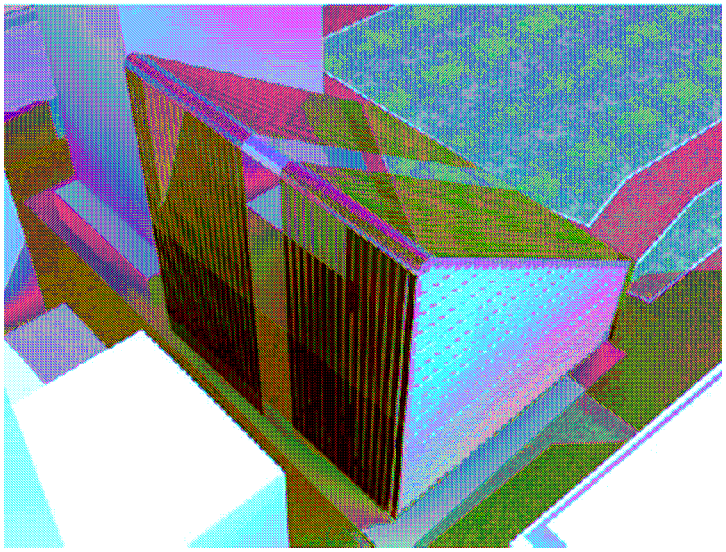
Appendix I

Wind effects study

Kann Finch Group Pty Ltd

Belmore Park Zone Sub-Station, Sydney - Wind Effects Study



Report No. 30B-08-0033-TNT-410880-1

Vipac Engineers & Scientists Ltd

Melbourne VIC

18th August 2008

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Belmore Park Zone Sub-Station, Sydney - Wind Effects Study

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00	6th June 2008	Initial Issue
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KEYWORDS: Wind Effects Statement, 430-450 Pitt Street

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EXECUTIVE SUMMARY

Kann Finch Architects Pty Ltd commissioned Vipac Engineers and Scientists Ltd to prepare a statement of wind effects for the ground level areas adjacent to the proposed Belmore Park Zone Sub-Station, Sydney, NSW. This appraisal is based on Vipac's experience as a wind-engineering consultancy.

Revised drawings of the proposed Development were supplied by Kann Finch Group Pty Ltd during August 2008 as described in Appendix C.

The findings of this study can be summarised as follows:

- Vipac does not expect the proposed Development to generate any wind conditions in excess of the criterion for safety.
- Vipac does not expect the proposed Development to generate any wind conditions in excess of the criterion for standing.
- Vipac expects most ground level areas would be close to or within the criterion for acceptability for walking.
- Vipac recommends a wait-and-see approach to the recommended wind control devices (mentioned in this report), which could be included post–construction if required.

The assessments provided in this report have been made based on a desktop assessment and experience of similar situations in Sydney and around the world. No wind tunnel test has been carried out at this stage.

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1. INTRODUCTION

Vipac Engineers & Scientists Ltd was commissioned by **Kann Finch Architects** to carry out an appraisal of the pedestrian level wind effects for the proposed Belmore park zone sub station office tower, located within Sydney's Central Business District (CBD).

The proposed Development is a 13 storey, 58 m high (approximately) commercial office tower, located to the south of Sydney's CBD. The Site is surrounded by a number of medium to high rise developments between south west and north east directions and by number of low to medium rise developments in the remaining directions (see Figures 2 and 3). The site of the proposed Development is located on a block bounded by Campbell Street to the north, Pitt Street to the west, Hay Street to the south and a through site link to the east.

