

**This copied document to be made
available
for the sole purpose of enabling
its consideration and review as
part of a planning process under the
Planning and Environment Act 1987.
The document must not be used for
any
purpose which may breach any
copyright**

**ADVERTISED
PLAN**

20th October 2023
Ref: 30-22-DE-EWC-00

Salta Properties Pty Ltd
Level 26, 35 Collins Street
Melbourne VIC 3000
Attn: Mr David O'Connell

**699 La Trobe Street
Environmental Wind Considerations**

A wind tunnel model study of the environmental wind conditions was completed for the proposed 699 La Trobe Street Development in August 2023, with the model constructed using drawings supplied by Fender Katsalidis received up to 8th August, 2023. The findings of the study were reported in MEL Consultants Report 30-22-WT-ENV-00 (refer to Appendix A).

The design of the proposed Development has been amended according to Fender Katsalidis drawings received on the 16th October 2023, with the following notable changes that would have an impact from an environmental wind conditions perspective,

- Building height (Figure 1)
 - Reduced by approximately 10m (new building height ≈ 130m).
- Ground level (Figure 2)
 - New operable façade along the west face for the café located at the northwest corner
 - Southern entrance moved away from building corner and recessed

- Levels 2 to 6 (Figure 3)
 - Additional balconies along the north and west faces of the building, extending to the northwest corner.
- Level 7 (Figure 4)
 - Following the issue of MEL Consultants Report 30-22-WT-ENV-00, alternative options have been explored to replace the requirement of removing the pavilion (i.e. part of Mitigation A in main report). MEL have recommended the introduction of an additional level of void (i.e. Level 9, refer to Figures 1 and 5) to bleed flow through this void for northerly winds which would limit the amount of downwash to ground level. Therefore, satisfying the mitigation requirements at ground level while maintaining a pavilion on Level 7.
 - This recommendation has been adopted by Fender Katsalidis and now forms part of the updated design. To this end, MEL supports in full the use of this alternate strategy as a replacement of the approach (i.e. removal of pavilion) recommended within the MEL Consultant Report 30-22-WT-ENV-00.
- Level 9 (Figure 5)
 - Maintains the floor plan with Level 8 (i.e. void on the western side above the planned pavilion)
- Levels 10 to 28 (Figure 6)
 - Northwest corner cut-out at every 3rd level, starting from Level 10, to satisfy wind mitigation requirement.
- Levels 34 to Rooftop (Figure 7)
 - Building cut-out at the northeast corner

The following discussions are based on the updated design by Fender Katsalidis drawings received on the 16th October 2023.

The wind conditions outside the southern entrance would be expected to satisfy the recommended standing comfort criterion for building entrances as it benefits from being away from building corners and recessed. The operable façade for the café would require a management system where it can only be opened when external wind conditions are perceived to be appropriate.

The wind conditions on the additional balconies on Levels 2 to 6 located along the north and west faces, near the northwest corner of the building, would be expected to satisfy the walking comfort and safety criterion as they benefit from being open to only one aspect (i.e. full height glazing at the northwest corners).

The wind conditions in the communal outdoor space of Level 7 would be expected to be similar to those measured for the Proposed Configuration with Mitigation A and B in MEL Consultant Report 30-22-WT-ENV-00, where wind conditions satisfied the walking comfort criterion at a minimum and the safety criterion with the exception of a localised area at the northwest corner which had failed the safety criterion. This northwest corner would be a non-trafficable landscaped area (highlighted in red in Figure 4) according on the updated design.

In summary, the updated design by Fender Katsalidis drawings received on the 16th October 2023 have adopted the wind mitigation recommendations from MEL Consultants Report 192-20-WT-ENV-00 (or their equivalent) whilst maintaining a similar built form massing. Therefore, the environmental wind conditions on and in the streetscapes surrounding the proposed Development for the updated design would be expected to be similar to those of the Proposed Configuration with Mitigation A and B as detailed in MEL Consultants Report 192-20-WT-ENV-00.

Prepared By:



J. Tan

Released By:



J. Kostas

20th October 2023

**This copied document to be made available
for the sole purpose of enabling
its consideration and review as
part of a planning process under the
Planning and Environment Act 1987.
The document must not be used for any
purpose which may breach any
copyright**

This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright.

ADVERTISED PLAN

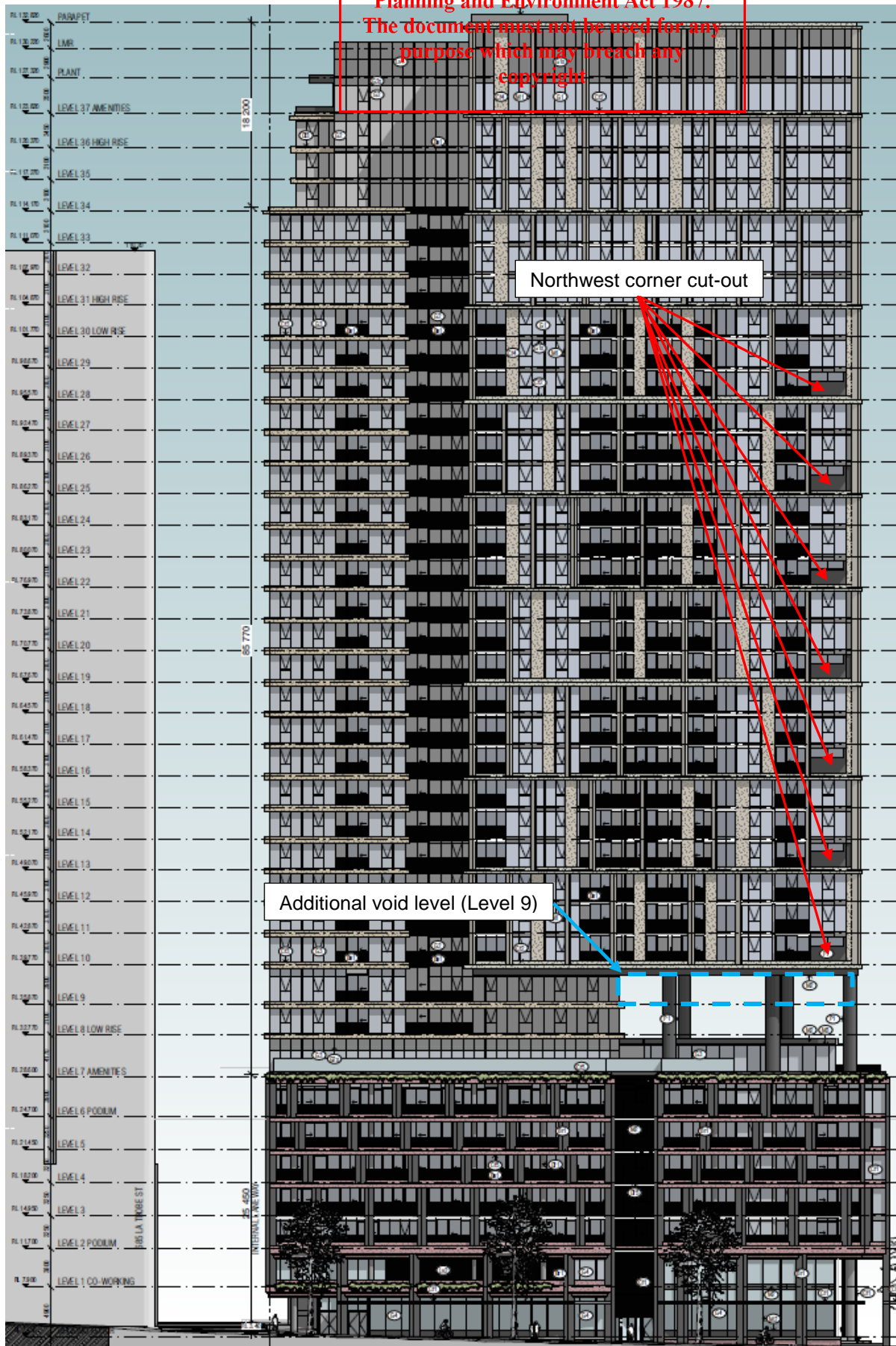


Figure 1: North Elevation

**ADVERTISED
PLAN**



This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright

ADVERTISED PLAN

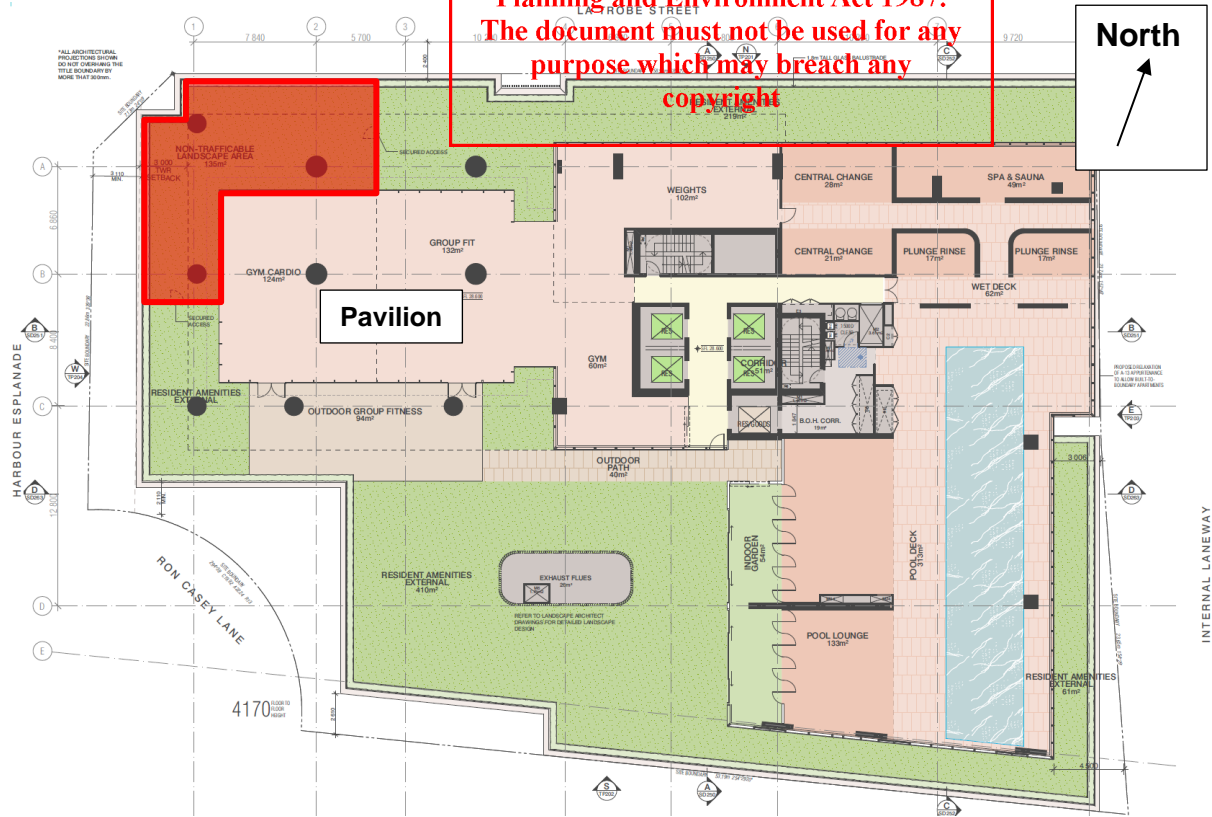


Figure 4: Level 7 (non-trafficable area highlighted in red)

