PEDESTRIAN WIND ENVIRONMENT STATEMENT

LOT 500, RESERVE STREET, SCARBOROUGH

WF825-01F02(REV0)- WS REPORT

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Prepared for:

Edge Visionary Living

Unit 2, 23 Hood Street Subiaco WA, 6008

WINDTECH Consultants Pty Ltd
Head Office: 607 Forest Road, Bexley, NSW 2207, Australia
P +61 2 9503 0300 **E** reception@windtechglobal.com **W** www.windtechconsult.com

Sydney | Dubai | London | Melbourne | Mumbai | New York | Hong Kong | Singapore

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EXECUTIVE SUMMARY

This report presents an opinion on the likely impact of the proposed development known as Lot 500, located on Reserve Street, Scarborough, on the local wind environment at the critical outdoor areas within and around the subject development. The effect of wind activity is examined for the three predominant wind directions for the Perth region; namely the easterly, south-westerly, and westerly winds. The analysis of the wind effects relating to the proposed development was 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 was 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. 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 site benefits from the shielding provided by the subject and neighbouring buildings to immediate direct wind effects within outdoor trafficable areas located downstream of the buildings. However, there are some outdoor trafficable areas that may be susceptible to wind effects that can potentially impact the local wind comfort and amenity, due to the interaction of the prevailing winds with the building morphology. It is expected that the wind effects identified in the report can be ameliorated and the local wind conditions enhanced with the consideration of the following treatment strategies into the design of the development:

Lower Ground to Ground Level Outdoor Areas

- The inclusion of densely foliating vegetation such as trees or shrubs/hedge planting within the proposed landscape planter areas within and around the subject development site as indicated in the architectural drawings; in particular within the tiered "The Corner" landscape planter area and around the corner areas of the Stages 01 and 02 Buildings.

- Outdoor seating areas are recommended to be located adjacent to the landscape planter areas; populated with densely foliating vegetation, to benefit from the wind mitigation provided by the vegetation. The inclusion of high-back seating in these areas would also be effective in wind mitigation and enhancing the local wind conditions.

- For outdoor seating areas along the Esplanade that are proposed to be located over 2m away from the landscape planter areas, the wind mitigation provided by the densely foliating vegetation is expected to be a minimal impact due to its large proximity to the seating areas. Localised wind mitigation features such as mobile screening/barrier or planter boxes populated with densely foliating vegetation are recommended to be

included around the outdoor seating area; with their most effective location along the eastern and western boundary of the seating areas.

- Areas intended for short duration stationary activities such as outdoor seating are recommended to be restricted/situated away from the corners of the proposed towers as these areas highly susceptibility to adverse wind conditions such as accelerating flows around the building; in particular the outdoor areas exposed to the prevailing easterly winds which are the strongest for the region.
- The inclusion of impermeable balustrades along the exposed perimeter edge of the public lookout.
- The inclusion of localised wind mitigation features such as screening or densely foliating vegetation within the public lookout area; in particular around areas intended for short duration stationary activities such as outdoor seating etc.

Level 2 Communal Outdoor Areas

- The inclusion of impermeable balustrades along the exposed perimeter edge of the communal outdoor areas.
- The strategic inclusion of densely foliating trees within the proposed landscape areas of the pool deck and fire pit. This is indicated in Figure 3.
- The inclusion of full-height porous screens to the soffit of the proposed Pavilion 2 canopy structure. This is indicated in Figure 3.
- The inclusion of impermeable screens at least 1.2m high along the eastern perimeter edge of the proposed pool deck. This is indicated in Figure 3.
- The inclusion of localised wind mitigation features such as screening or densely foliating vegetation within the various communal outdoor areas; in particular around areas intended for short duration stationary activities such as outdoor seating etc.
- Areas intended for short duration stationary activities such as outdoor seating are recommended to be restricted/situated away from the corners of the proposed towers as these areas highly susceptibility to adverse wind conditions such as accelerating flows around the building; in particular the outdoor areas exposed to the prevailing easterly winds which are the strongest for the region.

Private Balconies and Terraces

- The inclusion of full-height impermeable privacy/blade walls between the private balconies as indicated in the architectural drawings; in particular those located along the eastern and western aspects of the Stages 01 and 02 Buildings.
- The inclusion of impermeable balustrades along the exposed perimeter edges of the private balconies.

With the consideration of the abovementioned treatment strategies in the final design, it is expected that wind conditions for the various trafficable outdoor areas within and around the development will be suitable for their intended uses and their applicable criteria as detailed within the report.