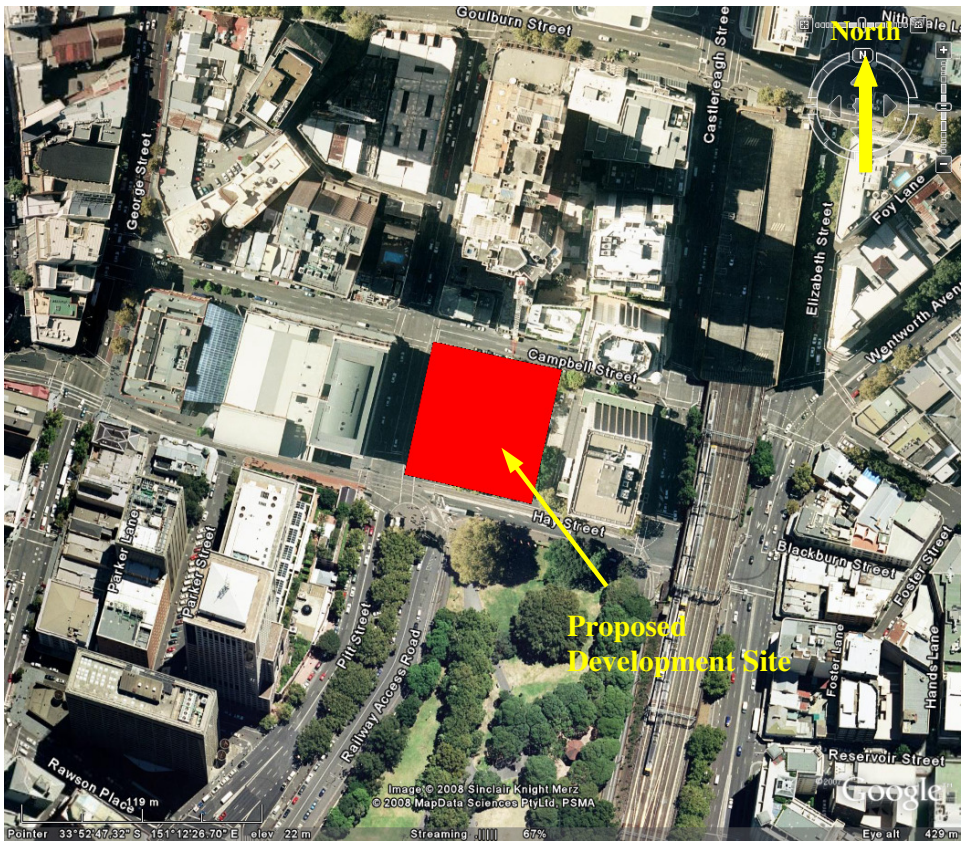


Figure 1- Satellite image of the site of the proposed Belmore Park Zone substation Development, 430 – 450 Pitt Street, Sydney, NSW.

Figure 2- **Satellite image of the site of the proposed Belmore Park Zone substation Development, 430 – 450 Pitt Street, Sydney, NSW and surrounding terrain.**

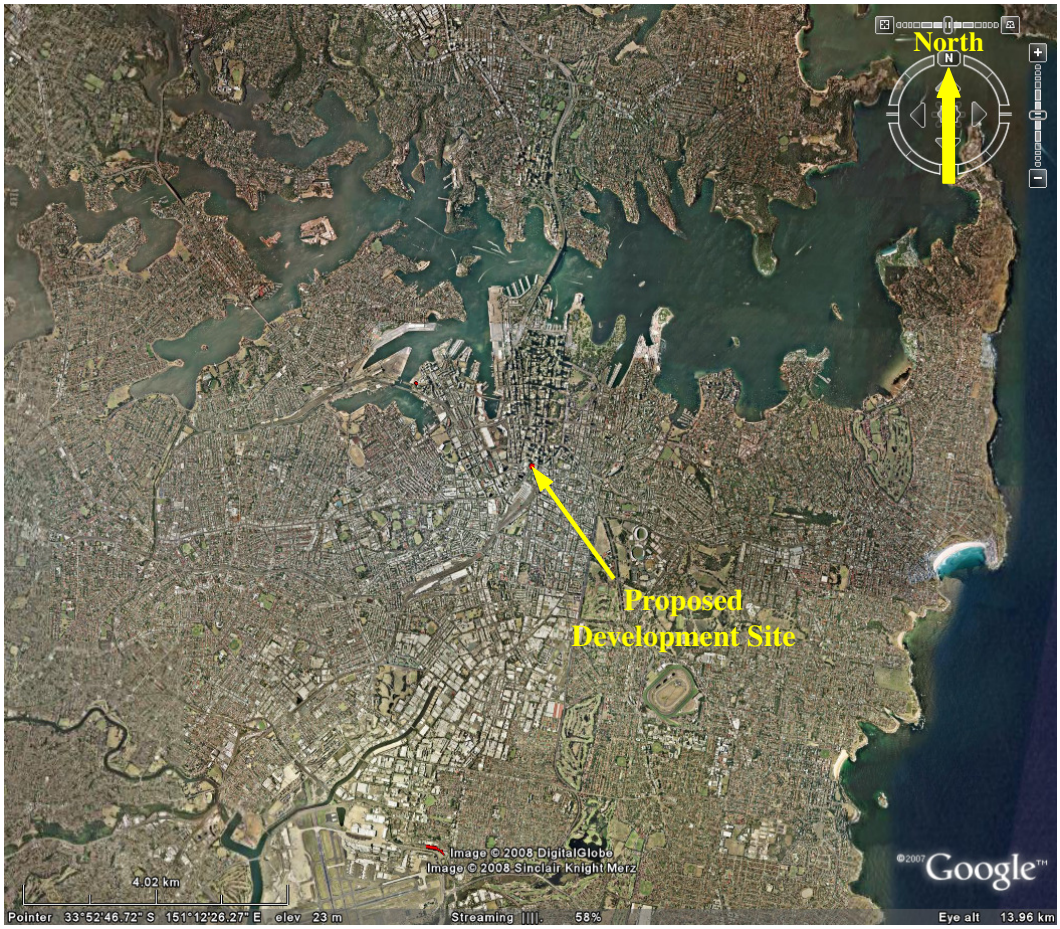


Figure 3 - Satellite image of the site of the proposed Belmore Park Zone substation Development, 430 – 450 Pitt Street, Sydney, NSW and surrounding terrain.