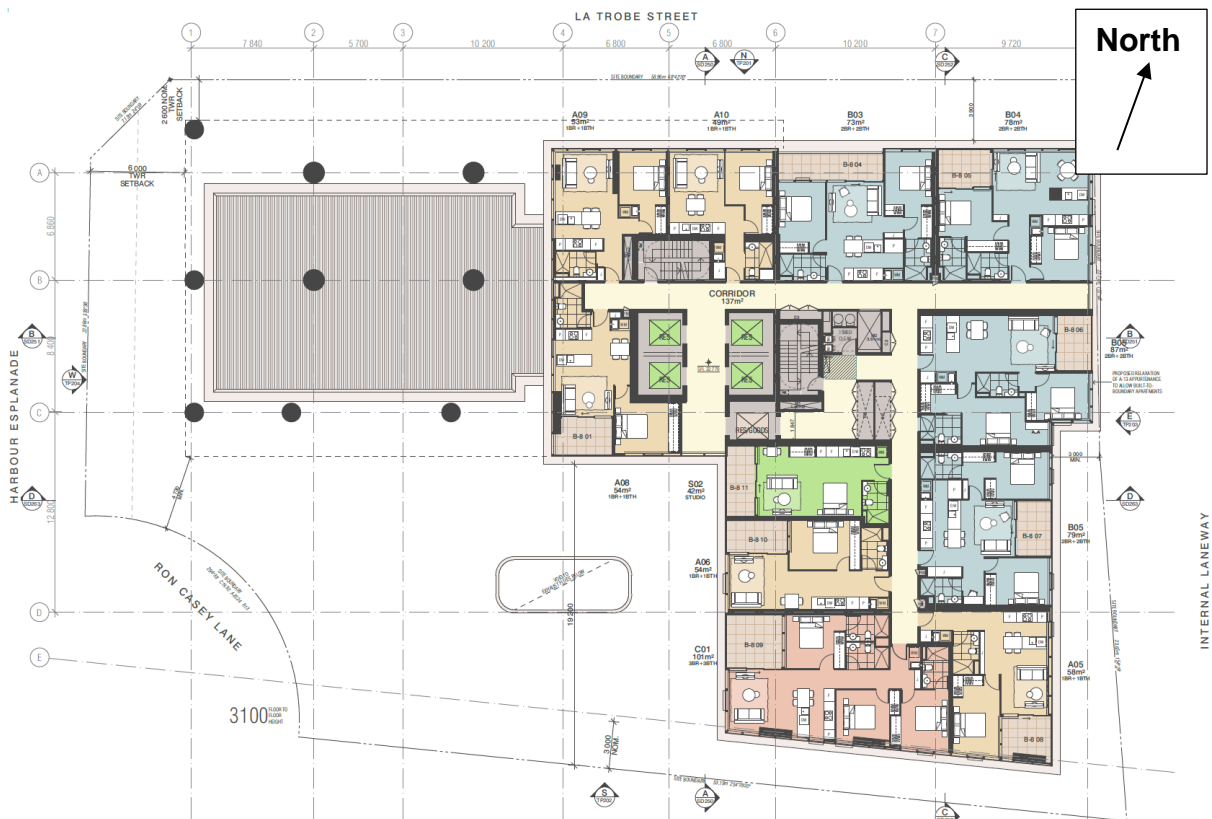


Figure 5: Levels 8 & 9

This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright

ADVERTISED PLAN



Figure 6: Typical Levels 10 to 28 (every 3rd level)

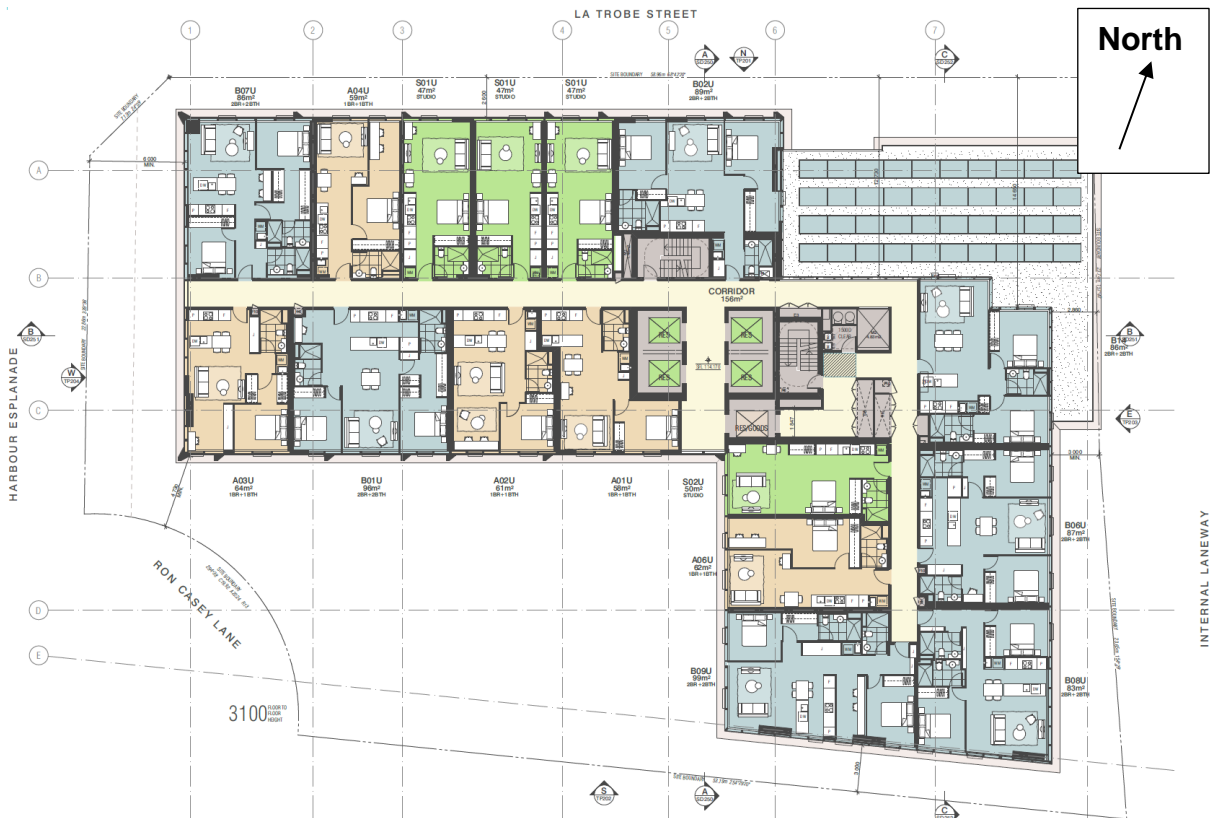


Figure 7: Level 34

Appendix A

This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright

**ADVERTISED
PLAN**

**ENVIRONMENTAL WIND SPEED MEASUREMENTS
ON A WIND TUNNEL MODEL OF THE 699 LA TROBE STREET
DEVELOPMENT, DOCKLANDS**

by
J. Tan
and
J. Kostas

**ADVERTISED
PLAN**

SUMMARY

A wind tunnel study has been conducted on a 1/400 scale model of the proposed 699 La Trobe Street Development, Docklands. The model of the Development within surrounding buildings, was tested in a simulated upstream boundary layer of the natural wind to determine likely environmental wind conditions. These wind conditions have been related to the freestream mean wind speed at a reference height of 300m and compared with criteria developed for the Melbourne region as a function of wind direction.

For the Proposed Configuration, the wind conditions for all Test Locations in the streetscapes surrounding the Development have been shown to satisfy the walking comfort and safety criteria except near the northwest corner of the Development and some areas on the west side of Harbour Esplanade where the safety criterion failed for the north wind direction. However, it has been demonstrated that with the incorporation of tower built form wind mitigation strategies (Mitigations A) these wind conditions would improve to satisfy the walking comfort and safety criteria. The wind conditions at the main entrance into the building, located along the western frontage of the Development, have been shown to satisfy the sitting comfort criterion.

With regards to the wind conditions on the terraces and balconies, the wind conditions on the west side of the Level 7 podium rooftop terrace for the Proposed Configuration with Mitigations A have been shown to fail the safety criterion for the north wind direction. However, it has been demonstrated that with appropriate wind mitigation strategies (Mitigations B), the wind conditions within the pedestrian trafficable areas of the Level 7 podium rooftop terrace would satisfy the walking comfort and safety criteria. The wind

This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright

conditions on the balconies of Levels 9 to 19 for the Proposed Configuration would be expected to be similar to those measured on Level 12 which were shown to satisfy the standing comfort criterion at minimum and the safety criterion, while conditions on Levels 20 to 29 balconies would be expected to be similar to those measured on Level 29 which were shown to satisfy the walking comfort criterion at a minimum and the safety criterion.



Report 30-22-WT-ENV-00

August 2023

**ADVERTISED
PLAN**

**This copied document to be made available
for the sole purpose of enabling
its consideration and review as
part of a planning process under the
Planning and Environment Act 1987.
The document must not be used for any
purpose which may breach any
copyright**

699 LA TROBE STREET DEVELOPMENT, MELBOURNE ENVIRONMENTAL WIND TUNNEL MODELLING

MEL CONSULTANTS REPORT NO: 30-22-WT-ENV-00

PREPARED FOR:

Salta Properties Pty Ltd
Level 26, 35 Collins Street
Melbourne VIC 3000


PREPARED BY:

MEL Consultants Pty Ltd
22 Cleeland Road
Oakleigh South VIC 3167

Contact: David O'Connell
Ph: +61 4 1814 1302

Contact: James Tan
Ph: +61 3 8516 9680

PREPARED BY:


J. Tan
Senior Engineer

Date: 14 August 2023

REVIEWED BY:


J. Kostas
Director

Date: 18 August 2023

RELEASED BY:


M. Eaddy
Managing Director

Date: 24 August 2023

REVISION HISTORY

Revision No:	Date Issued	Reason/Comment
0	24 August 2023	Initial Issue

DISTRIBUTION

Copy No:
1

Copy	Location	Type
1	Salta Properties Pty Ltd	Electronic PDF
2	MEL Consultants – Report Library	Electronic PDF
3	MEL Consultants – Project File	Hardcopy

NOTE: This is a controlled document within the document control system. If revised, it must be marked SUPERSEDED and returned to the MEL Consultants Pty Ltd contact.