Due to the overall massing of the subject development and the complexity of the building form, wind tunnel testing is recommended to be undertaken as part of the detailed design phase. This will provide a quantitative analysis of the wind conditions and determine the requirement for wind mitigation measures; including the optimisation of the size and extent of the treatments required to ensure suitable wind conditions are achieved at all outdoor pedestrian accessible locations within and around the development.

Note the densely foliating vegetation is to be of an evergreen species to ensure their effectiveness in wind mitigation throughout the year and the vegetation should be spaced such that the foliage is able to interlock between plants (where possible). Furthermore, the use of loose glass-tops and light-weight sheets or covers (including loose BBQ lids) is not appropriate on high-rise outdoor balconies or terraces. Lightweight furniture is not recommended unless it is securely attached to the balcony or terrace floor slab.

CONTENTS

1 INTRODUCTION

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 was 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 was 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 THE DEVELOPMENT AND SURROUNDINGS

The development site is bounded by the West Coast Highway to the east, Reserve Street to the south, the Esplanade to the west and residential buildings varying up to 7 storeys high abutting the site to the north. Surrounding the site is Scarborough beach to the west, with predominantly low-rise private residential housing/buildings along the remaining boundaries with intermittent medium-rise high residential buildings along the West Coast Highway corridor. A survey of the land topography indicates there is a general rise in elevation towards the east of the site. An aerial image of the subject site and the local surroundings is shown in Figure 1.

The existing site consists of bushland and the Reserve Street Scarborough parking site. The proposed development is comprised of two buildings detailed as follows:

- Stage 01 Building – Comprised of 12 tower levels atop of 4 podium levels on the Scarborough Beach frontage of the site.
- Stage 02 Building – Comprised of 16 tower levels atop of 3 podium levels on the West Coast Highway frontage of the site.

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

- Lower Ground to Ground Level pedestrian footpaths, Pocket Park and Public Lookout outdoor areas.
- The Level 02 Communal Outdoor Areas on the Stage 01 Building.
- Private residential balconies and terraces on the Stage 01 and 02 Buildings.

Figure 1: Aerial Image of the Site Location

3 REGIONAL WIND

The Perth region is governed by three principal wind directions, and these can potentially affect the subject development. These winds prevail from the east, south-west and west. A summary of the principal time of occurrence of these winds throughout the year is presented in Table 1 below. This summary is based on an analysis of wind rose data obtained by the Bureau of Meteorology from Perth Airport, from 1944 to 2006. From this analysis, directional probabilities of exceedance and directional wind speeds for the Perth region are determined. The directional wind speeds and corresponding directional frequencies of occurrence are presented in Figure 2.

As shown in Figure 2, the easterly winds are the most frequent for the Perth region, and are also the strongest. The south-westerly winds occur most frequently during the warmer months of the year for the Perth region, and hence are usually welcomed within outdoor areas. South-westerly winds are also similar strength to the westerly winds, but not as strong as the easterly events. The south-westerly and westerly winds typically occur during the afternoon periods

Table 1: Principal Time of Occurrence of Winds for the Perth Region

Month	Easterly	South-Westerly	Westerly
January	X	X	
February	X	X	
March	X	X	X
April	X	X	X
May	X		X
June			X
July			X
August		X	X
September	X	X	X
October	X	X	X
November	X	X	X
December	X	X	