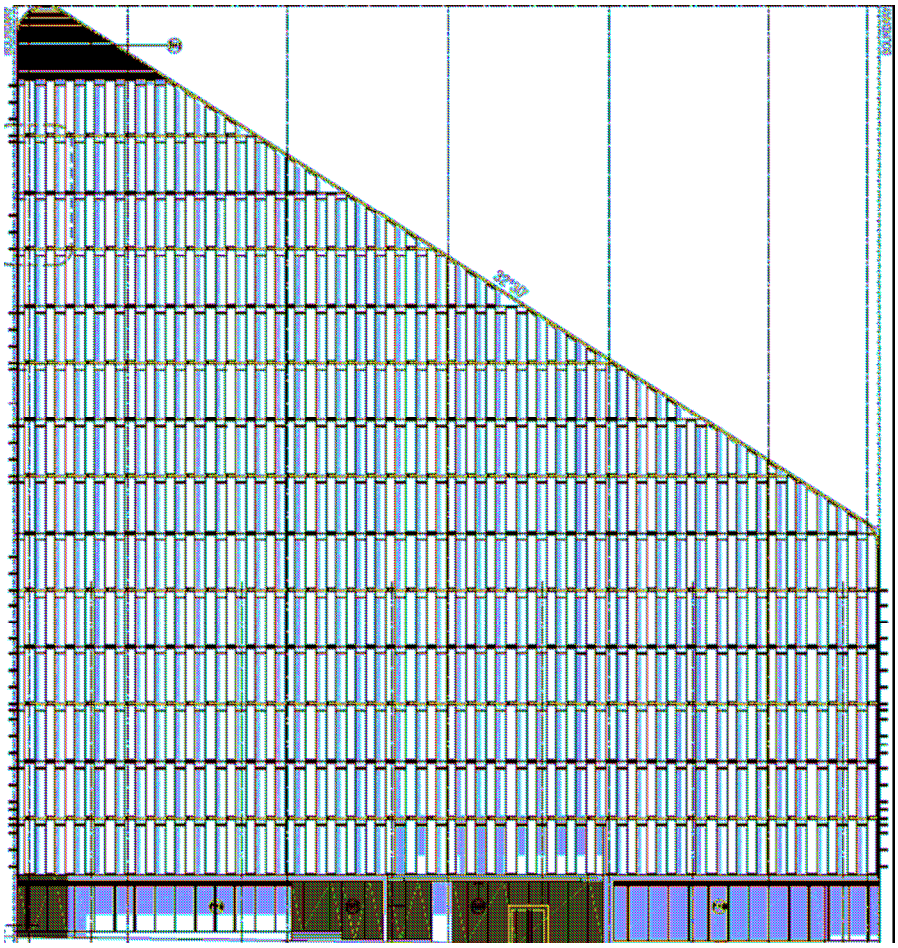


Figure 4 – Schematic view of west elevation from Pitt Street side of the proposed Development.

This report details the opinion of Vipac as an experienced wind engineering consultancy regarding the wind effects in ground level public areas and access-ways in and adjacent to the Development as proposed. No wind tunnel testing has been carried out for this Development. Vipac has carried out wind tunnel studies on a large number of developments of similar shape and having similar exposure to that of the proposed Pitt Street Development. These serve as a valid reference for the prediction of wind effects. Empirical data for typical buildings in boundary layer flows has also been used to estimate the likely ground level wind conditions adjacent to the proposed Development [2] & [3].

2. ANALYSIS APPROACH

In assessing whether a proposed development is likely to generate adverse wind conditions in adjacent ground level areas, Vipac has considered five main points:

- The exposure of the proposed development to wind
- The regional wind climate
- The geometry and orientation of the proposed development
- The interaction of flows with adjacent developments
- The assessment criteria, determined by the intended use of the public areas affected by wind flows generated or augmented by the proposed development.