This copied document to be made available
for the sole purpose of enabling
its consideration and review as
part of a planning process under the
Planning and Environment Act 1987.
The document must not be used for any
purpose which may breach any
copyright

CONTENTS

SUMMARY

**ADVERTISED
PLAN**

1.	INTRODUCTION	5 -
2.	ENVIRONMENTAL WIND CRITERIA	6 -
2.1	Suggested Pedestrian Comfort Criteria.....	7 -
3.	MODEL AND EXPERIMENTAL TECHNIQUES.....	8 -
4.	DISCUSSION OF RESULTS.....	9 -
4.1	Summaries of Discussion	11 -
4.2	La Trobe Street	11 -
4.3	Harbour Esplanade	13 -
4.4	West and South frontages of the Development	15 -
4.5	Laneway on the east side of the Development	16 -
4.6	Marvel Stadium	17 -
4.7	Level 7 - Podium Rooftop Terrace.....	18 -
4.8	Levels 12 and 29 Balconies	19 -
4.9	Level 40 Rooftop Terrace	20 -
5.	CONCLUSIONS	21 -
	REFERENCES.....	22 -
	FIGURES	23 -
	APPENDIX A	36 -

This copied document to be made available
for the sole purpose of enabling
its consideration and review as
part of a planning process under the
Planning and Environment Act 1987.
The document must not be used for any
purpose which may breach any
copyright

1. INTRODUCTION

The proposed 699 La Trobe Street Development will be an approximately 140m high residential building located at the corner of La Trobe Street and Harbour Esplanade, in Docklands, Victoria.

A wind tunnel study was commissioned by Salta Properties Pty Ltd to examine the wind conditions for the 699 La Trobe Street Development and, if necessary, to develop wind mitigation strategies.

These tests were carried out in the MEL Consultants 400kW Boundary Layer Wind Tunnel during August 2023.

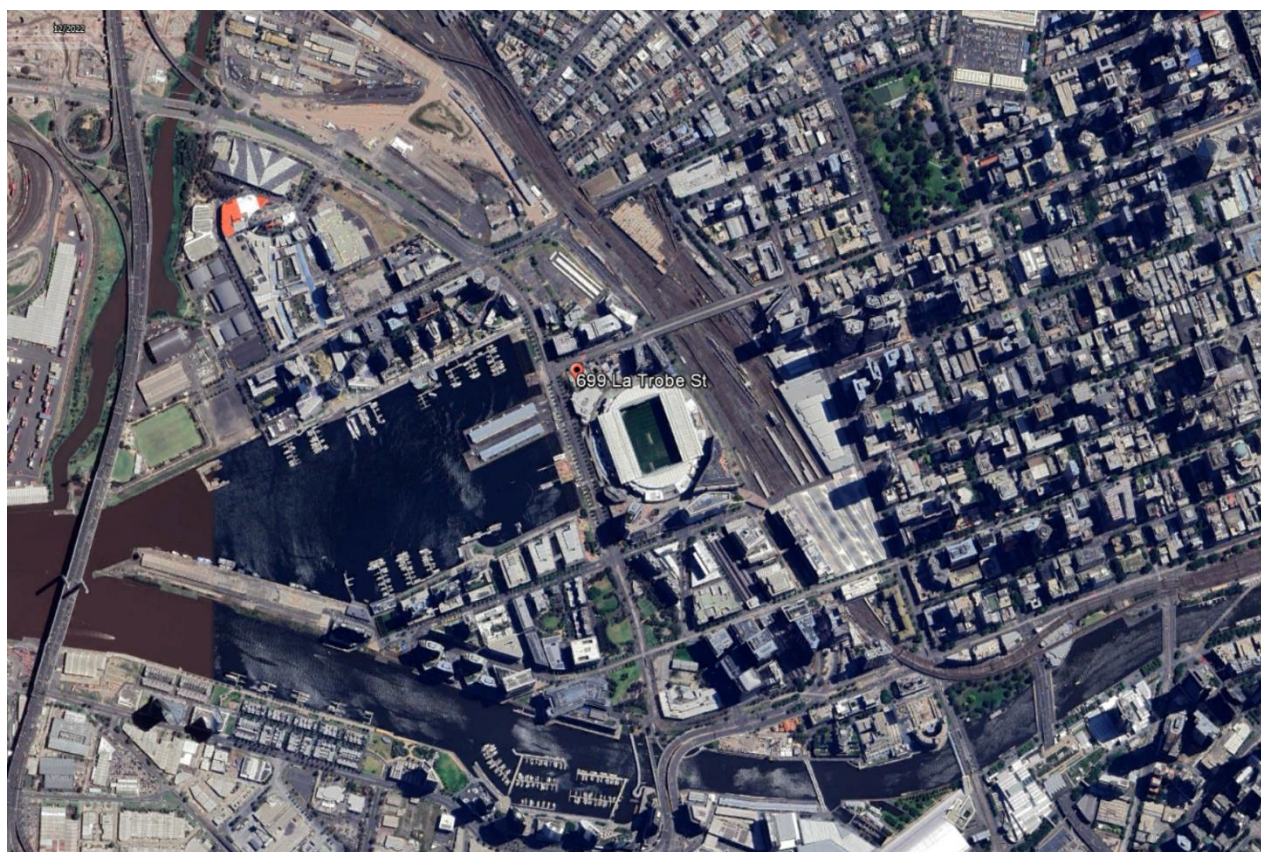


Figure 1 – The proposed Development site at 699 La Trobe Street, Melbourne (Red drop pin) [Google Earth].

**This copied document to be made available
for the sole purpose of enabling
its consideration and review as
part of a planning process under the
Planning and Environment Act 1987.
The document must not be used for any
purpose which may breach any
copyright**

2. ENVIRONMENTAL WIND CRITERIA

To assess whether the predicted wind conditions are likely to be acceptable or not, wind criteria, safety and comfort, from the City of Melbourne Planning Scheme Clause 58.04-4 (Standard D17) will be applied or used. The definition of the criteria is as follows:

Standard D17

Development of five or more storeys should:

- *not cause unsafe wind conditions specified in Table D6 in public land, publicly accessible areas on private land, private open space and communal open space; and*
- *achieve comfortable wind conditions specified in Table D6 in public land and publicly accessible areas on private land*

within a distance of half the greatest length of the building, or half the total height of the building measured outwards on the horizontal plane from the ground floor building façade, whichever is greater.

Trees and landscaping should not be used to mitigate wind impacts. This does not apply to sitting areas, where trees and landscaping may be used to supplement fixed wind mitigation elements.

Wind mitigation elements, such as awnings and screens should be located within the site boundary, unless consistent with the existing urban context or preferred future development of the area.

Table D6 Wind Conditions

Unsafe	Comfortable
<i>Annual maximum 3 second gust wind speed exceeding 20 metres/second with a probability of exceedance of 0.1% considering at least 16 wind directions.</i>	<i>Hourly mean wind speed or gust equivalent mean speed (3 second gust wind speed divided by 1.85), from all wind directions combined with probability of exceedance less than 20% of the time, equal to or less than:</i> <ul style="list-style-type: none">• <i>3 metres/second for sitting areas</i>• <i>4 metres/second for standing areas</i>• <i>5 metres/second for walking areas</i>

The above criteria are pass/fail criteria as they only assess the summation of probabilities of exceedance across all wind directions to determine whether a location passes or fails the threshold criterion i.e. the criteria assess the average wind conditions.

2.1 Suggested Pedestrian Comfort Criteria.

The following wind criteria are suggested for the 699 La Trobe Street Development:

- | | |
|-------------------------------|--------------------|
| • Pedestrian transit areas | Walking Criterion |
| • Main building entrances | Standing Criterion |
| • Outdoor terraces/balconies* | Walking Criterion* |

*The wind conditions at outdoor terraces/balconies have been suggested to satisfy the walking criterion as these premises could be considered elective when external conditions would be perceived as acceptable for the desired activity. Users of these terraces will need to be educated on the wind effects and loose objects should not be left unattended in outdoor areas.

**ADVERTISED
PLAN**

The activation of the public realm external to the site would depend on the existing wind conditions in the streetscapes that are often beyond the control of the proposed development. For cases where the existing wind conditions in the public realm external to the site are on or above the walking criterion, then the proposed development should not have any adverse wind effects in these areas.

**This copied document to be made available
for the sole purpose of enabling
its consideration and review as
part of a planning process under the
Planning and Environment Act 1987.
The document must not be used for any
purpose which may breach any
copyright**

3. MODEL AND EXPERIMENTAL TECHNIQUES

A 1/400 scale model of the 699 La Trobe Street Development was constructed from digital information prepared by Fender Katsalidis and received up to 8th August 2023.

The model of the 699 La Trobe Street Development was inserted into a proximity model of surrounding buildings out to a minimum radius of 400m. No existing or proposed street trees were included within the model. The building model was tested in a model of the natural wind generated by flow over roughness elements augmented by vorticity generators at the beginning of the wind tunnel working section. The basic natural wind model was for flow over suburban terrain, the characteristics of which are given in Figure 2.

The techniques used to investigate the environmental wind conditions and the method of determining the local criteria are given in detail in Reference 2. In these tests measurements in the development areas are inside separated regions and peak velocity squared ratios were required to make conclusions about likely wind conditions. In summary, measurements were made of the peak gust wind velocity with a hot wire anemometer at various stations and expressed as a squared ratio with the mean wind velocity at a scaled reference height of 300m. This gives the peak velocity squared ratio

$$\left| \frac{\hat{V}_{local}}{\bar{V}_{300m}} \right|^2$$

Wind tunnel velocity measurements were made for an equivalent 1 hour period in full scale and filtered to provide an equivalent full scale 3 second gust wind speed. Photographs of the model as tested in the wind tunnel are shown in Figures 3a and 3b.

The wind tunnel study has been undertaken to exceed the requirements of the Australasian Wind Engineering Society Quality Assurance Manual for Wind Tunnel Studies.

**This copied document to be made available
for the sole purpose of enabling
its consideration and review as
part of a planning process under the
Planning and Environment Act 1987.
The document must not be used for any
purpose which may breach any
copyright**

4. DISCUSSION OF RESULTS

Velocity measurements were made at various locations around the 699 La Trobe Street Development for different wind directions at 22.5° intervals. As discussed in Section 2, Standard D17 criteria are pass/fail criteria based on an assessment of the probability for all wind directions combined. The wind comfort criteria for sitting, standing and walking are given in percentage for which a given mean wind speed is exceeded. A test location will pass the sitting, standing and walking criteria if the percentage for which a given mean wind speed is exceeded is below 20%. Therefore, to assess the wind conditions, the exceedances will be presented in tabular form in Tables 1 – 7 and colour coded; **green** for below 20% exceedance, **orange** for 20% or above exceedance and **green** or **red** for passing/failing the safety criterion respectively. For completeness, these data are also provided in Appendix A as a function of wind direction and compared with the pedestrian criteria for gust wind speeds.

