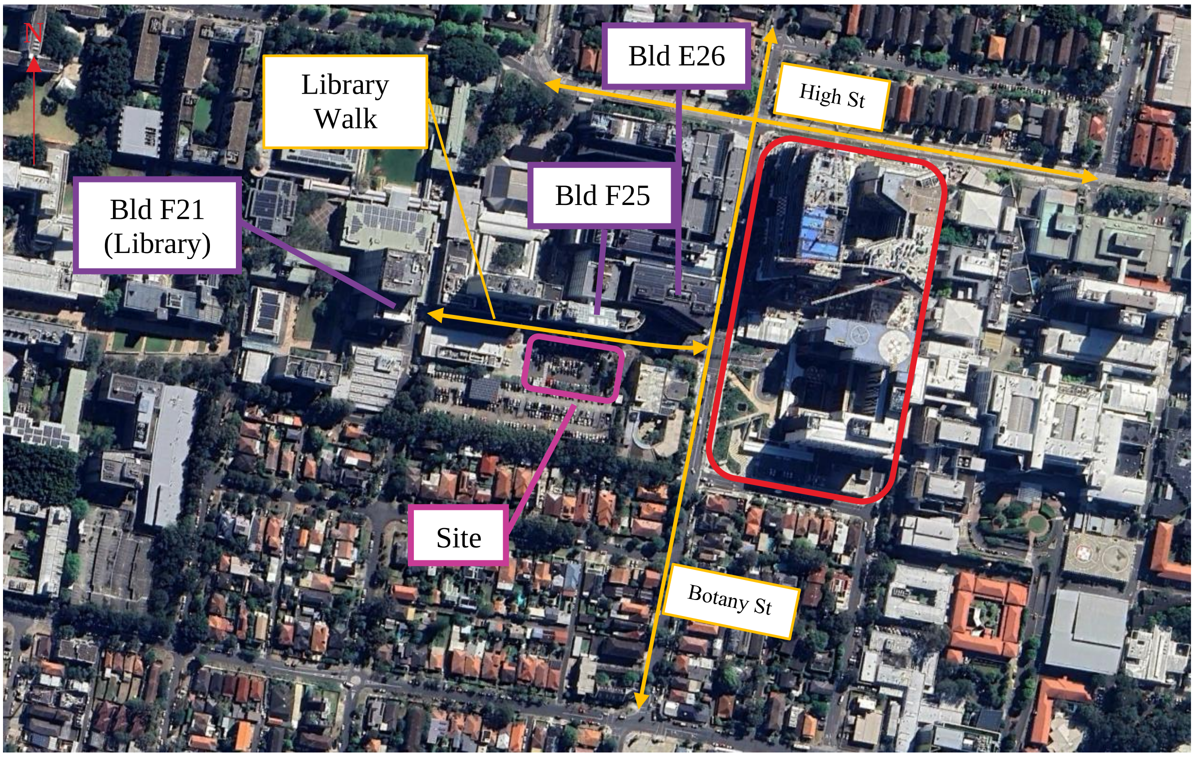

Figure 3: Aerial view of site (Google Earth 2024)

The proposed development is rectangular in form, Figure 5, with rounded corners and an articulated (and scalloped) north façade (Figure 4, left). The building rises to a total height of approximately 50 m above ground level, Figure 4, which is similar and/or slightly taller than the surrounding buildings.

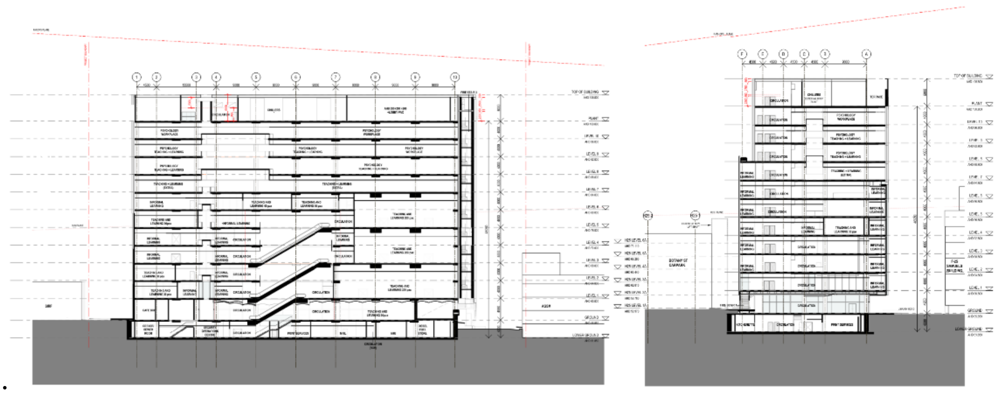

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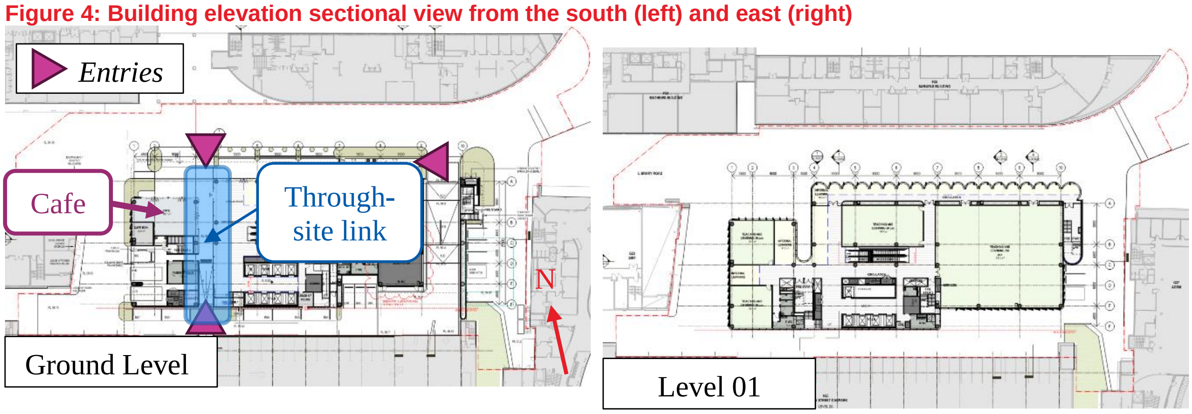
Figure 4: Building elevation sectional view from the south (left) and east (right)



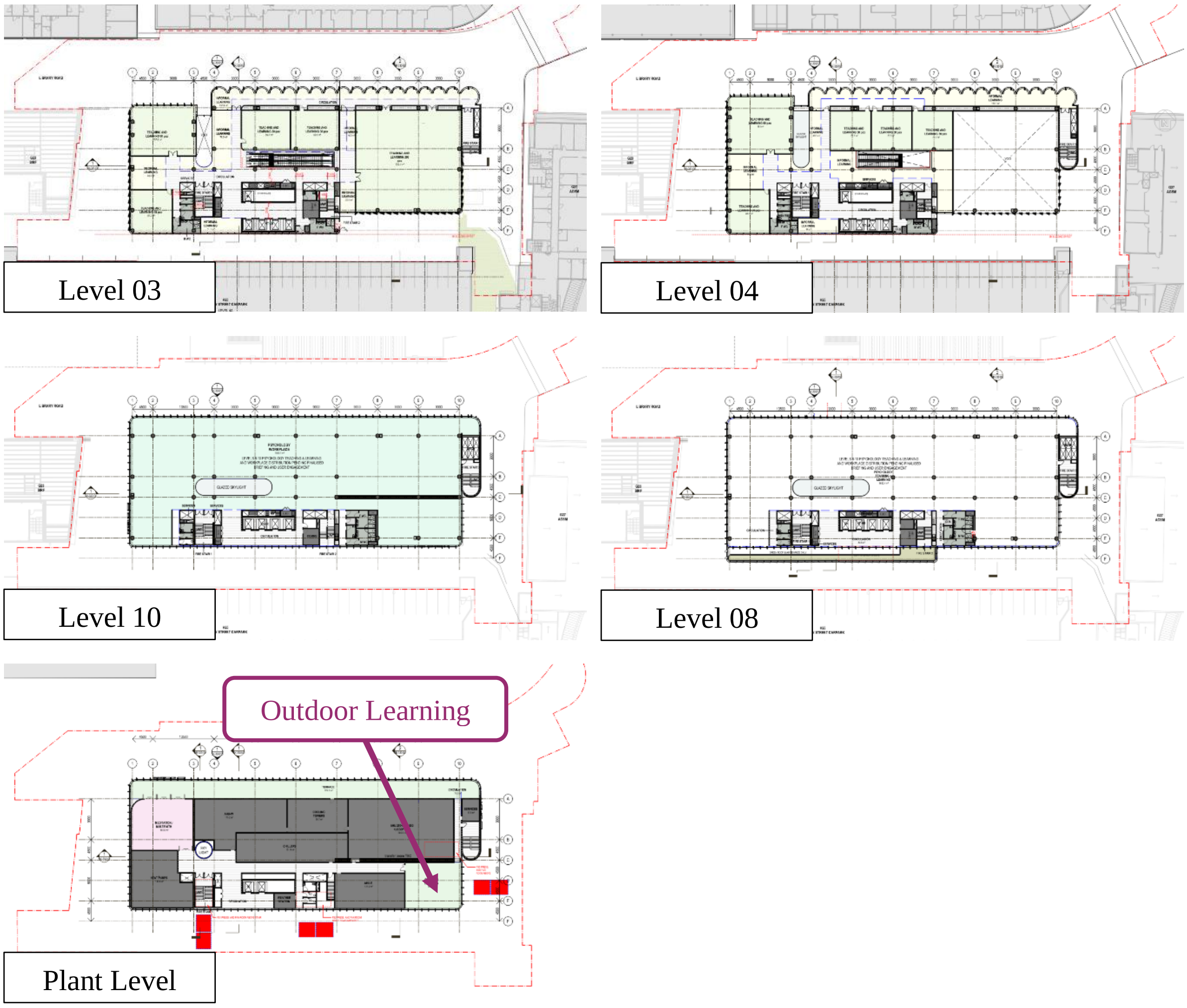


Figure 5: Floor plans at various levels

At the ground level, there is an outdoor café seating area proposed along the north façade, Figure 5 (Ground Level), with pedestrian entries on the north side of the building. At Ground Level, the floorplan is divided by a through-link which connects the north and south sides of the proposed development. There is an Outdoor Learning area proposed at plant level (rooftop level).