The pedestrian wind comfort at specific locations around a site may be assessed by predicting the worst annual 3-second wind gust expected at that location. The location may be deemed generally acceptable for its intended use if the annual 3-second gust is within the threshold values noted in Section 2.5. Where Vipac predicts that a location would not meet its appropriate comfort criterion, the use of wind control devices and/or local building geometry modifications to achieve the desired comfort rating may be recommended. For complex flow scenarios or where predicted flow conditions are well in excess of the recommended criteria, Vipac recommend scale model wind tunnel testing to determine the type and scope of the wind control measures required to achieve acceptable wind conditions.

2.1 SITE EXPOSURE

The site of the proposed Pitt Street Development is located in the southern section of the Sydney's CBD area. Within a 1km radius of the site of the proposed Development there is a mixture of low, medium and a significant number of high-rise developments and expanses of parklands. The site of the proposed Development is located on terrain that rises towards north.

Therefore, considering the immediate surroundings and terrain, the site of the proposed Development is considered to be terrain category 4 between south west and north east directions and terrain category 3 for all the remaining wind directions [1], see Figure 5.

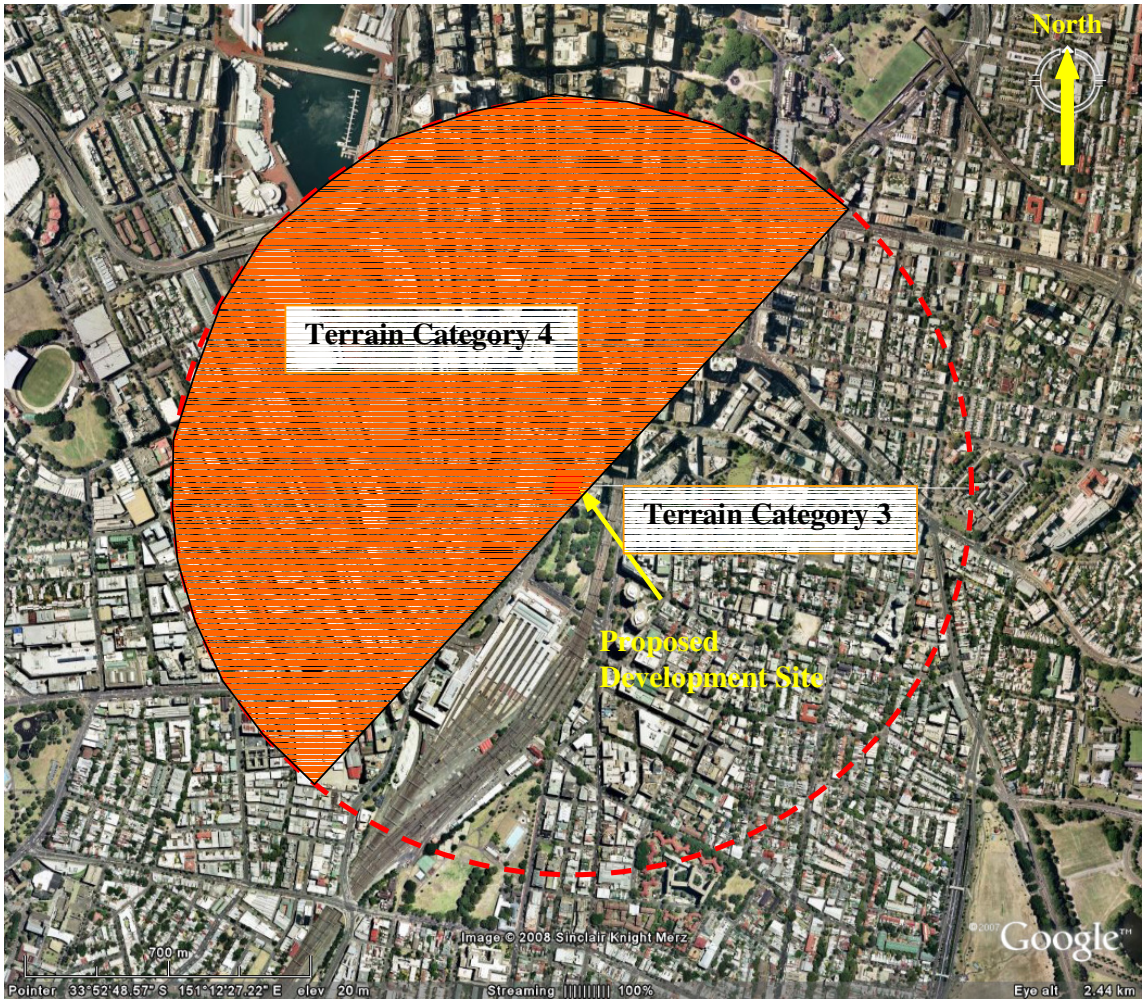


Figure 5 – Terrain Category for the site of the proposed 430 – 450 Pitt Street Development, Sydney, New South Wales.