**ADVERTISED
PLAN**

The following model configurations were tested:

- Existing Configuration
- Proposed Configuration
- Proposed Configuration + Wind Mitigation Strategies

The Existing Configuration is defined as the existing vacant site. The Proposed Configuration for the proposed 699 La Trobe Street Development was constructed from digital information prepared by Fender Katsalidis and received up to 8th August 2023.

The wind mitigation strategies tested can be grouped as follows:

Mitigations A (refer to Figures 4a and 4b)

- Building cut-out (4.5m x 4m) at the northwest corner at every 3rd level from Level 11 to Level 29
- Removal of the planned pavilion on the Level 7 podium rooftop terrace to create a double level void

Mitigations B (on Level 7 only, refer to Figure 8b)

- Wind-break screens (height = 1.8m, porosity ≈ 30%)
- “No-go” zone at the northwest corner of the terrace
- Gate at “no-go” zone
- Increased northern balustrade height to 1.8m

This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright

None of the above configurations included or relied on existing or proposed landscaping trees for wind mitigation.

The results of these measurements are presented on polar diagrams against a background plot of the various criteria for each Test Location as a function of wind direction. The Test Locations on the ground and upper levels are shown in Figures 5a to 5d.

**ADVERTISED
PLAN**

**This copied document to be made available
for the sole purpose of enabling
its consideration and review as
part of a planning process under the
Planning and Environment Act 1987.
The document must not be used for any
purpose which may breach any
copyright**

4.1 Summaries of Discussion

A summary of wind comfort criteria satisfied at each Test Location in the surrounding streetscapes and on the upper level terraces/balconies have been summarised using a colour code system in the following figures:

- Figure 6 Ground Level - Existing Configuration
- Figure 7a Ground Level - Proposed Configuration
- Figure 7b Levels 12 and 29 Balconies - Proposed Configuration
- Figure 7c Level 40 Rooftop Terrace - Proposed Configuration
- Figure 8a Ground Level – Mitigations A + B
- Figure 8b Level 7 Terrace – Mitigations A
- Figure 8c Level 7 Terrace – Mitigations A + B

Different colours have been used to represent the wind criteria satisfied at the respective Test Locations.

**ADVERTISED
PLAN**

4.2 La Trobe Street

The wind conditions for the Proposed Configuration along La Trobe Street (Test Locations 1 to 12) have been shown to satisfy the walking comfort and safety criteria. The main entrance into the building (Test Location 4) have been shown to satisfy the recommended standing comfort criterion for building entrances. These criteria satisfied have been presented in Table 1 as well as data for the Existing Configuration for comparison.

The wind conditions as a function of wind direction based on the gust criteria developed for Melbourne are presented in Appendix A (Figures A2 to A4). It is noted that at each Test Location the directional specific wind conditions may be higher than those of the tabulated results for certain incident wind directions.

**This copied document to be made available
for the sole purpose of enabling
its consideration and review as
part of a planning process under the
Planning and Environment Act 1987.
The document must not be used for any
purpose which may breach any
copyright**

Table 1: Pedestrian Wind Comfort and Safety – La Trobe Street

Test Location	Configuration	Wind Comfort Criteria			Safety
		Sitting	Standing	Walking	
1	Existing	19%	9%	4%	Pass
	Proposed	30%	16%	8%	Pass
2	Existing	31%	17%	9%	Pass
	Proposed	42%	28%	18%	Pass
	Mitigations A + B	36%	22%	13%	Pass
3	Existing	19%	8%	3%	Pass
	Proposed	33%	18%	9%	Pass
4	Existing	30%	16%	8%	Pass
	Proposed	27%	14%	7%	Pass
5	Existing	42%	27%	17%	Pass
	Proposed	40%	26%	15%	Pass
6	Existing	39%	23%	13%	Pass
	Proposed	44%	29%	19%	Pass
7	Existing	45%	30%	18%	Pass
	Proposed	40%	26%	17%	Pass
8	Existing	44%	30%	19%	Pass
	Proposed	36%	21%	11%	Pass
9	Existing	24%	13%	7%	Pass
	Proposed	23%	11%	5%	Pass
10	Existing	41%	27%	17%	Pass
	Proposed	34%	22%	13%	Pass
11	Existing	40%	27%	17%	Pass
	Proposed	37%	23%	14%	Pass
12	Existing	43%	28%	17%	Pass
	Proposed	42%	28%	17%	Pass

This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright

4.3 Harbour Esplanade

The wind conditions for the Proposed Configuration along Harbour Esplanade (Test Locations 13 to 23, 30, 31, 39 and 40) have been shown to satisfy the walking comfort and safety criteria at most Test Locations except near the northwest corner of the Development (Test Location 18), and a localised area on the west side of Harbour Esplanade (Test Locations 20 and 22) where the safety criterion were shown to fail for the north wind direction which arose from wind flow being deflected and induced to ground off the northwest edge of the tower. However, it has been demonstrated that the incorporation of Mitigations A & B (refer to Figures 4a, 4b and 8c) disrupted the flow separating off the tower edge and thus improving the wind conditions at Test Locations 18, 20 and 22 to satisfy the walking comfort and safety criteria.

**ADVERTISED
PLAN**

These criteria satisfied have been presented in Table 2 as well as data for the Existing Configuration for comparison.

The wind conditions as a function of wind direction based on the gust criteria developed for Melbourne are presented in Appendix A (Figures A5 and A8). It is noted that at each Test Location the directional specific wind conditions may be higher than those of the tabulated results for certain incident wind directions.

**This copied document to be made available
for the sole purpose of enabling
its consideration and review as
part of a planning process under the
Planning and Environment Act 1987.
The document must not be used for any
purpose which may breach any
copyright**

Table 2: Pedestrian Wind Comfort and Safety – Harbour Esplanade

Test Location	Configuration	Wind Comfort Criteria			Safety
		Sitting	Standing	Walking	
13	Existing	40%	26%	16%	Pass
	Proposed	41%	27%	16%	Pass
14	Existing	36%	21%	11%	Pass
	Proposed	35%	21%	11%	Pass
15	Existing	33%	19%	10%	Pass
	Proposed	36%	21%	11%	Pass
16	Existing	38%	24%	16%	Pass
	Proposed	39%	25%	16%	Pass
17	Existing	34%	21%	12%	Pass
	Proposed	41%	28%	17%	Pass
18	Existing	27%	16%	10%	Pass
	Proposed	41%	29%	19%	FAIL
	Mitigations A + B	38%	25%	16%	Pass
19	Existing	36%	22%	14%	Pass
	Proposed	29%	18%	12%	Pass
20	Existing	35%	21%	13%	Pass
	Proposed	36%	24%	17%	FAIL
	Mitigations A + B	35%	22%	15%	Pass
21	Existing	27%	18%	12%	Pass
	Proposed	31%	21%	14%	Pass
	Mitigations A + B	30%	21%	13%	Pass
22	Existing	32%	19%	12%	Pass
	Proposed	32%	21%	15%	FAIL
	Mitigations A + B	31%	19%	13%	Pass
23	Existing	26%	14%	8%	Pass
	Proposed	32%	19%	13%	Pass
30	Existing	27%	16%	10%	Pass
	Proposed	42%	29%	19%	Pass
	Mitigations A + B	40%	26%	17%	Pass
31	Existing	34%	19%	10%	Pass
	Proposed	39%	24%	14%	Pass
39	Existing	38%	22%	13%	Pass
	Proposed	39%	25%	15%	Pass
40	Existing	27%	16%	9%	Pass
	Proposed	28%	19%	13%	Pass

4.4 West and South frontages of the Development

The wind conditions for the Proposed Configuration on ground level along the west (Test Locations 32 to 35) and south (Test Locations 36, 36a and 37) frontages of the Development have been shown to satisfy the walking comfort criterion with the main entrance (Test Location 33) satisfying the sitting criterion. The wind conditions at the secondary entrance located along the southern frontage of the Development (Test Location 36) were shown to only satisfy the walking comfort criterion. It would be recommended that this entrance be moved away from the building corner towards Test Location 36a where wind conditions were shown to satisfy the standing comfort criterion, alternatively setting the entry at Test Location 36 in (i.e. recessed) by approximately 2m would achieve the standing criterion and thus be more appropriate for an entry.

. These criteria satisfied have been presented in Table 3 as well as data for the Existing Configuration for comparison.

The wind conditions as a function of wind direction based on the gust criteria developed for Melbourne are presented in Appendix A (Figures A9 and A10). It is noted that at each Test Location the directional specific wind conditions may be higher than those of the tabulated results for certain incident wind directions.

Table 3: Pedestrian Wind Comfort and Safety – West and South frontages of the Development

Test Location	Configuration	Wind Comfort Criteria			
		Sitting	Standing	Walking	Safety
32	Existing	25%	15%	9%	Pass
	Proposed	36%	22%	12%	Pass
33	Existing	21%	10%	5%	Pass
	Proposed	3%	1%	1%	Pass
34	Existing	23%	12%	6%	Pass
	Proposed	17%	6%	2%	Pass
35	Existing	22%	11%	5%	Pass
	Proposed	42%	28%	18%	Pass
36	Existing	32%	18%	10%	Pass
	Proposed	39%	24%	13%	Pass
36a					
	Proposed	33%	18%	9%	Pass
37	Existing	23%	13%	7%	Pass
	Proposed	23%	12%	6%	Pass

4.5 Laneway on the east side of the Development

The wind conditions for the Proposed Configuration along the Laneway located on the east side of the Development (Test Locations 24 to 27) have been shown to satisfy the walking comfort and safety criteria. These criteria satisfied have been presented in Table 4 as well as data for the Existing Configuration for comparison.

The wind conditions as a function of wind direction based on the gust criteria developed for Melbourne are presented in Appendix A (Figure A11). It is noted that at each Test Location the directional specific wind conditions may be higher than those of the tabulated results for certain incident wind directions.

**ADVERTISED
PLAN**

Table 4: Pedestrian Wind Comfort and Safety – Laneway on the east side of the Development

Test Location	Configuration	Wind Comfort Criteria			
		Sitting	Standing	Walking	Safety
24	Existing	37%	22%	12%	Pass
	Proposed	32%	21%	15%	Pass
25	Existing	38%	23%	13%	Pass
	Proposed	41%	27%	17%	Pass
26	Existing	14%	5%	2%	Pass
	Proposed	26%	14%	6%	Pass
27	Existing	33%	19%	10%	Pass
	Proposed	35%	21%	11%	Pass

This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright

4.6 Marvel Stadium

ADVERTISED PLAN

The wind conditions for the Proposed Configuration in the area towards the northwest side of Marvel Stadium (Test Locations 28, 29, 41 and 42), have been shown to satisfy the standing comfort and safety criteria. These criteria satisfied have been presented in Table 5 as well as data for the Existing Configuration for comparison.