5. Local wind climate

Weather data recorded at a standard height of 10 m at Sydney Airport have been used in this analysis, Figure 6. The arms of the wind rose point in the direction from where the wind is coming from. The anemometer is located about 6.5 km to the south-west of the site. The directional wind speeds measured here are considered representative of the wind conditions at the site.

It is evident from Figure 6 that strong prevailing winds are organised into three main groups which centre at about the north-east, south, and north-west quadrants.

- **North-East**: These winds are typically associated with maritime air masses, bringing moisture and influencing temperature along the coast. Most common in summer, often bringing 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 wind.
- **South:** More common in seasonal transitions and often can bring cooler air from the southern ocean. These winds are often associated with large synoptic frontal systems and generally provide the strongest gusts during summer.

- **North-West:** Strongest throughout the year, associated with significant synoptic events, varying from hot to cold based on inland conditions and tend to be associated with large scale synoptic events that can be hot or cold depending on inland conditions

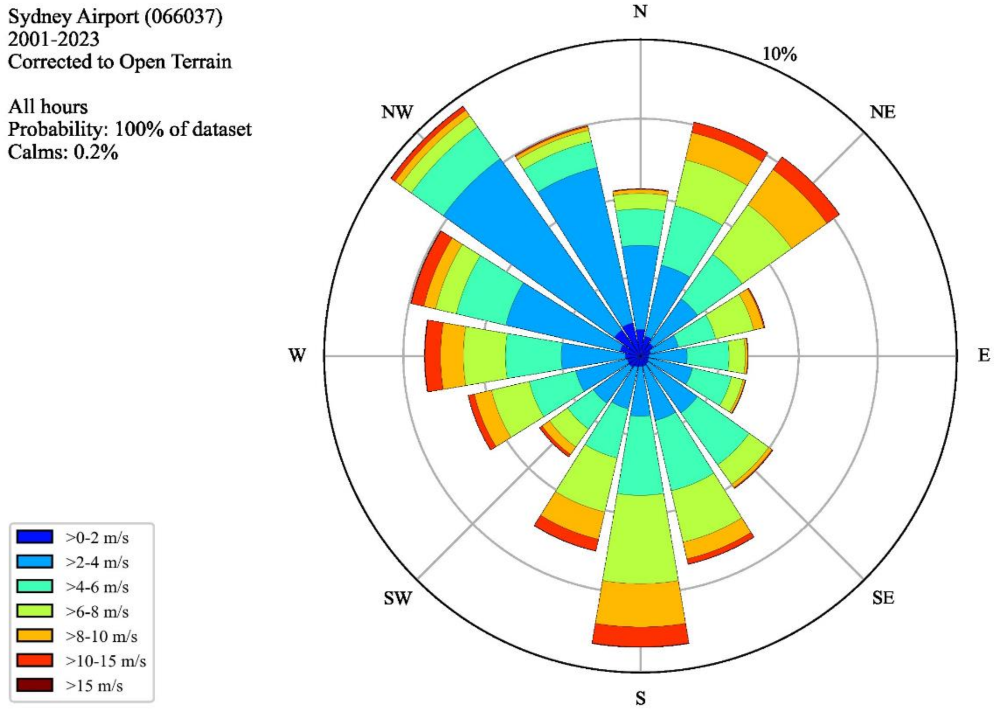


Figure 6: Annual wind rose showing probability of time of wind direction and speed

The annual wind rose is overlaid on the site showing the applicable key prevailing wind directions, Figure 7. A general description of flow patterns around buildings is given in Appendix A.1.

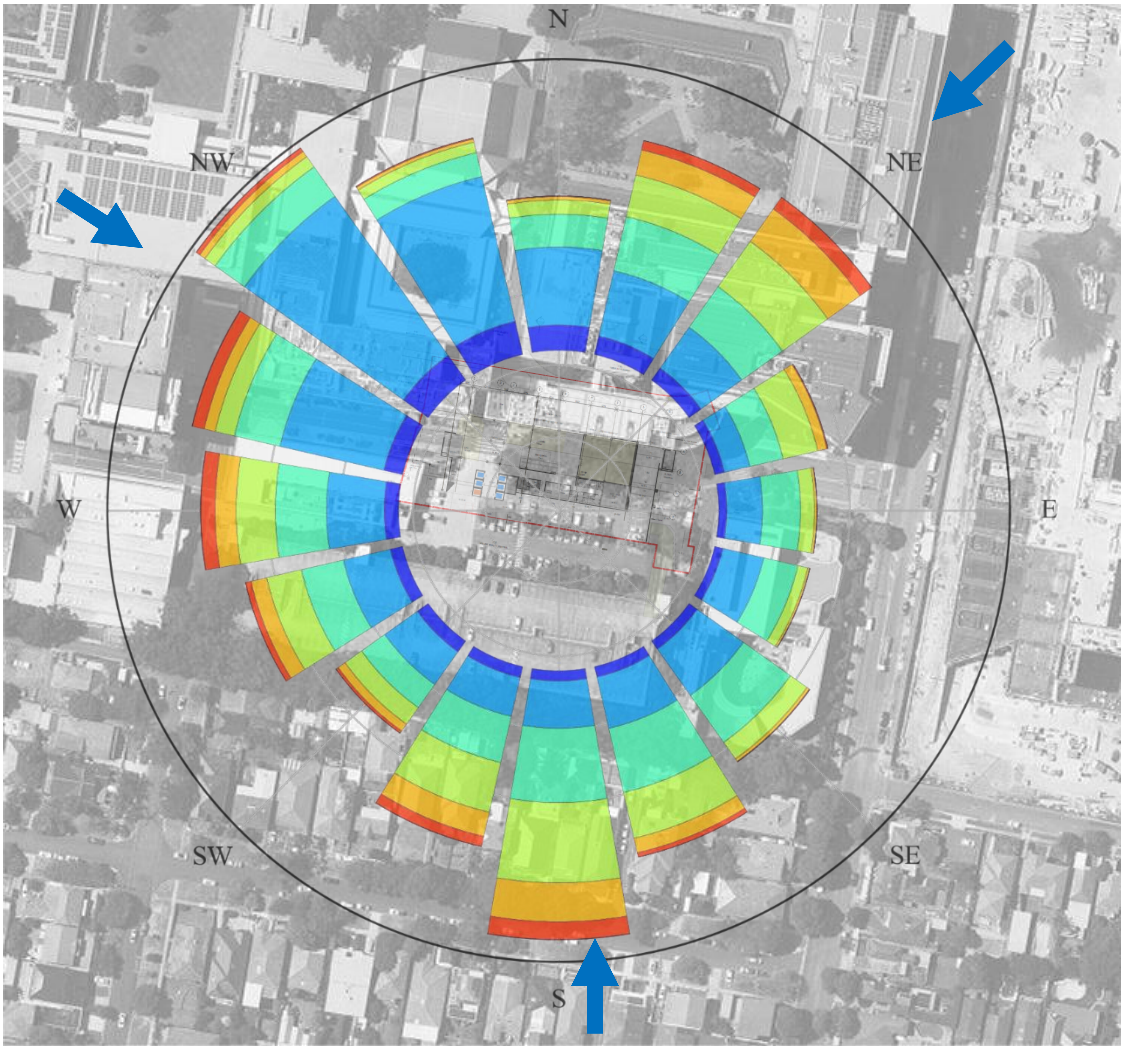


Figure 7: Annual wind rose overlaid on site showing probability of time of wind direction and speed

Seasonal

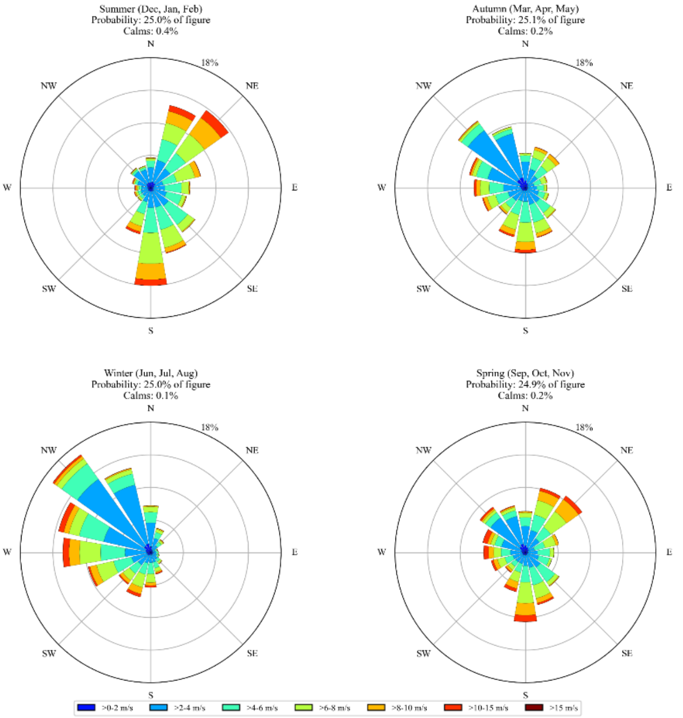


Figure 8: Seasonal wind roses showing probability of time of wind direction and speed

The region experiences distinct seasonal variations in wind patterns, each characterized by unique prevailing wind directions and intensities. The seasonal wind roses provide a detailed visual representation of these seasonal wind behaviours, Figure 8.