2.2 REGIONAL WIND CLIMATE

The mean and gust wind speeds have been recorded in the Sydney area for over 30 years. This data has been analysed and the directional probability distribution of wind speeds have been determined. The directional distribution of hourly mean wind speed at the gradient height (≈500m), with a probability of occurring once per year (i.e. 1 year return period) is shown in Figure 6. The wind data at this free stream height is common to all Sydney city sites and may be used as a reference to assess ground level wind conditions at the Site.

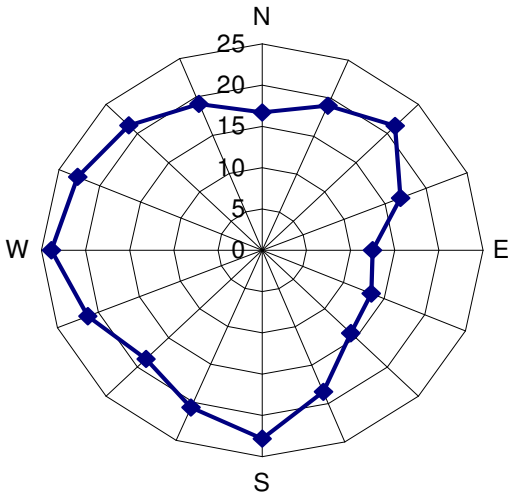


Figure 6 - Directional Distribution of Annual Return Period Mean Hourly Wind Velocities (ms-1) at Gradient Height of 500m for Sydney.

2.3 BUILDING GEOMETRY AND ORIENTATION

The proposed Development is a 13 storey, 58 m high (approximately) commercial office tower. The plan-form dimensions are 52 m x 55 m (approximately), with the longer axis running east west. Pedestrian entries are located on Pitt Street, Hay Street and Campbell Street side of the Development, See Figure 7.

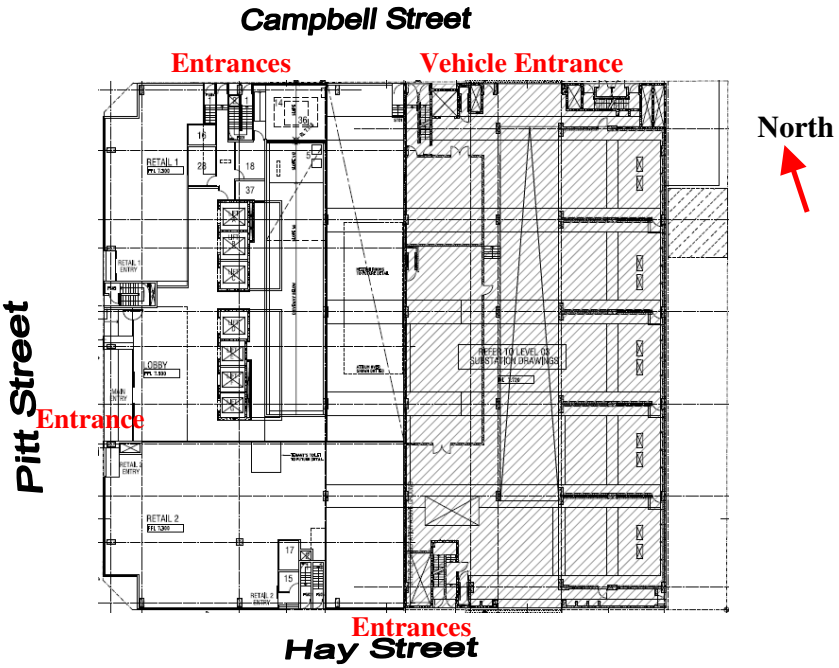


Figure 7 - Plan-form view of the proposed Development.

2.4 FLOW INTERACTIONS WITH ADJACENT DEVELOPMENTS

For northerly, north-westerly and north-easterly winds the ground level areas adjacent to the proposed Development are expected to be dominated by turbulent wake flows from existing developments immediately upstream of the site of the proposed Development. The resultant wind flows about the proposed Development for these wind directions are likely to be of intermittent nature with low mean velocities. The form of the proposed Development is not considered likely to strongly influence ground level wind conditions for these wind directions.

For winds from the west, south west and south directions, wind flows about the proposed Development are predicted to be influenced by aerodynamic interactions with adjacent developments. Furthermore the winds approaching from west and south directions could result in downwash flows near the pedestrian areas on Pitt Street and Hay Street sides of the Development.