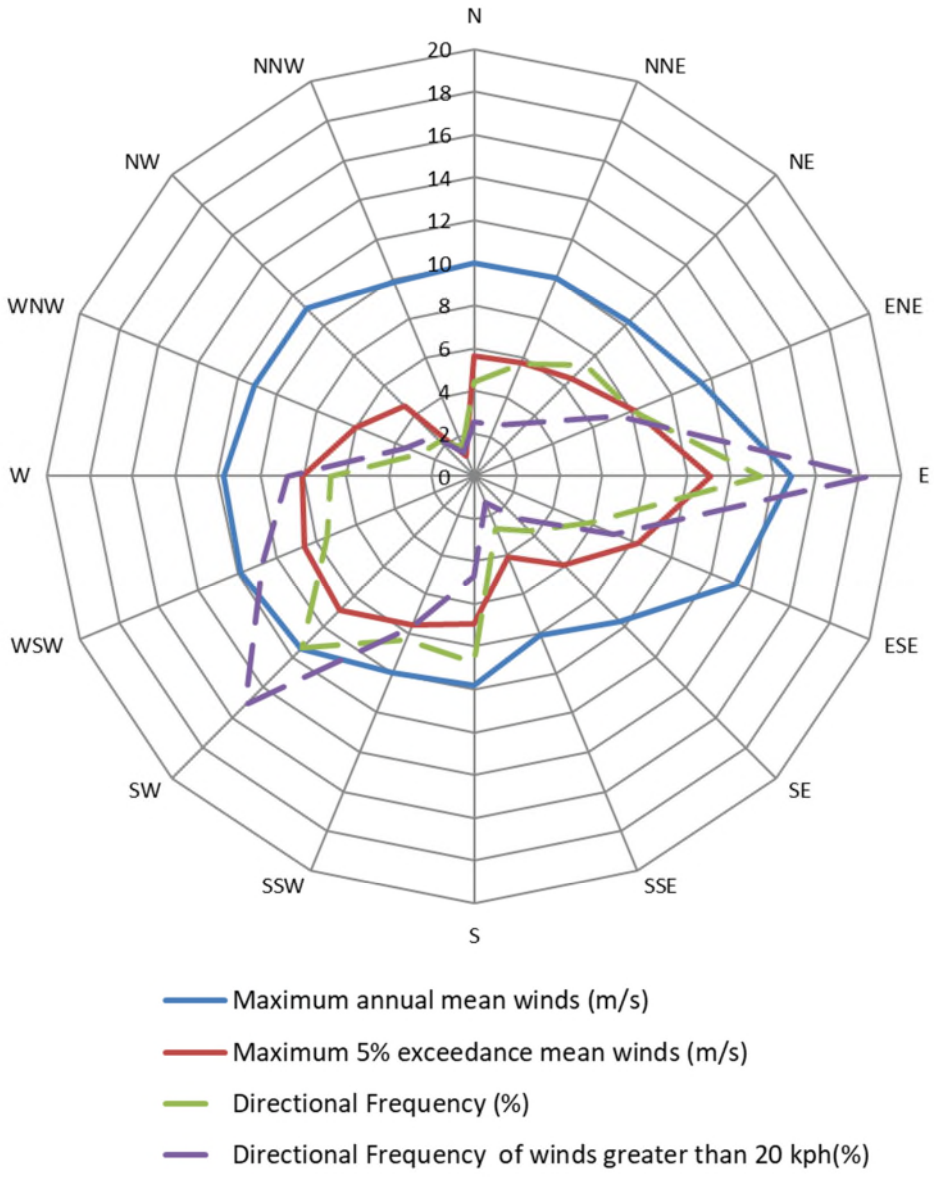

Figure 2: Annual and 5% Exceedance Hourly Mean Wind Speeds, and Frequencies of Occurrence, for the Perth Region

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 2 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 2: 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 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 (rather than referencing specific wind speeds). 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 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.

For this assessment, the wind comfort criterion that were considered as part of this assessment were the following:

- Comfortable Walking Criterion (7.5m/s with a 5% probability of exceedance) for general circulation and pedestrian thoroughfares, e.g. footpaths, private balconies/terraces, through-site links etc.
- Short Exposure Criterion (5.5m/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.
- Long Exposure Criterion (3.5m/s with a 5% probability of exceedance) for stationary activities longer than an hour, e.g. outdoor cinemas, outdoor fine dining etc.

5.1 Lower Ground to Ground Level Areas

The podium build-form of the Stage 01 and 02 buildings, and the neighbouring medium-rise building to the north and south of the site can provide shielding to ground level direct wind effects; from the prevailing wind directions, to outdoor trafficable areas that are located down-stream of the podium. Down-wash wind effects off the building façade are expected to be minimal on the outdoor trafficable areas due to tower setback from the podium edge. However, the development site is surrounded by open car-parking of Scarborough Beach and low-rise residential buildings to the east that will provide minimal shielding to the prevailing westerly to south-westerly, and easterly winds respectively. Furthermore, the interaction of the prevailing winds with the subject and neighbouring buildings may generate wind effects that can potentially impact the wind comfort and amenity within the outdoor trafficable areas that do not benefit from the immediate shielding provided by these buildings. This is summarised as follows:

- The Esplanade – The pedestrian footpath along the Esplanade is exposed to the direct wind effects from the prevailing south-westerly to westerly directions as it travels over the open terrain of Scarborough Beach. The outdoor trafficable areas around the northern corner of the Stage 01 building are also susceptible to accelerating flows around the Stage 01 building. The wind conditions at the southern corner intersection between the Esplanade and Reserve Street are expected to be similar to the existing

wind conditions due to the large separation distance of subject buildings to the pedestrian footpath.