- **Summer:** Winds predominantly come from the south and north-east quadrants, contributing to warmer temperatures and occasional storms.
- **Autumn:** Wind directions are more variable, with prevailing winds from the south and north-west. Wind speeds are moderate, reflecting a mix of winter and summer influences.
- **Winter:** Dominated by strong winds from the west to north-west, resulting in cooler weather and dynamic conditions.
- **Spring:** Features a range of prevailing wind directions with stronger and more frequent winds, marking dynamic and sometimes turbulent atmospheric conditions.

Diurnal

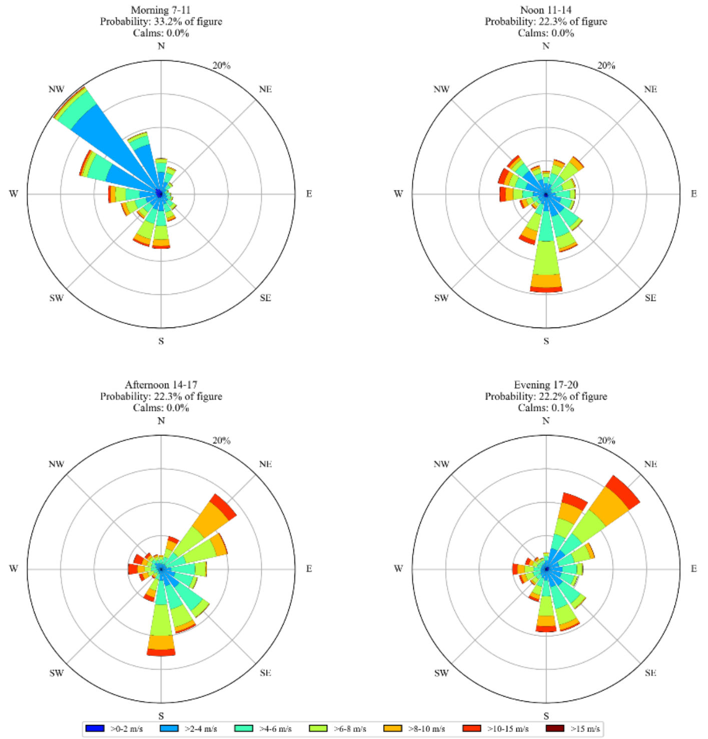


Figure 9: Diurnal wind roses showing probability of time of wind direction and speed

Based on the diurnal wind roses recorded at Sydney Airport, Figure 9, the following observations can be made regarding wind prevalence and strength throughout the day:

- **Morning:** Winds typically come from the north-west, with consistent and moderate strength.
- **Noon:** The prevalent wind direction shifts to the south, with south winds becoming more frequent and stronger, while north-west winds, though less frequent, become stronger.
- **Afternoon:** Winds shift to the north-east, becoming dominant as the day warms up. These winds are strong, contributing to the windiest period of the day.
- **Evening:** North-east winds continue to prevail, maintaining their strength into the evening, while south winds diminish

Based on temperature

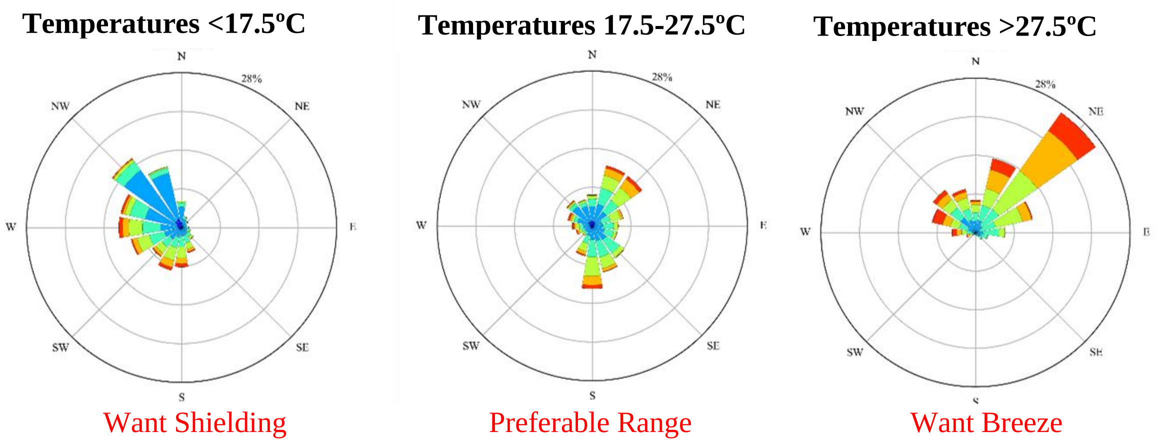


Figure 10: Temperature based wind roses showing probability of time of wind direction and speed

Based on the temperature wind roses recorded at Sydney Airport, Figure 10, the following observations can be made regarding wind prevalence and strength throughout the day:

- Want shielding:
    - Accounts for 40.9% of the time.
    - Prevailing winds from the west and north-west.
    - Shielding from these directions is recommended for comfort in cooler conditions.
- Preferable range:
    - Occurs for 55.4% of the time.
    - Winds are most prevalent from the south and north-east.
    - This range is ideal for thermal comfort, with moderate wind conditions.
- Want breeze:
    - Accounts for only 3.7% of the time.
    - Winds generally come from the north-east.
    - A breeze from this direction is preferable for cooling during hotter conditions.

6. Specific wind controls

Wind comfort is generally measured in terms of wind speed and rate of change of wind speed, where higher wind speeds and gradients are considered less comfortable. significantly affects thermal comfort and is generally welcome during hot summer conditions. This assessment is focused on wind speed in terms of mechanical comfort.

The criteria used in this study are based on the Randwick City Council DCP (2013), which specifies that Development Applications (DAs) for buildings over nine storeys must include a wind impact assessment. The DCP states that the proposed building must not generate ground-level wind speeds above 10 m/s for active frontages along Anzac Parade and 16 m/s for all other streets. However, it is unclear whether these wind speeds are based on gusts or mean values, nor is the probability of exceedance for such events specified. Based on the exceedance speeds, it is considered that the DCP controls correspond to the work of Melbourne (1978), where the 10 m/s and 16 m/s thresholds refer to pedestrian standing and walking classifications. Melbourne's work (1978) is based on the peak 3-second gust occurring within an hour from any direction, with a probability of exceedance of 0.1%.

To address the limited information in the Randwick City Council DCP (2013), the wind assessment criteria used in this study are based on Melbourne (1978), with additional recreational activity categories as defined in Table 2.

Table 2: Pedestrian comfort and safety criteria for various activities based on the work of Melbourne (1978)

Comfort & Safety (3 s gust wind speed in an hour exceeded for 0.1% of the time)	
<10 m/s	● Sitting
10-13 m/s	● Standing
13-16 m/s	● Walking
16-23 m/s	● Objective walking
>23 m/s	● Unsafe

7. Predicted wind conditions on ground plane

This section of the report outlines the predicted wind conditions in and around the site based on the local climate, topography, and building form.

Winds from the north-east

Winds from the north-east would approach the site over low-level buildings, before reaching the north-eastern corner of the campus, and also the UNSW Health Translation Hub (HTH) development, located on the eastern side of Botany Street, at the intersection with High Street, Figure 11. The site is semi-exposed for winds from the north-east, with the HTH development (under construction) and buildings to the north of the site, including F25 and E26, encouraging flow up and over the site. Further to this, the street grid pattern is irregular, which reduces flow penetration and channelling.

It is expected that some lower-level winds would still impinge on the north-east corner of the site, encouraging horizontal flow to wrap around the building. The discontinuity of the façade beyond the through-site link and its setback would encourage the wind flow to expend and reduce its speed around the north-west corner of the site, where the outdoor café seating would be located.

Upon completion of the HTH development, the site will be further protected for winds from the north-east.