2.5 ASSESSMENT CRITERIA

With some consensus of international opinion, pedestrian wind comfort is rated according to the suitability of certain activities at a site in relation to the expected annual peak 3-second gust velocity at that location for each wind direction. Each of the major areas around the site are characterised by the annual maximum gust wind speeds. Most patrons would consider a site generally unacceptable for its intended use if it were probable that during one annual wind event, a peak 3-second gust occurs which exceeds the established comfort threshold velocity. If that threshold is exceeded once per year then it is also likely that during moderate winds, noticeably unpleasant wind conditions would result, and the windiness of the location would be voted as unacceptable.

The threshold gust velocity criteria are:

Annual Maximum Gust Speed	Result on Perceived Pedestrian Comfort
>23m/s	Unsafe (frail pedestrians knocked over)
<16m/s	Acceptable for Walking (steady steps for most pedestrians)
<13m/s	Acceptable for Standing (window shopping, vehicle drop off, queuing)
<10m/s	Acceptable for Sitting (outdoor cafés, pool areas, gardens)

Table 1 – Recommended Wind Comfort and Safety Gust Criteria

In a similar manner, a set of hourly mean velocity criteria with a 1% probability of occurrence are also applicable to ground level areas in and adjacent to the proposed Development. An area should be within both the relevant mean and gust limits in order to satisfy the particular human comfort and safety criteria in question.

The threshold mean velocity criteria are:

Annual Maximum Mean Speed	Result on Perceived Pedestrian Comfort
>15m/s	Unsafe (frail pedestrians knocked over)
<10m/s	Acceptable for Walking (steady steps for most pedestrians)
<7m/s	Acceptable for Standing (window shopping, vehicle drop off, queuing)
<5m/s	Acceptable for Sitting (outdoor cafés, pool areas, gardens)

Table 2 – Recommended Wind Comfort and Safety Mean Criteria

Intended Use of Adjacent Ground Level Areas

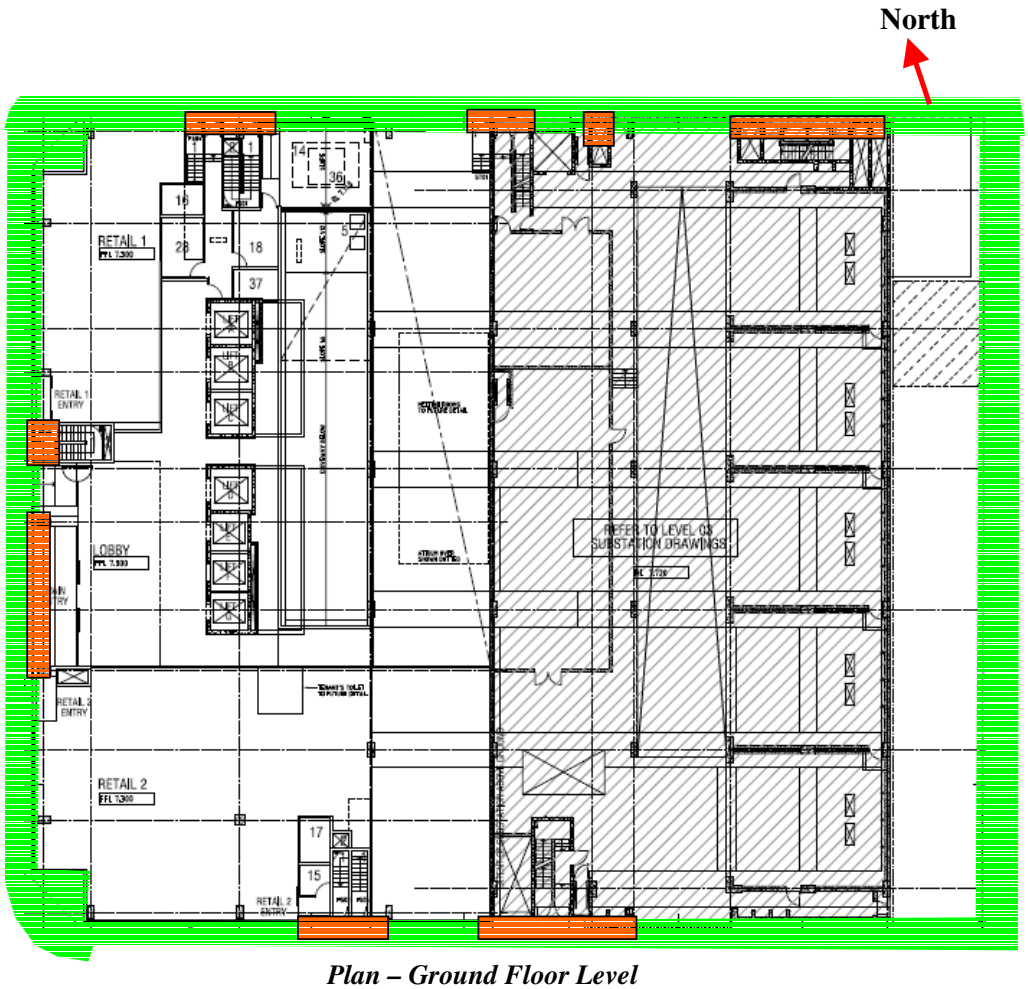
- Main building entrances are located on the Pitt Street side of the Development. Other entrances to the sub-station/ retail are located on Campbell Street and Hay Street side of the Development.
- Pedestrian footpaths are located on the Pitt Street, Campbell Street and Hay Street side of the Development. Also, a public walkway is located on the east between the proposed Development and the neighbouring building.
- Vehicle entrances are located on the Campbell Street side of the proposed Development.