- Pocket Park – The proposed Pocket Park located at the southern corner of the Stage 01 Building is exposed to direct wind effects from the prevailing south-westerly to westerly directions as it travels over the open terrain of Scarborough Beach and easterly winds as it travels along Reserve Street and side-streams along the podium façade. The Pocket park is also susceptible to the prevailing winds accelerating around the southern corner of the Stage 01 Building.

- Reserve Street – Due to the east to west/south-west alignment of Reserve Street, the pedestrian footpath along the street frontage is exposed to the prevailing winds travelling along the street; particularly from the south-westerly direction due to the rise in elevation that may induce the accelerated flow effects up the street. The corner intersection between Reserve Street and West Coast Highway is susceptible to accelerating flows around the southern corner of the Stage 02 building.

- West Coast Highway – The pedestrian footpath along the West Coast Highway frontage of the site is potentially exposed to direct wind effects from the prevailing easterly direction as it travels over the low-rise buildings to the east of the site, over the multi-lane highway and reattaching onto the pedestrian footpath.

- North-South Vehicular Lane between the Stage 01 and 02 Buildings – The pedestrian footpath along the proposed vehicular lane is well shielded by the Stage 01 and 02 Buildings, however it is susceptible to accelerating flows around the corners of the buildings.

- East-West Vehicular Lane along the northern boundary of the site – The pedestrian footpath along the proposed vehicular lane is exposed to the direct wind effects from the prevailing easterly and westerly directions travelling over West Coast Highway and Scarborough Beach respectively. Due to the Stage 02 Building's close proximity with the neighbouring medium-rise building to the north, the prevailing easterly winds may be accelerated along the vehicular lane due to a potential funnelling wind effect between the buildings.

It is expected the following treatment strategies to be effective in mitigating the abovementioned potential wind effects and enhance the local wind conditions along the various ground level pedestrian footpaths within and around the site, hence they are recommended to be considered in the design of the development:

- The inclusion of densely foliating vegetation such as trees or shrubs/hedge planting within the proposed landscape planter areas within and around the subject development site as indicated in the architectural drawings; in particular within the tiered "The Corner" landscape planter area and around the corner areas of the Stages 01 and 02 Buildings.

- Outdoor seating areas are recommended to be located adjacent to the landscape planter areas; populated with densely foliating vegetation, to benefit from the wind mitigation provided by the vegetation. The inclusion of high-back seating in these areas would also be effective in wind mitigation and enhancing the local wind conditions.

- For outdoor seating areas along the Esplanade that are proposed to be located over 2m away from the landscape planter areas, the wind mitigation provided by the densely foliating vegetation is expected to be a minimal impact due to its large proximity to the seating areas. Localised wind mitigation features such as mobile screening/barrier or planter boxes populated with densely foliating vegetation are recommended to be included around the outdoor seating area; with their most effective location along the eastern and western boundary of the seating areas.

- Areas intended for short duration stationary activities such as outdoor seating are recommended to be restricted/situated away from the corners of the proposed towers as these areas highly susceptibility to adverse wind conditions such as accelerating flows around the building; in particular the outdoor areas exposed to the prevailing easterly winds which are the strongest for the region.

- The inclusion of impermeable balustrades along the exposed perimeter edge of the public lookout.

- The inclusion of localised wind mitigation features such as screening or densely foliating vegetation within the public lookout area; in particular around areas intended for short duration stationary activities such as outdoor seating etc.

Note the densely foliating vegetation is to be of an evergreen species to ensure their effectiveness in wind mitigation throughout the year and the vegetation should be spaced such that the foliage is able to interlock between plants (where possible).

Due to the overall massing of the subject development and the complexity of the building form, wind tunnel testing is recommended to be undertaken as part of the detailed design phase. This will provide a quantitative analysis of the wind conditions and determine the requirement for wind mitigation measures; including the optimisation of the size and extent of the treatments required to ensure suitable wind conditions are achieved at all outdoor pedestrian accessible locations within and around the development.