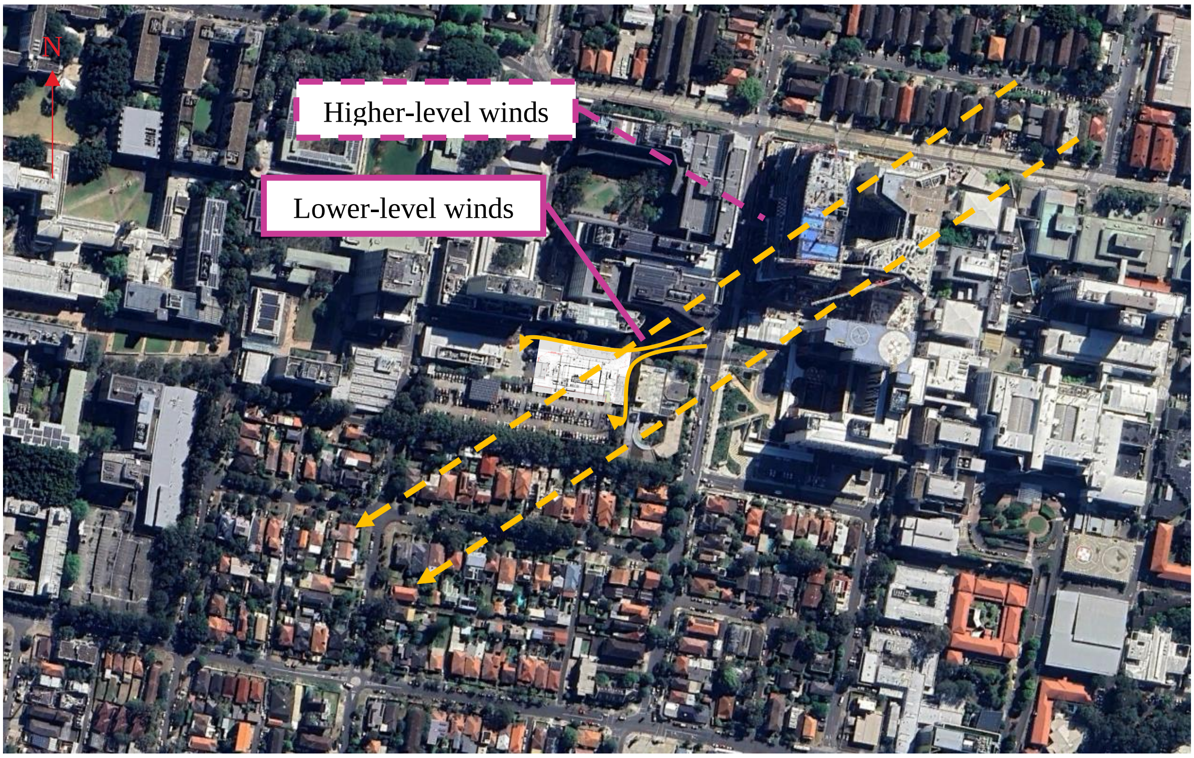


Figure 11: Predicted wind conditions at site for winds from the north-east (source: Google Earth 2024).

Winds from the south

With low-rise buildings immediately to the south, the site is exposed to winds from the south, Figure 12. Winds from this direction will impinge on the broad southern façade, creating downwash to ground level and acceleration around the south-east and south-west corners.

With the low-rise car park located upstream of the site, a significant pressure differential is expected between the two ends of the through-site link, which would likely accelerate wind flow through the passage. The alignment of the through-site link with Chancellery Walk and its placement towards the middle of the building is expected to exacerbate the wind conditions particularly for prevailing winds from the south and, to a lesser extent, winds from the north quadrant. If the through-site link is intended for purposes beyond transient walking, appropriate mitigation measures would be required to improve comfort.

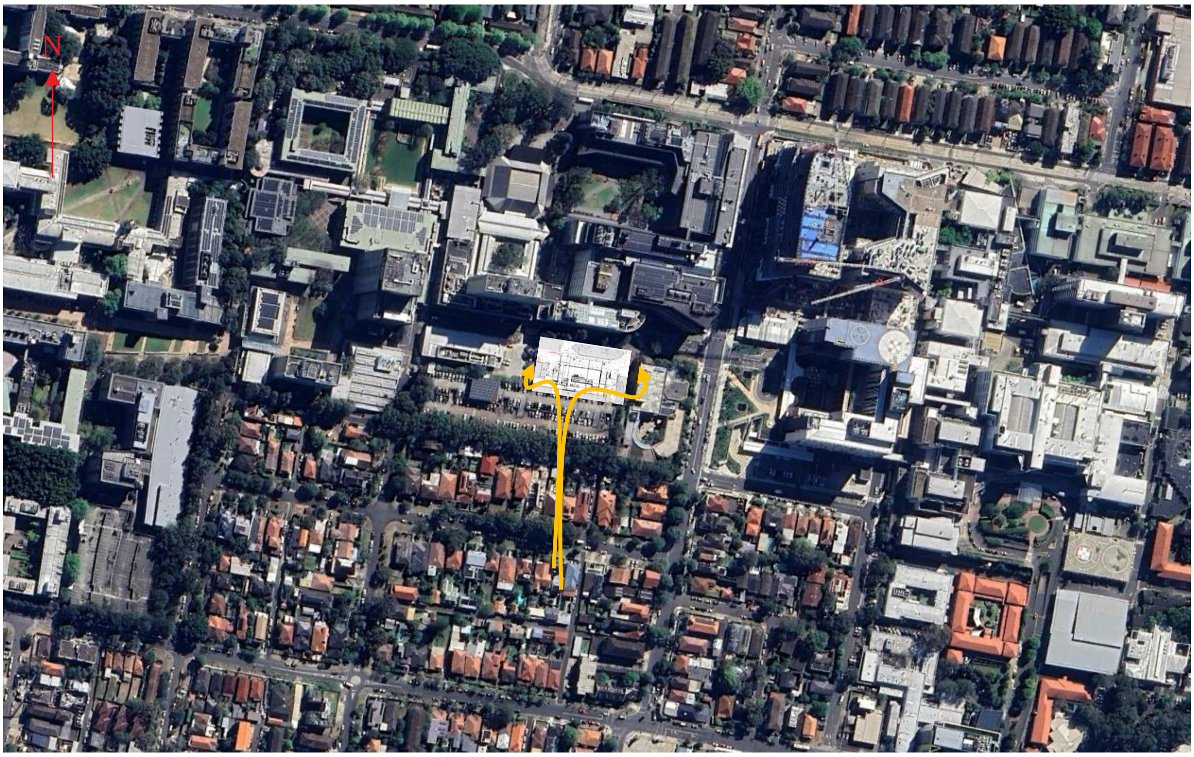


Figure 12: Predicted wind conditions at site for winds approaching from the south (source: Google Earth 2024)

Winds from the north-west

Wind approaching from the north-west quadrant will approach over the similar sized campus buildings to the west and north-west of the site, Figure 13, encouraging flow up and over the site. For any lower-level winds reaching the site, the narrow west façade will encourage any flow reaching the site to flow horizontally around the building, as opposed to creating significant downwash. There is the potential for some channelling of winds along Library Walk, although this is expected to be limited due to the nearby building to the west (F21, Library) blocking winds from the north-west quadrant along this corridor. These buildings would also help to shield the ground level café outdoor seating area, located on the northwest corner of the building’s floorplan, from strong winds. For winds from the west, the channelled wind flow along Library Walk would impinge of the western façade creating downwash which would get accelerated around the corner where the café is located. Introducing more mature trees around the corner perimeter as proposed in the proposed landscaping package would be beneficial in providing wind shielding for this area.

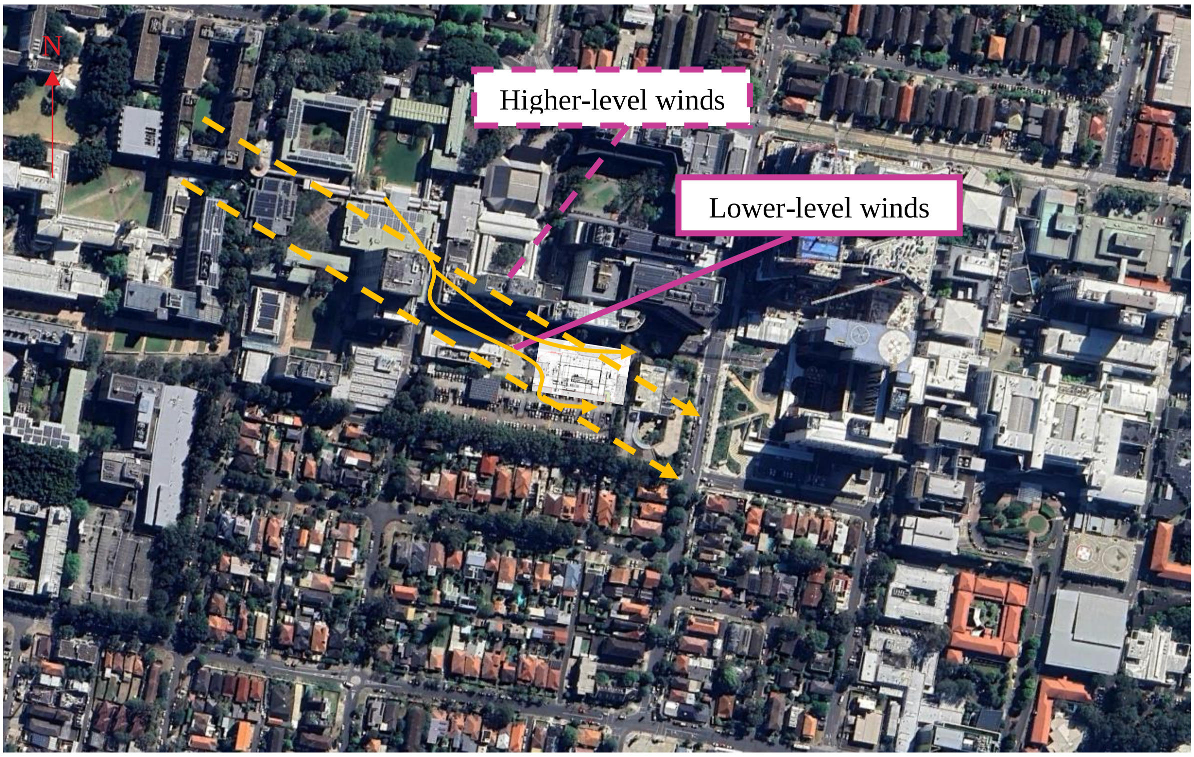


Figure 13: Predicted wind conditions at site under winds approaching from the north-west.