The wind conditions as a function of wind direction based on the gust criteria developed for Melbourne are presented in Appendix A (Figure A12). It is noted that at each Test Location the directional specific wind conditions may be higher than those of the tabulated results for certain incident wind directions.

Table 5: Pedestrian Wind Comfort and Safety – Marvel Stadium

Test Location	Configuration	Wind Comfort Criteria			
		Sitting	Standing	Walking	Safety
28	Existing	14%	6%	2%	Pass
	Proposed	26%	14%	6%	Pass
29	Existing	32%	18%	9%	Pass
	Proposed	31%	16%	7%	Pass
41	Existing	24%	11%	5%	Pass
	Proposed	24%	11%	5%	Pass
42	Existing	25%	14%	8%	Pass
	Proposed	27%	15%	8%	Pass

This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright

4.7 Level 7 - Podium Rooftop Terrace

As discussed in Section 4.3, Mitigations A were required for the ground level wind conditions along Harbour Esplanade to satisfy the safety criterion. Therefore, for the Proposed Configuration with Mitigations A (refer to Figures 4a and 4b), the wind conditions on the west side of the Level 7 podium rooftop terrace (Test Locations P1, P3 and P4) have been shown to fail the safety criterion for the north wind direction. However, it has been demonstrated that with the addition of Mitigations B (i.e. screens, gate, increased balustrade height, and “no-go” zone, refer to Figure 8c) the wind conditions within the pedestrian trafficable areas (Test Locations P2 to P10, and P1a) would satisfy the walking comfort criterion at a minimum and satisfy the safety criterion. These criteria satisfied have been presented in Table 6.

**ADVERTISED
PLAN**

The wind conditions as a function of wind direction based on the gust criteria developed for Melbourne are presented in Appendix A (Figures A13 to A15). It is noted that at each Test Location the directional specific wind conditions may be higher than those of the tabulated results for certain incident wind directions.

Table 6: Pedestrian Wind Comfort and Safety – Level 7 Podium Rooftop Terrace

Test Location	Configuration	Wind Comfort Criteria			Safety
		Sitting	Standing	Walking	
P1	Mitigations A	45.7%	32.4%	22.4%	FAIL
P1a					
	Mitigations A + B	43%	29%	18%	Pass
P2					
	Mitigations A + B	46%	31%	19%	Pass
P3	Mitigations A	54%	41%	30%	FAIL
	Mitigations A + B	41%	26%	15%	Pass
P3a					
	Mitigations A + B	52%	38%	27%	FAIL
P4	Mitigations A	51%	38%	27%	FAIL
	Mitigations A + B	46%	31%	19%	Pass
P5	Mitigations A	28%	19%	13%	Pass
P6					
	Mitigations A + B	37%	22%	13%	Pass
P7					
	Mitigations A + B	6%	2%	1%	Pass
P8					
	Mitigations A + B	28%	14%	6%	Pass
P9	Mitigations A	17%	7%	3%	Pass
P10					
	Mitigations A + B	41%	26%	17%	Pass

4.8 Levels 12 and 29 Balconies

ADVERTISED PLAN

The wind conditions for the Proposed Configuration on the Level 12 balconies (Test Locations B1 to B4) have been shown to satisfy the standing comfort criterion at a minimum, and would be representative of the conditions on the balconies at Levels 9 to 19. The wind conditions for the Proposed Configuration on the Level 29 balconies (Test Locations B5 to B8) have been shown to satisfy the walking comfort criterion at a minimum, and would be representative of the conditions on the balconies at Levels 20 to 29. The wind conditions at all balcony Test Locations have been shown to satisfy the safety criterion.

The wind conditions as a function of wind direction based on the gust criteria developed for Melbourne are presented in Appendix A (Figures A16 to A17). It is noted that at each Test Location the directional specific wind conditions may be higher than those of the tabulated results for certain incident wind directions.

Table 7: Pedestrian Wind Comfort and Safety – Levels 12 and 29 Balconies

Test Location	Configuration	Wind Comfort Criteria			Safety
		Sitting	Standing	Walking	
B1	Proposed	26%	15%	9%	Pass
B2	Proposed	10%	3%	1%	Pass
B3	Proposed	22%	12%	6%	Pass
B4	Proposed	3%	1%	1%	Pass
B5	Proposed	31%	21%	14%	Pass
B6	Proposed	16%	7%	3%	Pass
B7	Proposed	27%	18%	11%	Pass
B8	Proposed	1%	1%	1%	Pass

This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright

4.9 Level 40 Rooftop Terrace

ADVERTISED PLAN

The wind conditions for the Proposed Configuration on the Level 40 Rooftop Terrace (Test Locations T1 to T5) have been shown to satisfy the walking comfort criterion at a minimum and satisfy the safety criterion. These criteria satisfied have been presented in Table 8.

It would be recommended that users be educated on the wind impacts on terraces/balconies and that any objects to be left permanently on the terrace would be tethered/ fixed securely to the terrace and the fixing/ tethers inspected regularly for damage/ corrosion. Any loose items should not be left on the terrace when unattended.

The wind conditions as a function of wind direction based on the gust criteria developed for Melbourne are presented in Appendix A (Figures A18 and A19). It is noted that at each Test Location the directional specific wind conditions may be higher than those of the tabulated results for certain incident wind directions.

Table 8: Pedestrian Wind Comfort and Safety – Level 40 Rooftop Terrace

Test Location	Configuration	Wind Comfort Criteria			
		Sitting	Standing	Walking	Safety
T1	Proposed	16%	10%	7%	Pass
T2	Proposed	38%	23%	14%	Pass
T3	Proposed	34%	19%	10%	Pass
T4	Proposed	30%	16%	8%	Pass
T5	Proposed	27%	13%	5%	Pass

This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright

5. CONCLUSIONS

ADVERTISED PLAN

A wind tunnel study has been conducted on a 1/400 scale model of the proposed 699 La Trobe Street Development, Docklands. The model of the Development within surrounding buildings, was tested in a simulated upstream boundary layer of the natural wind to determine likely environmental wind conditions. These wind conditions have been related to the freestream mean wind speed at a reference height of 300m and compared with criteria developed for the Melbourne region as a function of wind direction.

For the Proposed Configuration, the wind conditions for all Test Locations in the streetscapes surrounding the Development have been shown to satisfy the walking comfort and safety criteria except near the northwest corner of the Development and some areas on the west side of Harbour Esplanade where the safety criterion failed for the north wind direction. However, it has been demonstrated that with the incorporation of tower built form wind mitigation strategies (Mitigations A) these wind conditions would improve to satisfy the walking comfort and safety criteria. The wind conditions at the main entrance into the building, located along the western frontage of the Development, have been shown to satisfy the sitting comfort criterion.

With regards to the wind conditions on the terraces and balconies, the wind conditions on the west side of the Level 7 podium rooftop terrace for the Proposed Configuration with Mitigations A have been shown to fail the safety criterion for the north wind direction. However, it has been demonstrated that with appropriate wind mitigation strategies (Mitigations B), the wind conditions within the pedestrian trafficable areas of the Level 7 podium rooftop terrace would satisfy the walking comfort and safety criteria. The wind conditions on the balconies of Levels 9 to 19 for the Proposed Configuration would be expected to be similar to those measured on Level 12 which were shown to satisfy the standing comfort criterion at minimum and the safety criterion, while conditions on Levels 20 to 29 balconies would be expected to be similar to those measured on Level 29 which were shown to satisfy the walking comfort criterion at a minimum and the safety criterion.

**This copied document to be made available
for the sole purpose of enabling
its consideration and review as
part of a planning process under the
Planning and Environment Act 1987.
The document must not be used for any
purpose which may breach any
copyright**

REFERENCES

1. W. H. Melbourne, Criteria for environmental wind conditions, Journal of Industrial Aerodynamics, Volume 3, 1978, pp. 241-249
2. W. H. Melbourne, Wind environment studies in Australia, Journal of Industrial Aerodynamics, Volume 3, 1978, pp. 201-214

**ADVERTISED
PLAN**

**This copied document to be made available
for the sole purpose of enabling
its consideration and review as
part of a planning process under the
Planning and Environment Act 1987.
The document must not be used for any
purpose which may breach any
copyright**