5.2 Level 2 Communal Outdoor Areas

The proposed tower build-form of the Stages 01 and 02 buildings can provide shielding to direct wind effects within the communal outdoor areas located down-stream of the towers. Down-wash wind effects are expected to be minimal due to the aforementioned shielding provided by the Stage 02 tower to the prevailing easterly winds, the westerly winds down-washing off the western tower façade of the Stage 01 tower will be redirected onto the non-trafficable areas of the podium, and the relatively narrow projection and design of the Stage 01 tower to the prevailing south-westerly winds that are likely to side-stream along the tower façade than down-wash onto the communal outdoor space below. However due to the large extent of the communal space, there are outdoor areas that do not benefit from the shielding afforded by the towers and are exposed to a number of potential adverse wind effects summarised as follows:

- Direct wind effects as the prevailing winds travels over Scarborough Beach to the west of the site, and over surrounding low-rise buildings to the east of the site that is expected to provide minimal shielding at this elevated position.
- Corner wind effects as the prevailing winds accelerate around the corners of the towers; in particular around the eastern corner of the Stage 01 tower and western corner of the Stage 02 tower.
- Funnelling wind effects within the communal outdoor areas along the western boundary between the Stage 01 tower and the proposed pavilion.

It is expected the following treatment strategies to be effective in mitigating the abovementioned potential wind effects and enhance the local wind conditions on the podium rooftop, hence they are recommended to be considered in the design of the development:

- The inclusion of impermeable balustrades along the exposed perimeter edge of the communal outdoor areas.
- The strategic inclusion of densely foliating trees within the proposed landscape areas of the pool deck and fire pit. This is indicated in Figure 3.
- The inclusion of full-height porous screens to the soffit of the proposed Pavilion 2 canopy structure. This is indicated in Figure 3.
- The inclusion of impermeable screens at least 1.2m high along the eastern perimeter edge of the proposed pool deck. This is indicated in Figure 3.
- The inclusion of localised wind mitigation features such as screening or densely foliating vegetation within the various communal outdoor areas; in particular around areas intended for short duration stationary activities such as outdoor seating etc.
- Areas intended for short duration stationary activities such as outdoor seating are recommended to be restricted/situated away from the corners of the proposed towers as these areas highly susceptibility to adverse wind conditions such as accelerating

flows around the building; in particular the outdoor areas exposed to the prevailing easterly winds which are the strongest for the region.

Note the densely foliating vegetation is to be of an evergreen species to ensure their effectiveness in wind mitigation throughout the year and the vegetation should be spaced such that the foliage is able to interlock between plants (where possible).

Figure 3: In-Principle Treatment Strategies for the Level 2 Communal Outdoor Areas

5.3 Private Balconies and Terraces

The wind conditions within the single aspect private balconies and terraces are expected to be suitable for their intended uses with the inclusion of the proposed balustrades and full-height privacy/blade walls along the exposed perimeter edges that are effective limiting the ability for the prevailing winds to side-stream across the tower facade and creating stagnation zones. Furthermore, the inclusion of densely foliating vegetation along the exposed perimeter edges of the private balconies and terraces are expected to be effective in further enhancing the local wind conditions within these areas; particularly if they are located along the western and eastern perimeter edges.

The double aspect wrap-around corner private balconies on both the Stage 01 and 02 towers however are exposed to adverse wind effects such as accelerating flows around the corners of the towers, side-stream wind effects along the tower façade, and direct wind effects due to the lack of shielding provided by the surrounding buildings at these elevated positions.

It is expected the following treatment strategies to be effective in mitigating the abovementioned potential wind effects and enhance the local wind conditions on the podium rooftop, hence they are recommended to be considered in the design of the development:

- The inclusion of full-height impermeable privacy/blade walls between the private balconies as indicated in the architectural drawings; in particular those located along the eastern and western aspects of the Stages 01 and 02 Buildings.
- The inclusion of impermeable balustrades along the exposed perimeter edges of the private balconies.

As a general note, the use of loose glass-tops and light-weight sheets or covers (including loose BBQ lids) is not appropriate on high-rise outdoor balconies or terraces. Lightweight furniture is not recommended unless it is securely attached to the balcony or terrace floor slab.

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7 APPENDIX – WIND EFFECTS GLOSSARY

7.1 Downwash and Upwash Effects

The downwash wind effect occurs when wind is deflected down the building's windward facade causing accelerated wind speeds 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 A1. This can also lead to recirculating flow in the presence of a shorter upstream building, causing the local ground level wind flow to move towards 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.