Recommended Criteria

The following table lists the specific areas adjacent to the Development and the corresponding recommended criteria.

Area	Recommended Criteria
Public Footpaths, Building Stairs	Acceptable for Walking
Building Entrances, Terraces	Acceptable for Standing

Table 3 – Recommended application of criteria



Plan – Ground Floor Level

Recommended Acceptable for Walking **Recommended Acceptable for Standing**

Figure 8 - Schematic plan view of the proposed Development with the recommended wind criteria overlaid on adjacent ground level areas.

3. PEDESTRIAN LEVEL WIND EFFECTS AND RECOMMENDATIONS

Key Points:

- The proposed Development incorporates a number of wind mitigating features such as horizontal façade elements and canopies/awning over the main entrance area. Furthermore, the proposed Development possesses reduced frontal area for facades exposed to the strong wind directions.

- Vipac does not expect the proposed Development to generate any wind conditions in excess of the criterion for safety.

- Vipac does not expect the proposed Development to generate any wind conditions in excess of the criterion for standing.

- Vipac expects the wind conditions in most of the ground level areas would be within the criterion for acceptability for walking.

- Vipac expects the wind conditions to be close to the criterion for acceptability for walking in the public walkway to the east of the proposed Development.

Discussion

The Sydney wind climate is relatively strong from north-west, north and north-east directions. Any downwash flows caused by winds approaching from these directions are expected to be deflected by roofs of the immediately adjacent buildings. Thus the proposed Development is not expected to produce wind conditions (in adjacent ground level areas) in excess of the recommended criteria as mentioned in Section 2.5. Furthermore, the geometric shape of the building and the presence of horizontal façade elements would also assist to ameliorate the adverse wind flows.

The proposed Development is considered to be relatively exposed to the strong westerly and southerly winds. Therefore winds approaching from these directions could result in down wash flows over the pedestrian footpath on Pitt Street and Hay Street sides of the Development. However, considering the presence of horizontal façade elements, it is expected that most of these adverse wind conditions would be ameliorated.

No exceedences of the criterion for safety, either currently existing or with the proposed Development are predicted.

The region of the highest ground level wind speeds adjacent to the proposed Development is likely to be the footpath and entrance areas on the Pitt Street and Hay Street side of the Development and also the through site link to the east (The later of which is expected to be caused by channelling flows from the strong southerly winds). However, calculations from empirical data [2], [3] suggest ground level wind conditions generated by southerly, north easterly, north westerly and westerly winds would be within the criterion for acceptability for walking. For other directions either the surrounding developments are expected to significantly shelter the proposed Development or the form of the proposed Development is considered unlikely to produce adverse ground level wind effects or the wind climate for those directions is weak.

3.1 RECOMMENDATIONS

After careful consideration of the areas at the base of the proposed Development, Vipac predicts that the proposed Development would present a significant change in wind conditions in adjacent ground level areas, especially for winds approaching from west and south directions.

The presence of horizontal façade elements would help to ameliorate most of the adverse wind conditions in the adjacent ground level areas. However, in order to mitigate the effects of the strong westerly and southerly winds, canopies (2m wide) are recommended at locations as shown in Figure 9. The inclusion of these canopies would help to mitigate the downwash flows over the pedestrian footpath area (caused by these strong winds) and provide conditions that are suitable for walking on Pitt Street and Hay Street side of the Development. These are the type of features that, in our experience would be required to achieve acceptable wind conditions in ground level areas in and adjacent to the proposed Development given the predicted exposure and wind sensitive nature of those areas.

There is a significant uncertainty inherent in the prediction of turbulent flow patterns based on experience alone and there is a limited capacity of the design of the proposed Development to remedy any existing elevated wind conditions on the public walkway to the east of the proposed Development. Therefore, in this case a wait-and-see approach to wind conditions would be justified and the recommended wind control device could be added post-construction if required.