Conclusion

A qualitative environmental wind impact assessment was completed for the proposed G25 Building at the UNSW Kensington campus. The site is located in an area of similar height buildings at the south-eastern corner of the campus and is therefore only partially exposed to prevailing winds, mainly from the south.

Given its size and form, the proposed building would be expected to have an impact on the pedestrian level wind conditions. It is expected that the wind speed would be increased at the corners of the site, depending on the prevailing wind direction.

Qualitatively, integrating the expected directional wind conditions around the site with the wind climate, it is considered that from a comfort perspective, the wind conditions at the majority of locations around the site would be classified as suitable for pedestrian sitting or standing type activities at ground level, increasing to pedestrian walking around the corners of the site and through the ground level through-site link.

All areas around the development would be expected to meet the pedestrian safety criterion.

To quantify the qualitative advice provided in this report, numerical or physical modelling of the development would be required, which is best conducted during detailed design.

8. Mitigation Measures

Based on the qualitative wind assessment, if the through-site link is intended for purposes beyond transient walking, mitigation measures would be required to enhance comfort. One potential solution could be the introduction of a vertical down-stand façade to partially block the entrance, reducing wind acceleration through the link.

For the café, additional mitigation measures would be required to enhance the amenity of the space and ensure wind conditions suitable for sitting activities. This could be achieved by planting trees around the perimeter for wind shielding and positioning seating areas away from the thoroughfare entrance to minimise exposure to accelerated wind flow.

9. Additional information

The proposed Outdoor Learning space is located at rooftop level at the southeast corner of the building floorplan, Figure 14. For a building of this size, conditions at roof level would be reasonably windy primarily due to exposure to prevailing winds and height above ground level. The space is rectangular in plan and is exposed to the wind on the south and east sides, allowing for wind to pass through the learning space with increased intensity closer to the exposed edges.. High balustrades/parapet, in the order of 2-3 m high are recommended to assist with providing shielding for this space. Sectioning of the space with booth-style seating or otherwise is also recommended to provide adequate protection for sedentary type activities, as protection behind vertical barriers (i.e. balustrades at the perimeter of the terrace) diminishes with distance from the barrier; refer to Section A.1 for further information.

The proposed terrace is located at the rooftop level and would occupy a thin strip of floorspace spanning the entire north side of the proposed development, Figure 14. High balustrade/parapet, in the order of 2-3 m high are again recommended to offer shielding to people in these spaces. If a balustrade/parapet with sufficient height is not a viable option, improving wind conditions in this space could be achieved by sectioning the long terrace into smaller terraces using vertical barriers. This approach would help disrupt wind flow and enhance comfort for occupants.

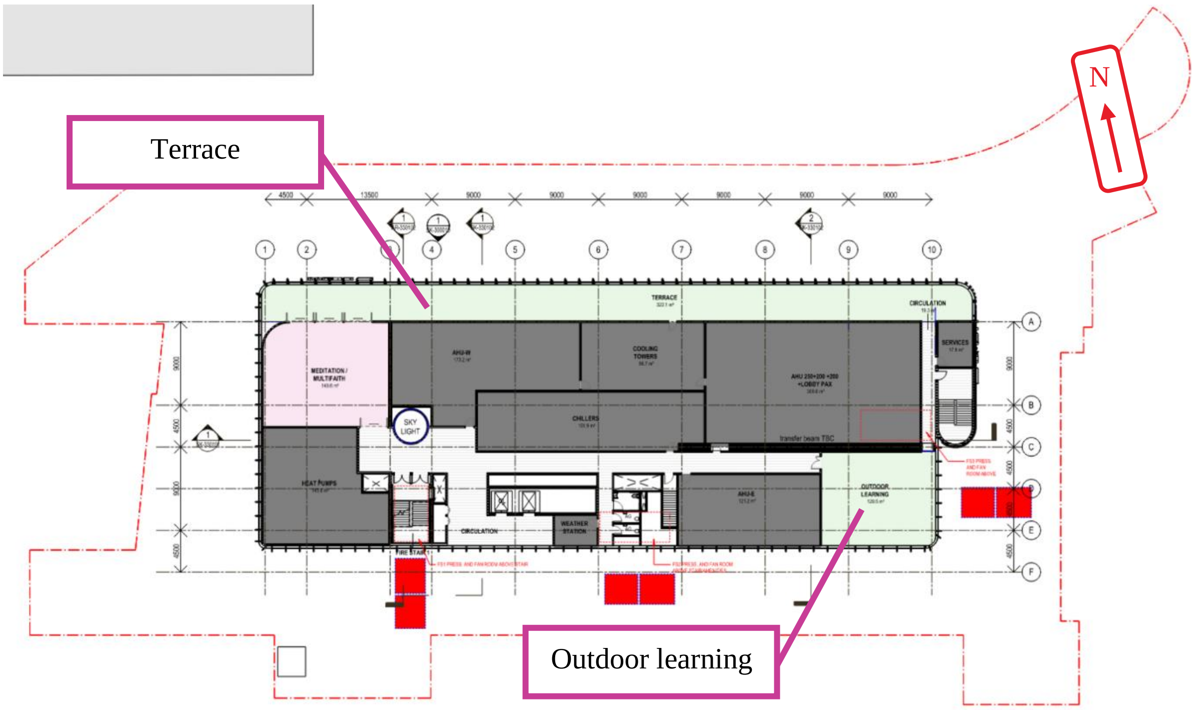


Figure 14: Outdoor learning space at plant (rooftop) level

10. References

Australasian Wind Engineering Society (2019), Quality Assurance Manual: Wind engineering studies of buildings, AWES-QAM-1-2019.

City of Auckland, (2016), Auckland Unitary Plan Operative.

City of Sydney (2016), Central Sydney Planning Strategy 2016-2036.

City of Melbourne (2017), Melbourne Planning Scheme.

Hunt, J.C.R., Poulton, E.C., and Mumford, J.C., (1976), The effects of wind on people; new criteria based on wind tunnel experiments, Building and Environment, Vol.11.

Isyumov, N. and Davenport, A.G., (1975), The ground level wind environment in built-up areas, Proc. 4th Int. Conf. on Wind Effects on Buildings, Cambridge University Press, U.K.

Lawson, T.V., and Penwarden, A.D., (1975), The effects of wind on people in the vicinity of buildings, Proc. 4th Int. Conf. on Wind Effects on Buildings, Cambridge University Press, U.K.

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. Wind Engineering and Industrial Aerodynamics, Vol.3, No.2-3, pp.241-249.

Netherlands Standardization Institute, NEN, (2006). Wind comfort and wind danger in the built environment, NEN 8100 (in Dutch) Dutch Standard.

Randwick City Council (2013), Randwick City Development Control Plan 2013.

Penwarden, A.D. and Wise, A.F.E. (1975), Wind environment around buildings, Building Research Establishment Report, HMSO.

San Francisco Planning Department, (2015) San Francisco Planning Code Section 148.

Appendix A

A.1 Wind flow mechanisms

An urban environment generates a complex wind flow pattern around closely spaced structures, hence it is exceptionally difficult to generalise the flow mechanisms and impact of specific buildings as the flow is generated by the entire surrounds. However, it is best to start with an understanding of the basic flow mechanisms around an isolated structure.

Isolated building

When the wind hits an isolated building, the wind is decelerated on the windward face generating an area of high pressure, Figure 15, with the highest pressure at the stagnation point at about two thirds of the height of the building. The higher pressure bubble extends a distance from the building face of about half the building height or width, whichever is lower. The flow is then accelerated down and around the windward corners to areas of lower pressure, Figure 15. This flow mechanism is called **downwash** and causes the windiest conditions at ground level on the windward corners and along the sides of the building.

Rounding the building corners or chamfering the edges reduces downwash by encouraging the flow to go around the building at higher levels. However, concave curving of the windward face can increase the amount of downwash. Depending on the orientation and isolation of the building, uncomfortable downwash can be experienced on buildings of greater than about 6 storeys.