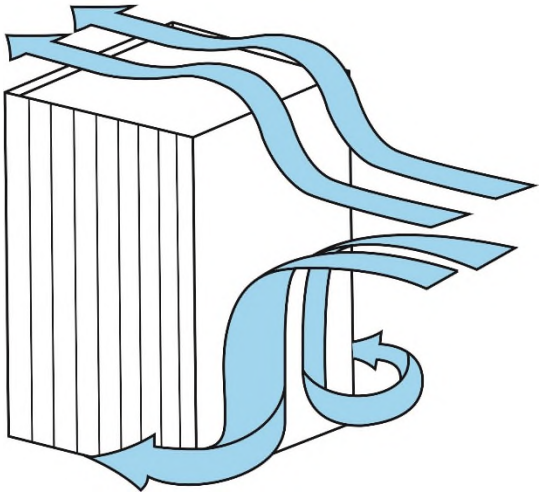

Figure A1: Downwash Leading to Corner Wind Effect, and Upwash Effects

7.2 Funnelling/Venturi Effect

Funnelling effects occur when the wind interacts with two or more buildings which are located adjacent to each other and the building form design results in a bottleneck, as shown in Figure A2. This can cause the wind to be forced 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.

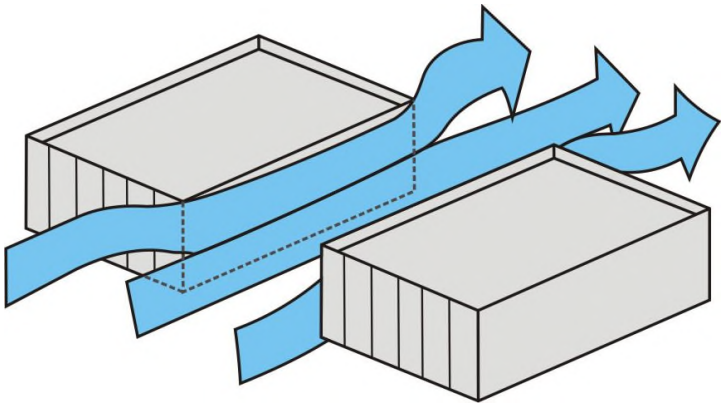

Figure A2: Funnelling/Venturi Wind Effect

7.3 Gap Effect

The gap effect occurs in small openings in the façade that are open to wind on opposite faces, as seen in Figure A3. 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.

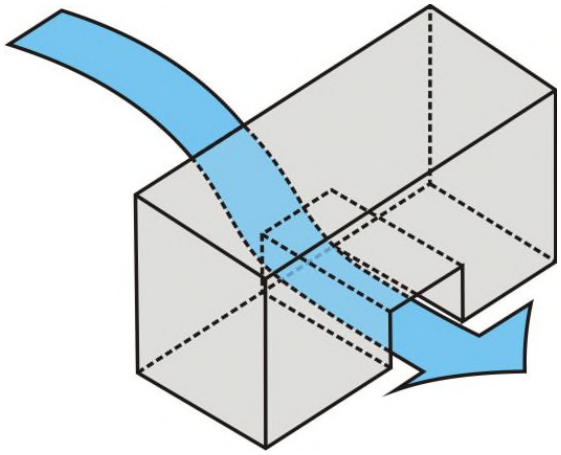

Figure A3: Gap Wind Effect

7.4 Sidestream and Corner Effects

The sidestream effect is due to a gradual accumulation of winds 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 A4

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.

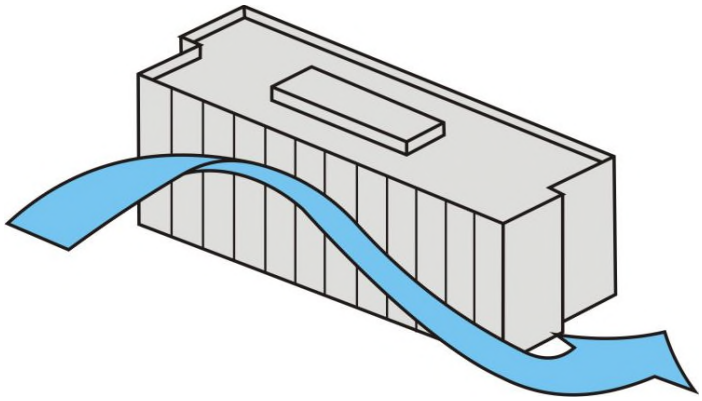

Figure A4: Sidestream and Corner Wind Effect

7.5 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.