FIGURES

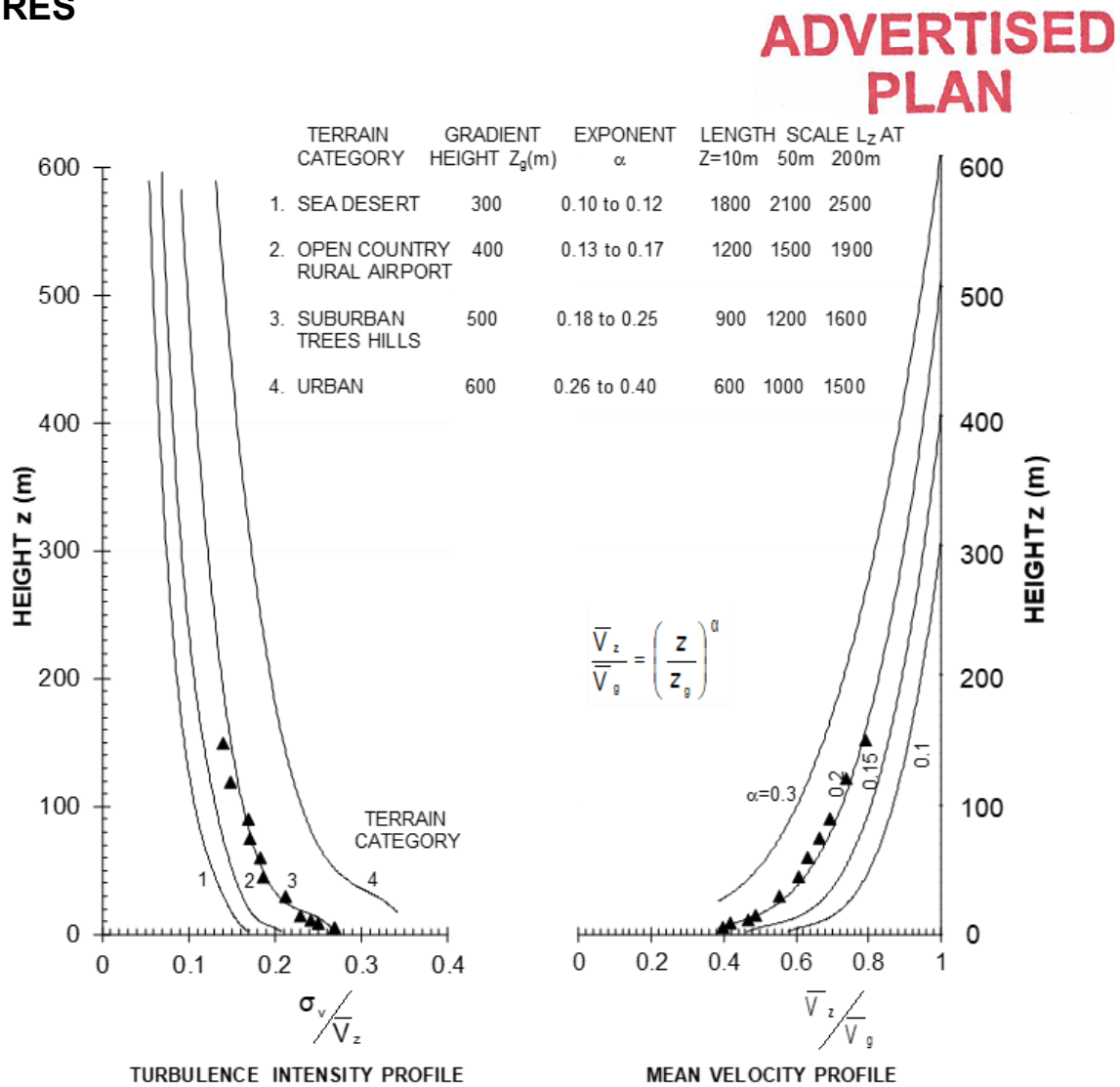


Figure 2 - 1/400 scale TC3 boundary layer turbulence intensity and mean velocity profiles in the MEL Consultants Boundary Layer Wind Tunnel 4.8m x 2.2m working section, scaled to full scale dimensions.

This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright



Figure 3a – View from the northwest of the 1/400 scale Proposed Configuration model of the 699 La Trobe Street Development in the wind tunnel.

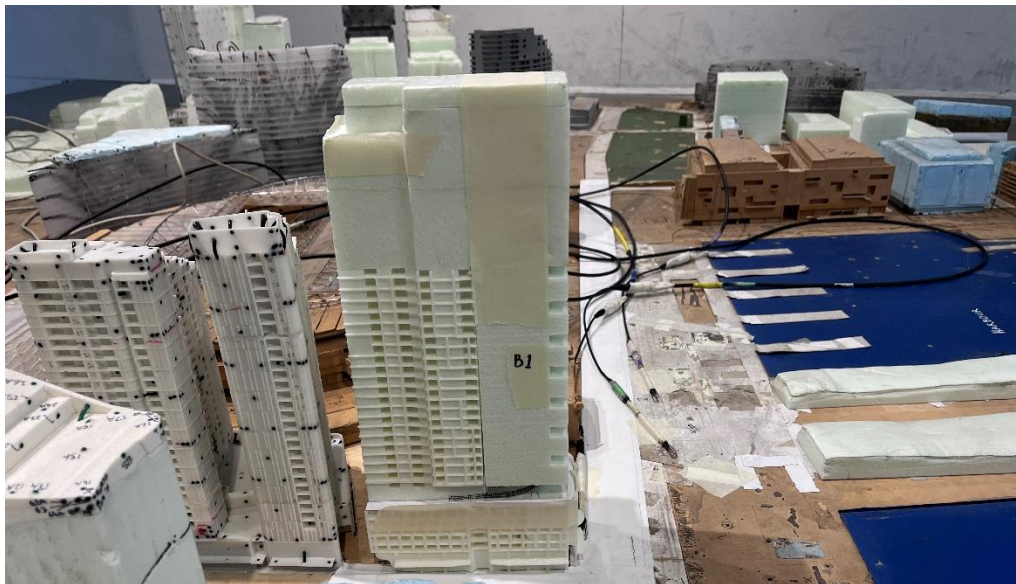
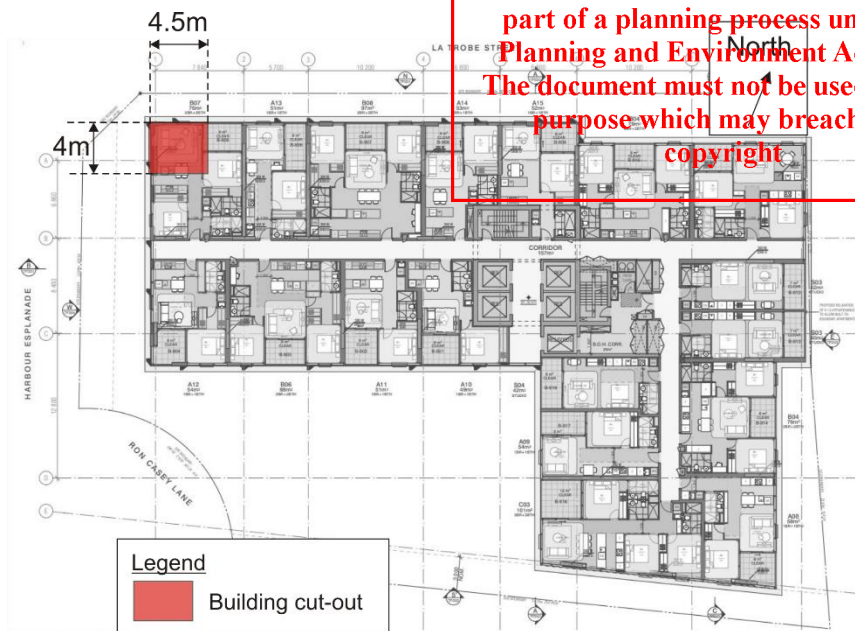


Figure 3b – View from the north-northwest of the 1/400 scale model for the Proposed Configuration with Mitigations A and B of the 699 La Trobe Street Development in the wind tunnel.

This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright



**ADVERTISED
PLAN**

Figure 4a – Plan view of building cut-out at northwest corner (i.e. Mitigations A)



Figure 4b – North elevation view showing Mitigations A

ADVERTISED PLAN

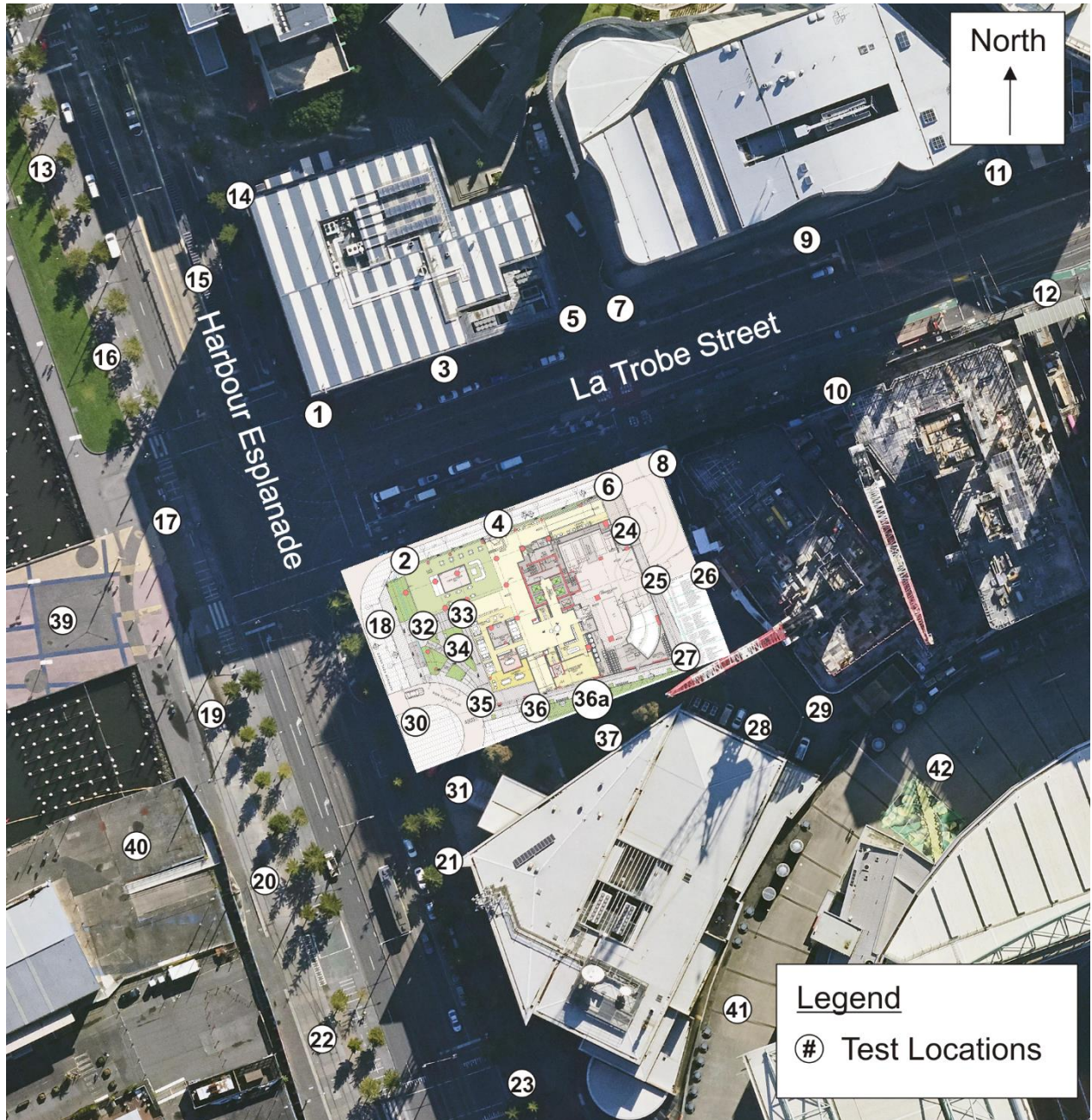


Figure 5a - Ground Level Test Locations in the surrounding streetscapes for the proposed 699 La Trobe Street Development.