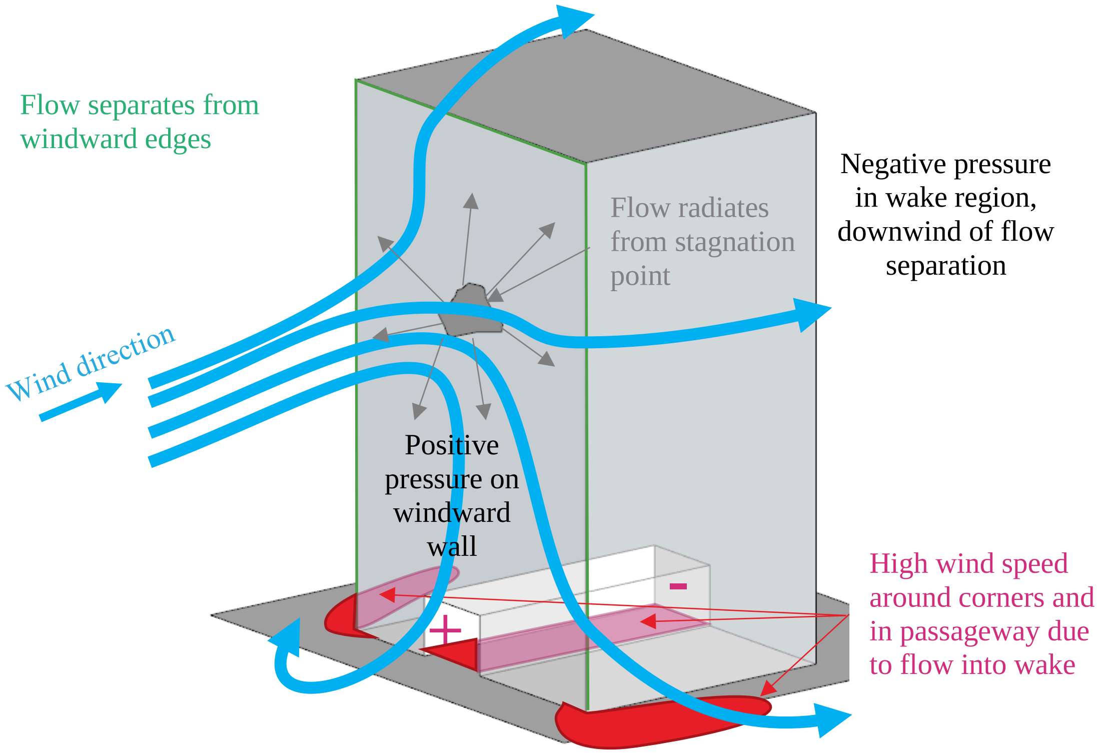


Figure 15: Schematic wind flow around tall isolated building

Techniques to mitigate the effects of downwash winds at ground level include the provision of horizontal elements, the most effective being a podium to divert the downward flow away from pavements and building entrances, but this will generate windy conditions on the podium roof, Figure 16. Generally, the lower the podium roof and deeper the setback from the podium edge to the tower improves the ground level wind conditions. The provision of an 8 m setback on an isolated building is generally sufficient to improve ground level conditions, but is highly dependent on the building isolation, orientation to prevailing wind directions, shape and width of the building, and any plan form changes at higher level.

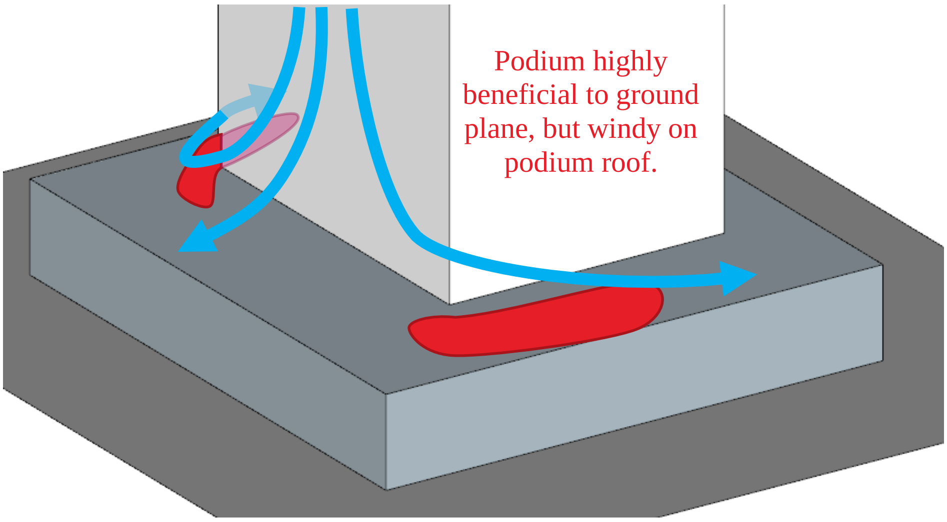


Figure 16: Schematic flow pattern around building with podium

Awnings along street frontages perform a similar function as a podium, and generally the larger the horizontal projection from the façade, the more effective it will be in diverting downwash flow, Figure 17. Awnings become less effective if they are not continuous along the entire façade, or on wide buildings as the positive pressure bubble extends beyond the awning resulting in horizontal flow under the awning.

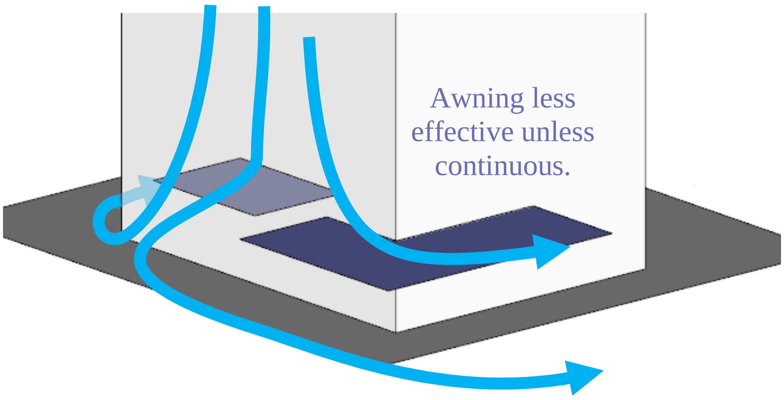


Figure 17: Schematic flow pattern around building with podium

It should be noted that colonnades at the base of a building with no podium generally create augmented windy conditions at the corners due to an increase in the pressure differential, Figure 18. Similarly, open through-site links through a building cause wind issues as the pressure tries to equilibrate between the entrances to the link causing strong flow, Figure 15. If the link is blocked, wind conditions will be relatively calm, Figure 19. This area is in a region of high pressure and therefore there is the potential for internal flow issues. A ground level recessed corner has a similar effect as an undercroft, resulting in windier conditions, Figure 19.

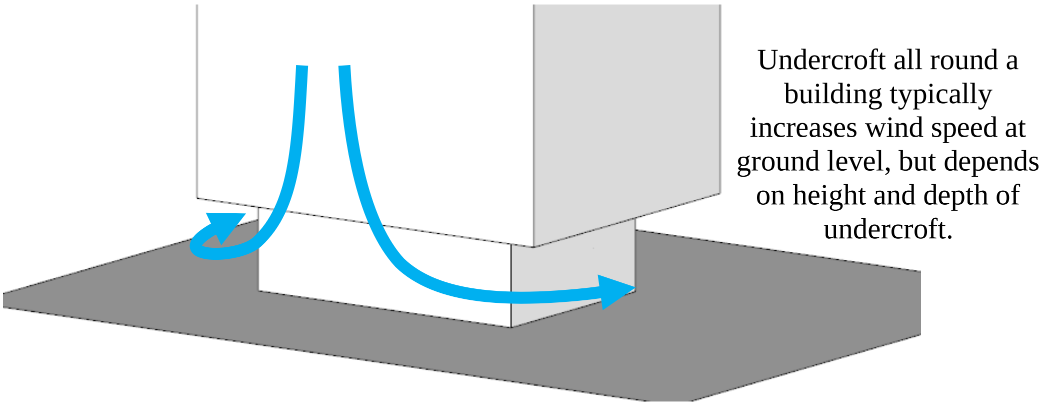


Figure 18: Schematic of flow patterns around isolated building with undercroft

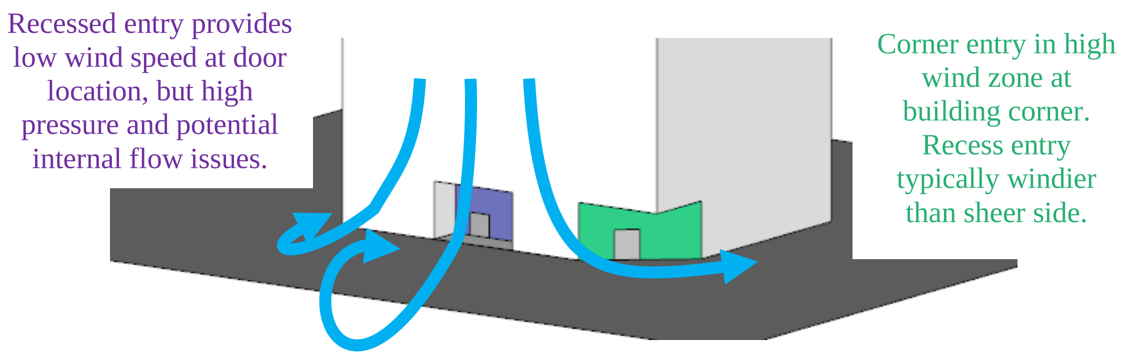


Figure 19: Schematic of flow patterns around isolated building with ground articulation

Multiple building

When a building is located in a city environment, depending on upwind buildings, the interference effects may be positive or negative, Figure 20. If the building is taller, more of the wind impacting on the exposed section of the building is likely to be drawn to ground level by the increase in height of the stagnation point, and the additional negative pressure induced at the base. If the upwind buildings are of similar height then the pressure around the building will be more uniform hence downwash is typically reduced with the flow passing over the buildings.