Figure 9 - Schematic plan view of the proposed Development with the recommended wind control devices overlaid on around the site of the proposed Development.

4. CONCLUSIONS

An appraisal of the likely wind conditions adjacent to the proposed Belmore Park Zone Sub-Station Development, 430-450 Pitt Street, NSW has been made.

The proposed Development consists of a high–rise building on a site that is located to the south of Sydney's CBD.

The building is in close proximity to few high rise Developments to the north and east directions. There is some elevated exposure to the relatively strong westerly and southerly wind flows of the Sydney region over the immediate surrounding developments.

Vipac have carefully considered the flow structures likely to be generated by the proposed Development that would affect the adjacent ground level areas. From this analysis it is considered likely that the pedestrian footpath areas could experience wind conditions that are close to the criterion for acceptability for walking. Therefore as a measure for mitigating these adverse effects, canopies were recommended at appropriate locations. However, Vipac recommended a wait-and-see approach to these recommended additions, which could be included post–construction if required.

The assessments provided in this report have been made based on experience of similar situations in Sydney and around the world. As with any opinion, it is possible that an assessment of wind effects based on experience and without wind tunnel model testing can be in error. For this reason, if further studies of the wind effects are required, we recommend a wind tunnel based assessment to develop the predictions of this report and to finalise the building design.

This Report has been Prepared

For

Kann Finch Architects Pty Ltd

By

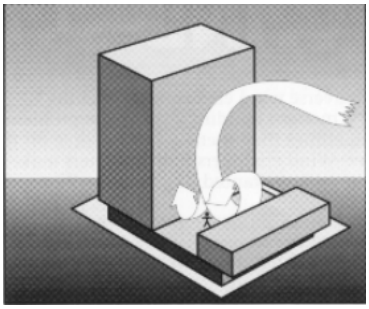
VIPAC ENGINEERS & SCIENTISTS LTD.

APPENDIX A - ENVIRONMENTAL WIND EFFECTS

Atmospheric Boundary Layer

As wind flows over the earth it encounters various roughness elements and terrain such as water, forests, houses and buildings. To varying degrees, these elements reduce the mean wind speed at low elevations and increase air turbulence. The wind above these obstructions travels with unattenuated velocity, driven by atmospheric pressure gradients. The resultant increase in wind speed with height above ground is known as a wind velocity profile. When this wind profile encounters a tall building, some of the fast moving wind at upper elevations is diverted down to ground level resulting in local adverse wind effects.

The terminology used to describe the wind flow patterns around the proposed Development is based on the aerodynamic mechanism, direction and nature of the wind flow.



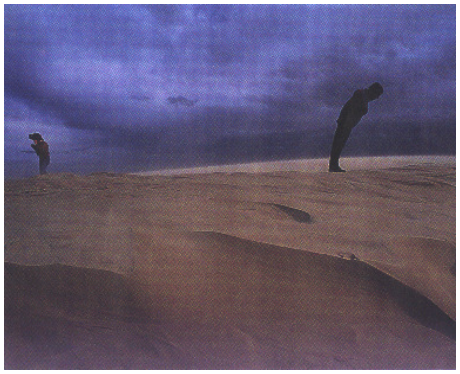
Downwash – refers to a flow of air down the exposed face of a tower. A tall tower can deflect a fast moving wind at higher elevations downwards.

Corner Accelerations – when wind flows around the corner of a building it tends to accelerate in a similar manner to airflow over the top of an aeroplane wing.

Flow separation – when wind flowing along a surface suddenly detaches from that surface and the resultant energy dissipation produces increased turbulence in the flow. Flow separation at a building corner or at a solid screen can result in gusty conditions.

Flow channelling – the well-known "street canyon" effect occurs when a large volume of air is funnelled through a constricted pathway. To maintain flow continuity the wind must speed up as it passes through the constriction. Examples of this might occur between two towers, in a narrowing street or under a bridge.

Direct Exposure – a location with little upstream shielding for a wind direction of interest. The location will be exposed to the unabated mean wind and gust velocity. Piers and open water frontage may have such exposure.



APPENDIX B - REFERENCES

[1] *Structural Design Actions, Part 2: Wind Actions*, Australian/New Zealand Standard 1170.2:2002

[2] *Wind Effects on Structures* E. Simiu, R Scanlan, Publisher: Wiley-Interscience

[3] *Architectural Aerodynamics* R. Aynsley, W. Melbourne, B. Vickery, Publisher: Applied Science Publishers

APPENDIX C – LIST OF DRAWINGS

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