This copied document to be made available
for the sole purpose of enabling
its consideration and review as
part of a planning process under the
Planning and Environment Act 1987.
The document must not be used for any
purpose which may breach any
copyright

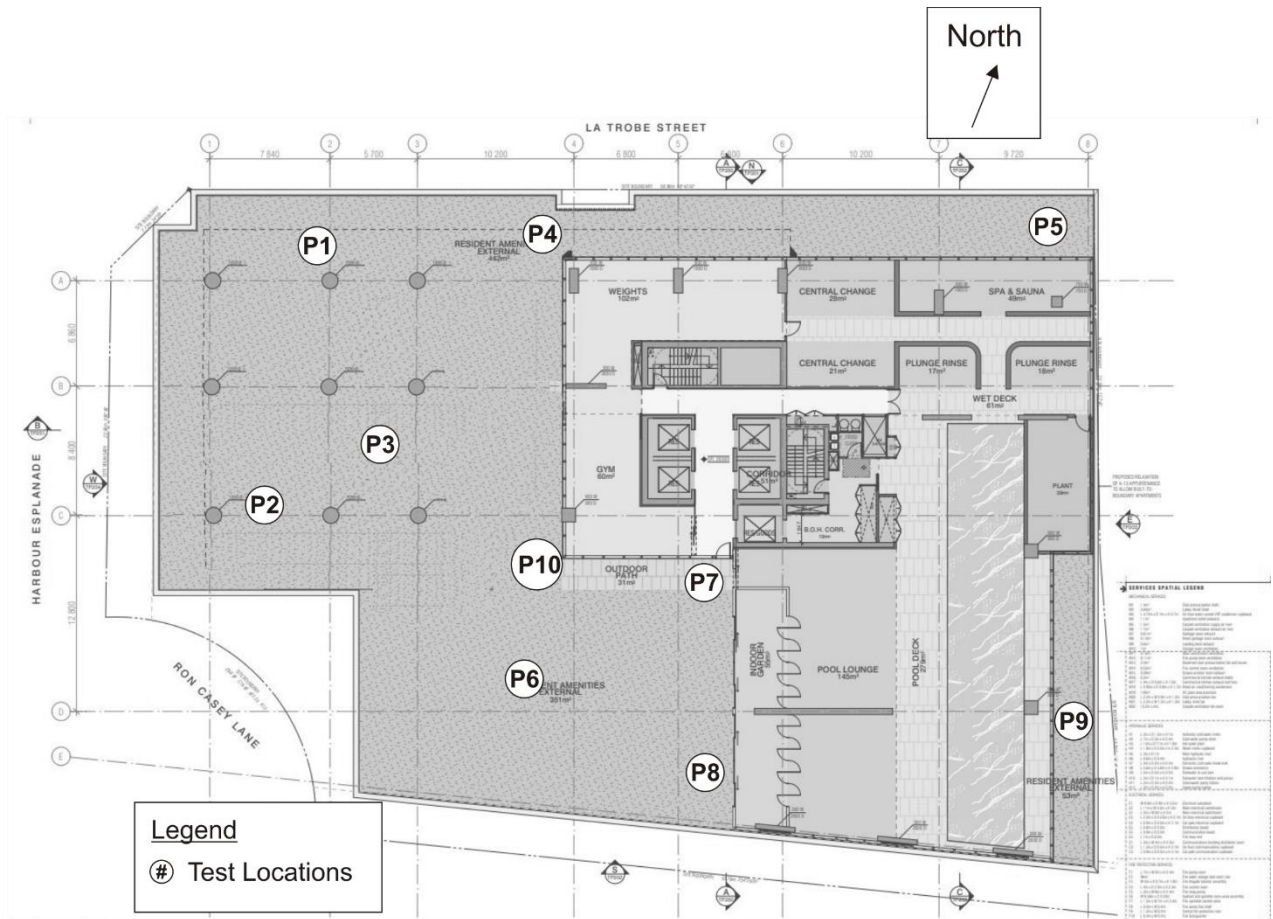


Figure 5b - Test Locations on the Levels 7 Podium Rooftop Terrace for the proposed 699 La Trobe Street Development without pavilion.

This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright



Figure 5c – Test Locations on the Levels 12 and 29 Balconies for the proposed 699 La Trobe Street Development.

This copied document to be made available
for the sole purpose of enabling
its consideration and review as
part of a planning process under the
Planning and Environment Act 1987.
The document must not be used for any
purpose which may breach any
copyright

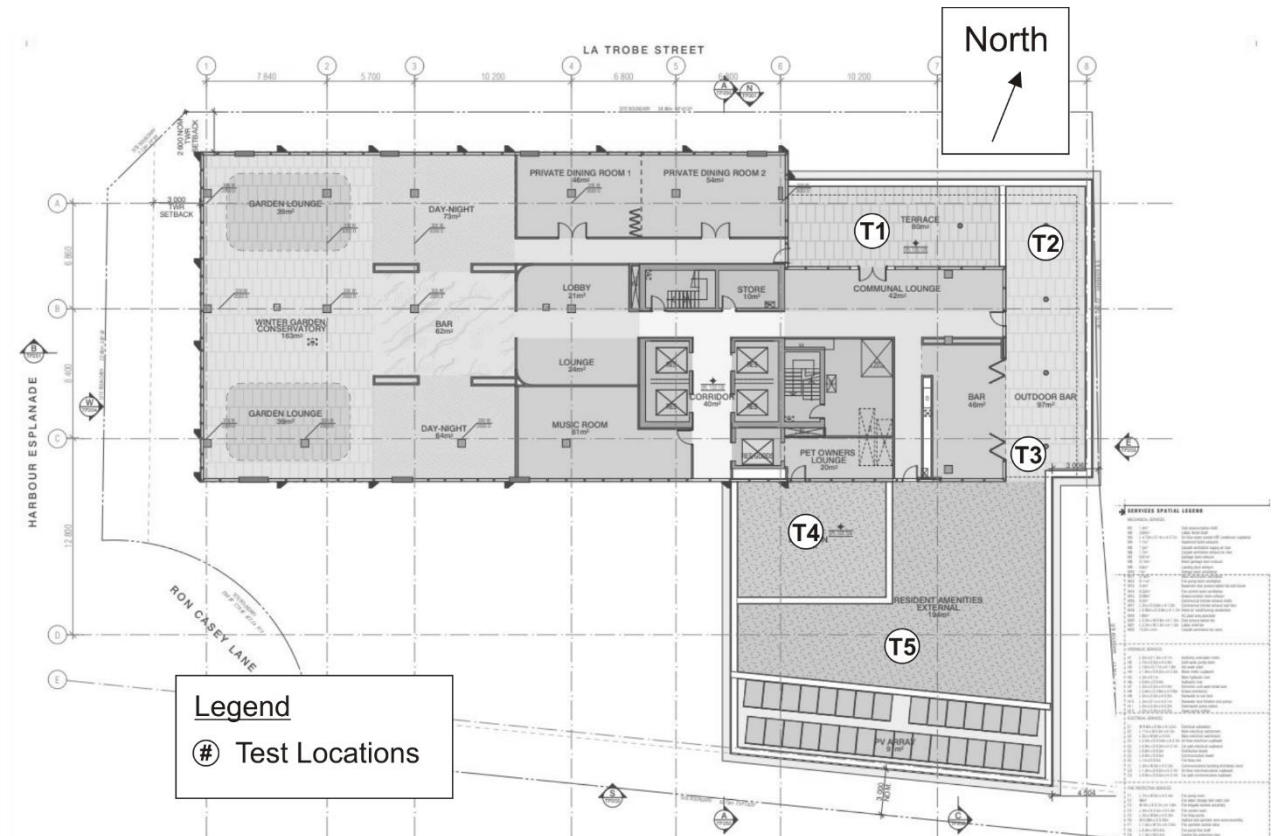


Figure 5d – Test Locations on the Levels 40 Rooftop Terrace for the proposed 699 La Trobe Street Development.

This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright

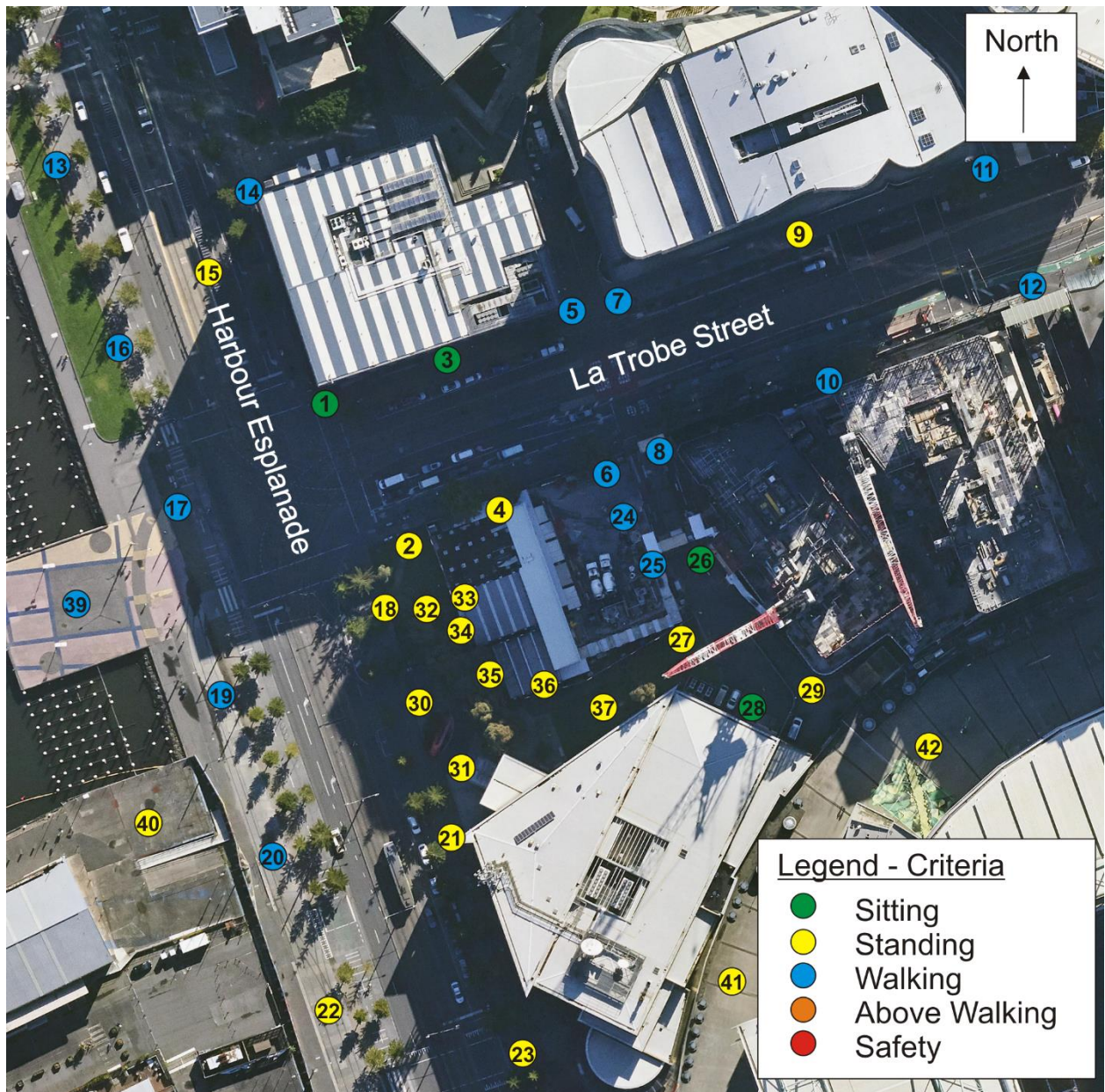


Figure 6 - Summary of satisfied wind criteria on the Ground Level wind conditions for the Existing Configuration around the 699 La Trobe Street Development.