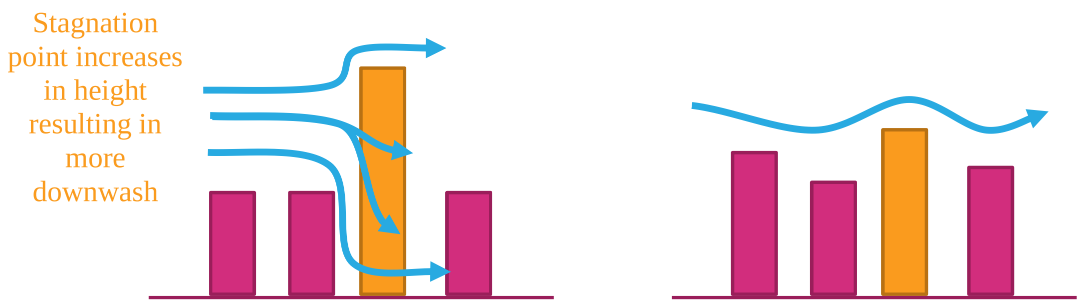


Figure 20: Schematic of flow pattern interference from surrounding buildings

The above discussion becomes more complex when three-dimensional effects are considered, both with orientation and staggering of buildings, and incident wind direction, Figure 21.

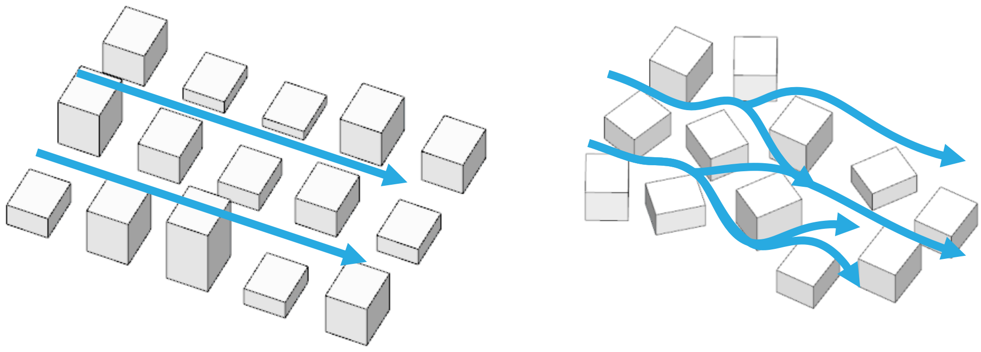


Figure 21 Schematic of flow patterns through a grid and random street layout

On the fringe of a city, the compound shape of neighbouring buildings instigates the flow pattern through the city. The overall massing causes an obstruction to the flow causing a slowing of the incident flow and increasing the windward pressure. Pressure driven flow is produced between the buildings, Figure 22. The vertical component in pressure driven flow is lower than downwash flow.

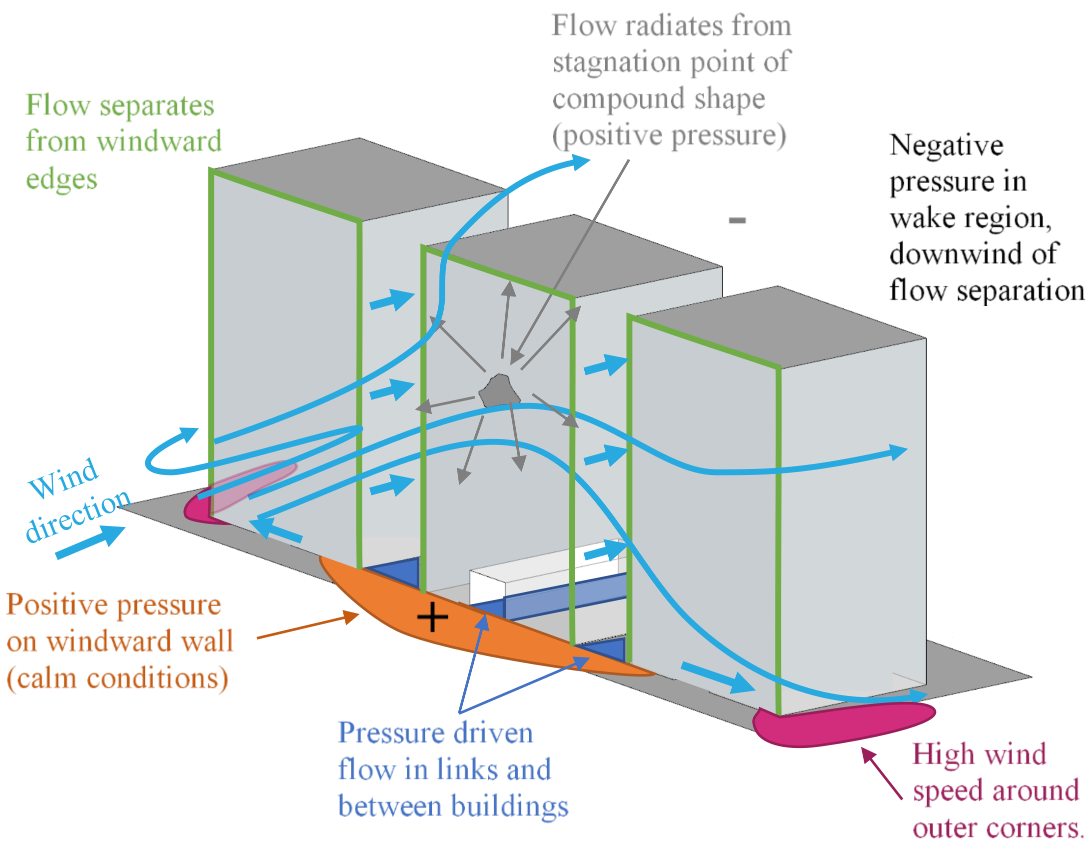


Figure 22: General flow pattern around multiple buildings

Channelling is instigated when pressure driven flow accelerates between two buildings, and continues along straight streets with buildings on either side, Figure 21(L). This occurs on the edge of large built-up areas where the approaching flow is diverted around the overall massing and channelled along the fringe by a relatively continuous wall of building facades. This is generally the primary mechanism producing strong wind conditions on the perimeter of a built-up area, particularly on corners, which can be exposed to multiple prevailing wind directions. The perimeter edge zone in a built-up area is typically about two blocks deep. Downwash is more important flow mechanism for the edge zone of a built-up area with buildings of similar height.

As the city expands, the central section of the city typically becomes calmer, particularly if the grid pattern of the streets is discontinued, Figure 21(R). When buildings are located on the corner of a central city block, the geometry becomes slightly more important with respect to the local wind environment.

Single barriers and screens

The wind flow pattern over a vertical barrier is illustrated in Figure 23, showing there will be recirculation zones near the windward wall and in the immediate lee of the barrier. The typical extent of these recirculation zones relative to the height of the barrier, h, is illustrated in Figure 23. These regions are not fixed but fluctuate in time. The mean wind speed in the wake areas drops significantly compared with the incident flow. With increasing distance from the barrier the flow pattern will resort to the undisturbed state. Typically the mean velocity and turbulence intensity at barrier height would be expected to be within 10% of the free stream conditions at 10 times the height of the structure downwind from the barrier.

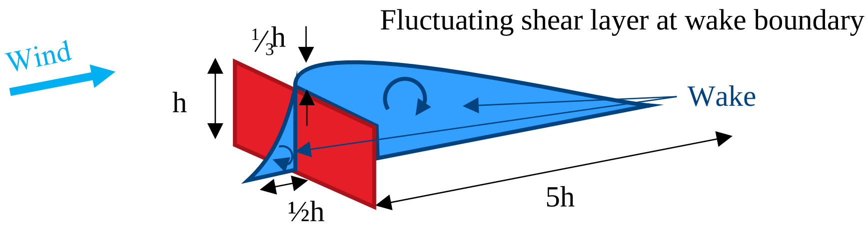


Figure 23: Sketch of the flow pattern over an isolated structure

A.2 Wind speed criteria

General discussion

Primary controls that are used in the assessment of how wind affects pedestrians are the wind speed, and rate of change of wind speed. A description of the effect of a specific wind speed on pedestrians is provided in Table 3. It should be noted that the turbulence, or rate of change of wind speed, will affect human response to wind and the descriptions are more associated with response to mean wind speed.

Table 3. Summary of wind effects on pedestrians

Description	Speed (m/s)	Effects
Calm, light air	0–2	Human perception to wind speed at about 0.2 m/s. Napkins blown away and newspapers flutter at about 1 m/s.
Light breeze	2–3	Wind felt on face. Light clothing disturbed. Cappuccino froth blown off at about 2.5 m/s.
Gentle breeze	3–5	Wind extends light flag. Hair is disturbed. Clothing flaps.
Moderate breeze	5–8	Raises dust, dry soil. Hair disarranged. Sand on beach saltates at about 5 m/s. Full paper coffee cup blown over at about 5.5 m/s.
Fresh breeze	8–11	Force felt on body. Limit of agreeable wind on land. Umbrellas used with difficulty. Wind sock fully extended at about 8 m/s.
Strong breeze	11–14	Hair blown straight. Difficult to walk steadily. Wind noise on ears unpleasant. Windborne snow above head height (blizzard).
Near gale	14–17	Inconvenience felt when walking.
Gale	17–21	Generally impedes progress. Difficulty with balance in gusts.
Strong gale	21–24	People blown over by gusts.

Local wind effects can be assessed with respect to a number of environmental wind speed criteria established by various researchers. These have all generally been developed around a 3 s gust, or 1 hour mean wind speed. During strong events, a pedestrian would react to a significantly shorter duration gust than a 3 s, and historic weather data is normally presented as a 10 minute mean.

Despite the apparent differences in numerical values and assumptions made in their development, it has been found that when these are compared on a probabilistic basis, there is some agreement between the various criteria. However, a number of studies have shown that over a wider range of flow conditions, such as smooth flow across water bodies, to turbulent flow in city centres, there is less general agreement among. The downside of these criteria is that they have seldom been benchmarked, or confirmed through long-term measurements in the field, particularly for comfort conditions. The wind criteria were all developed in temperate climates and are unfortunately not the only environmental factor that affects pedestrian comfort.

For assessing the effects of wind on pedestrians, neither the random peak gust wind speed (3 s or otherwise), nor the mean wind speed in isolation are adequate. The gust wind speed gives a measure of the extreme nature of the wind, but the mean wind speed indicates the longer duration impact on pedestrians. The extreme gust wind speed is considered to be suitable for safety considerations, but not necessarily for serviceability comfort issues such as outdoor dining. This is because the instantaneous gust velocity does not always correlate well with mean wind speed, and is not necessarily representative of the parent distribution. Hence, the perceived ‘windiness’ of a location can either be dictated by strong steady flows, or gusty turbulent flow with a smaller mean wind speed.

To measure the effect of turbulent wind conditions on pedestrians, a statistical procedure is required to combine the effects of both mean and gust. This has been conducted by various researchers to develop an equivalent mean wind speed to represent the perceived effect of a gust event. This is called the ‘gust equivalent mean’ or ‘effective wind speed’ and the relationship between the mean and 3 s gust wind speed is defined within the criteria, but two typical conversions are:

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

It is evident that a standard description of the relationship between the mean and impact of the gust would vary considerably depending on the approach turbulence, and use of the space.

A comparison between the mean and 3 s gust wind speed criteria from a probabilistic basis are presented in Figure 24 and Figure 26. The grey lines are typical results from modelling and show how the various criteria would classify a single location. City of Auckland has control mechanisms for accessing usability of spaces from a wind perspective as illustrated in Figure 24 with definitions of the intended use of the space categories defined in Figure 25.

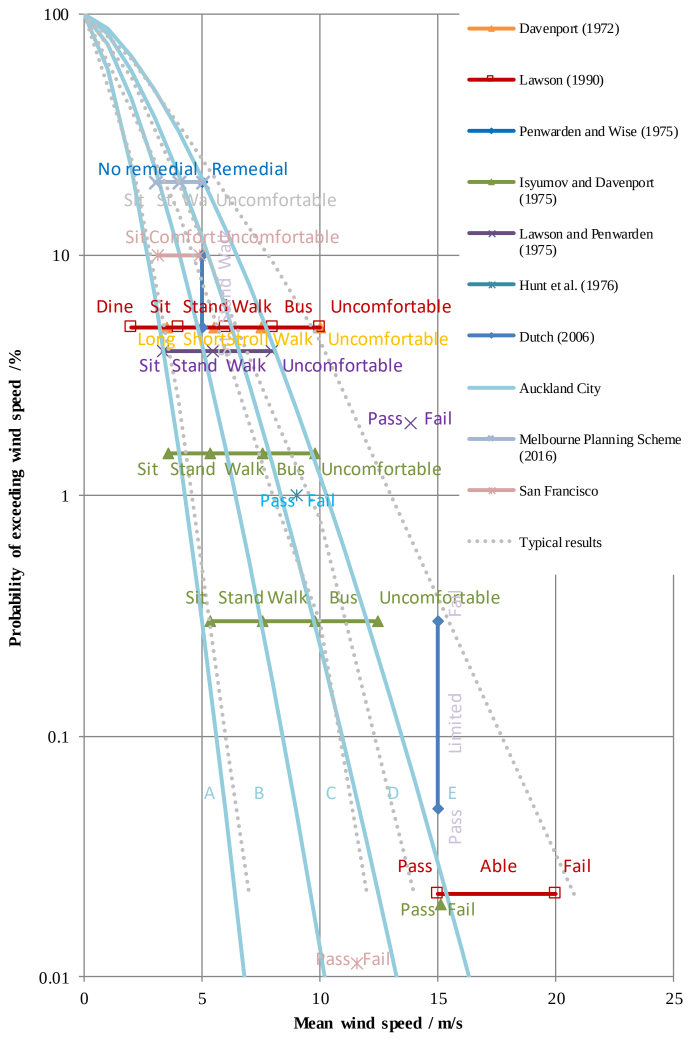


Figure 24. Probabilistic comparison between wind criteria based on mean wind speed

Category A	Areas of pedestrian use or adjacent dwellings containing significant formal elements and features intended to encourage longer term recreational or relaxation use i.e. public open space and adjacent outdoor living space
Category B	Areas of pedestrian use or adjacent dwellings containing minor elements and features intended to encourage short term recreation or relaxation, including adjacent private residential properties
Category C	Areas of formed footpath or open space pedestrian linkages, used primarily for pedestrian transit and devoid of significant or repeated recreational or relaxational features, such as footpaths not covered in categories A or B above
Category D	Areas of road, carriage way, or vehicular routes, used primarily for vehicular transit and open storage, such as roads generally where devoid of any features or form which would include the spaces in categories A - C above.
Category E	Category E represents conditions which are dangerous to the elderly and infants and of considerable cumulative discomfort to others, including residents in adjacent sites. Category E

Figure 25. Auckland Utility Plan (2016) wind categories

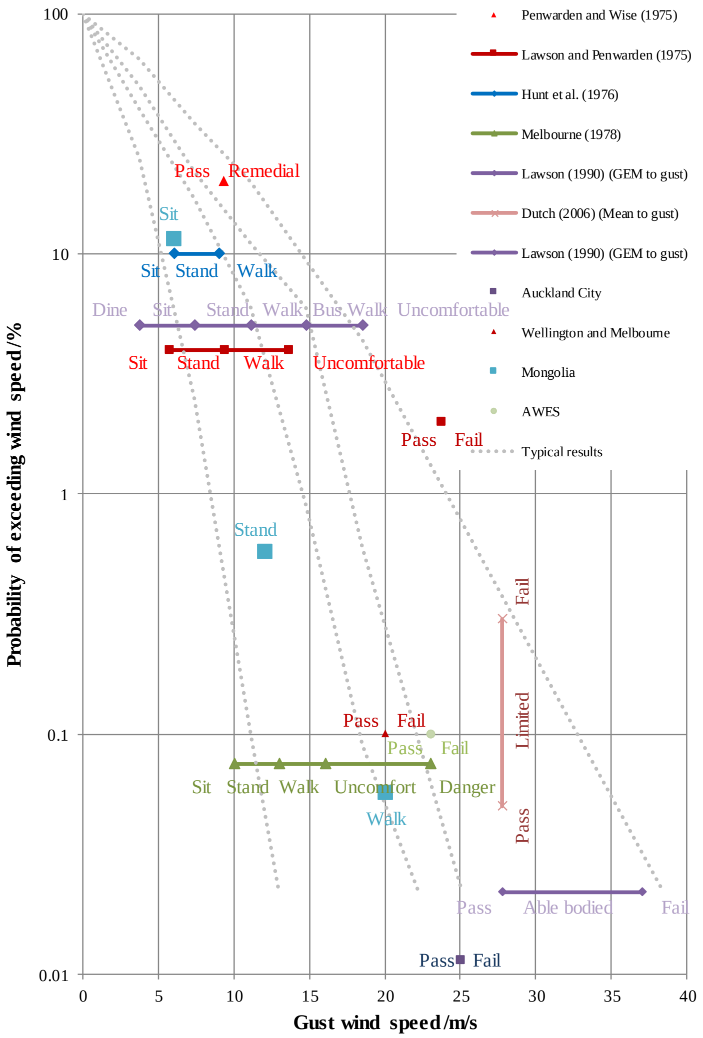


Figure 26. Probabilistic comparison between wind criteria based on 3 s gust wind speed

A.3 Reference documents

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

- Architectural Drawings, dated 27 November 2024 *(Issue for Test of Adequacy, Revision A.00)*