This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright

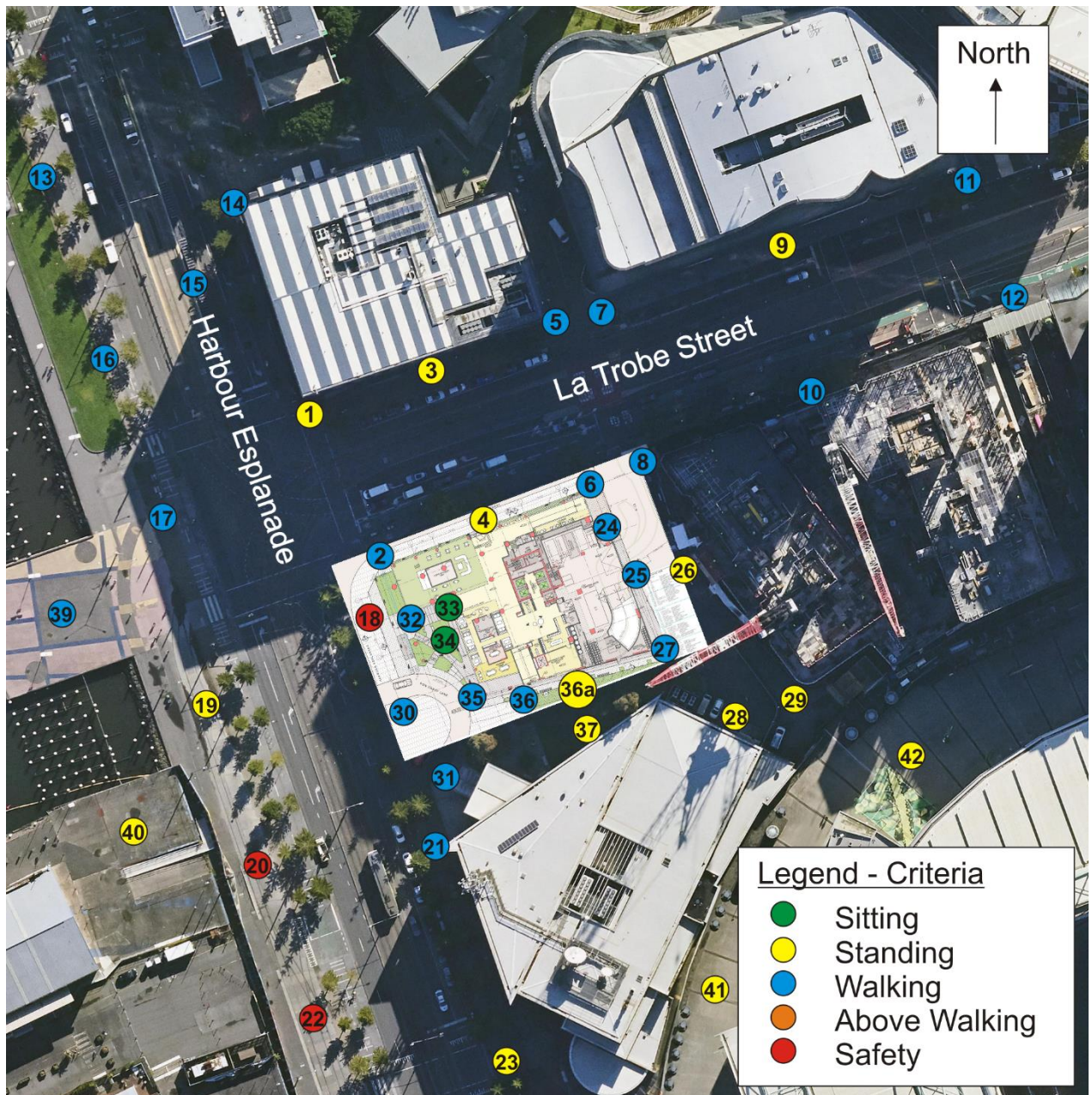
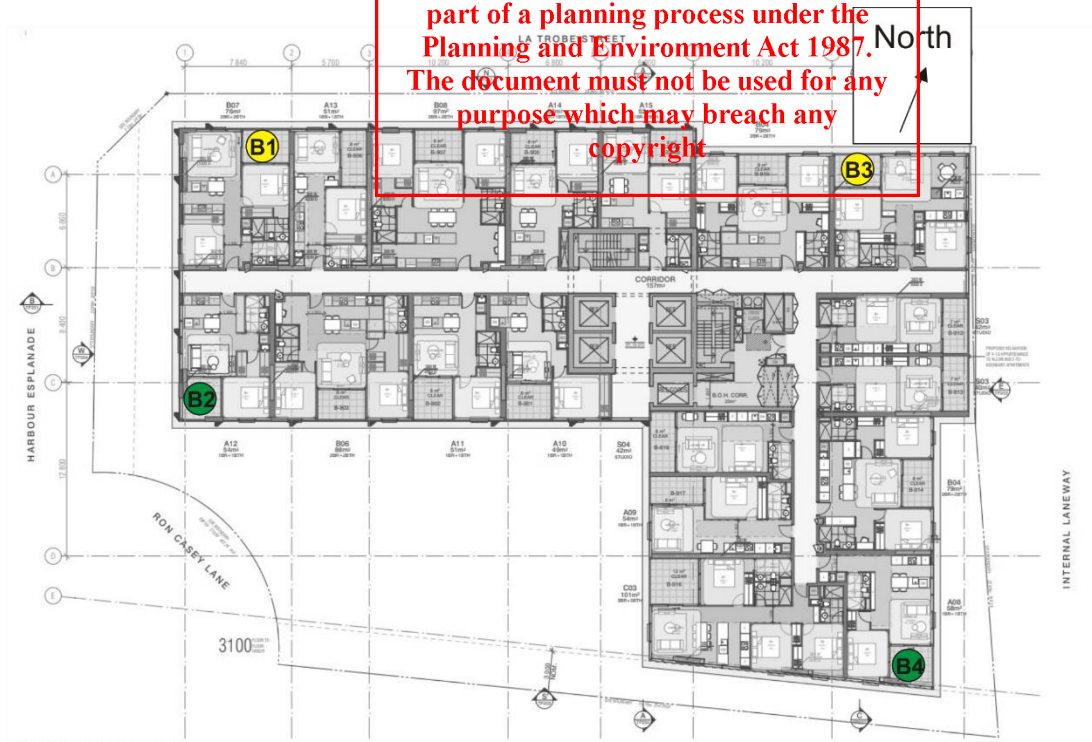


Figure 7a - Summary of satisfied wind criteria on the Ground Level for the Proposed Configuration around the 699 La Trobe Street Development.

This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright

This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright

ADVERTISED
PLAN



Level 12



Level 29

Legend - Criteria

- Sitting
- Standing
- Walking
- Above Walking
- Safety

Figure 7b - Summary of satisfied wind criteria on the Levels 12 and 29 Balconies for the 699 La Trobe Street Development for the Proposed Configuration.

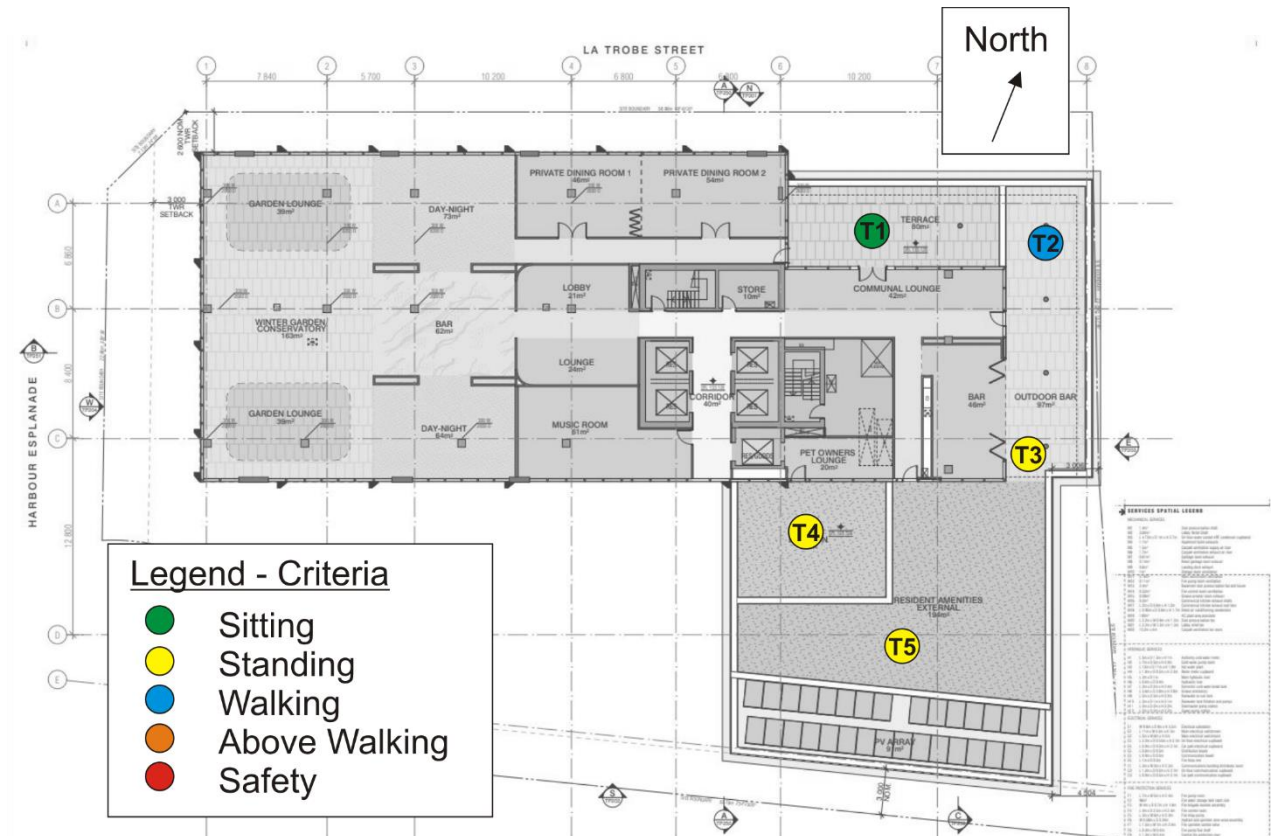


Figure 7c - Summary of satisfied wind criteria on the Level 40 Rooftop Terrace for the 699 La Trobe Street Development for the Proposed Configuration.

This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright

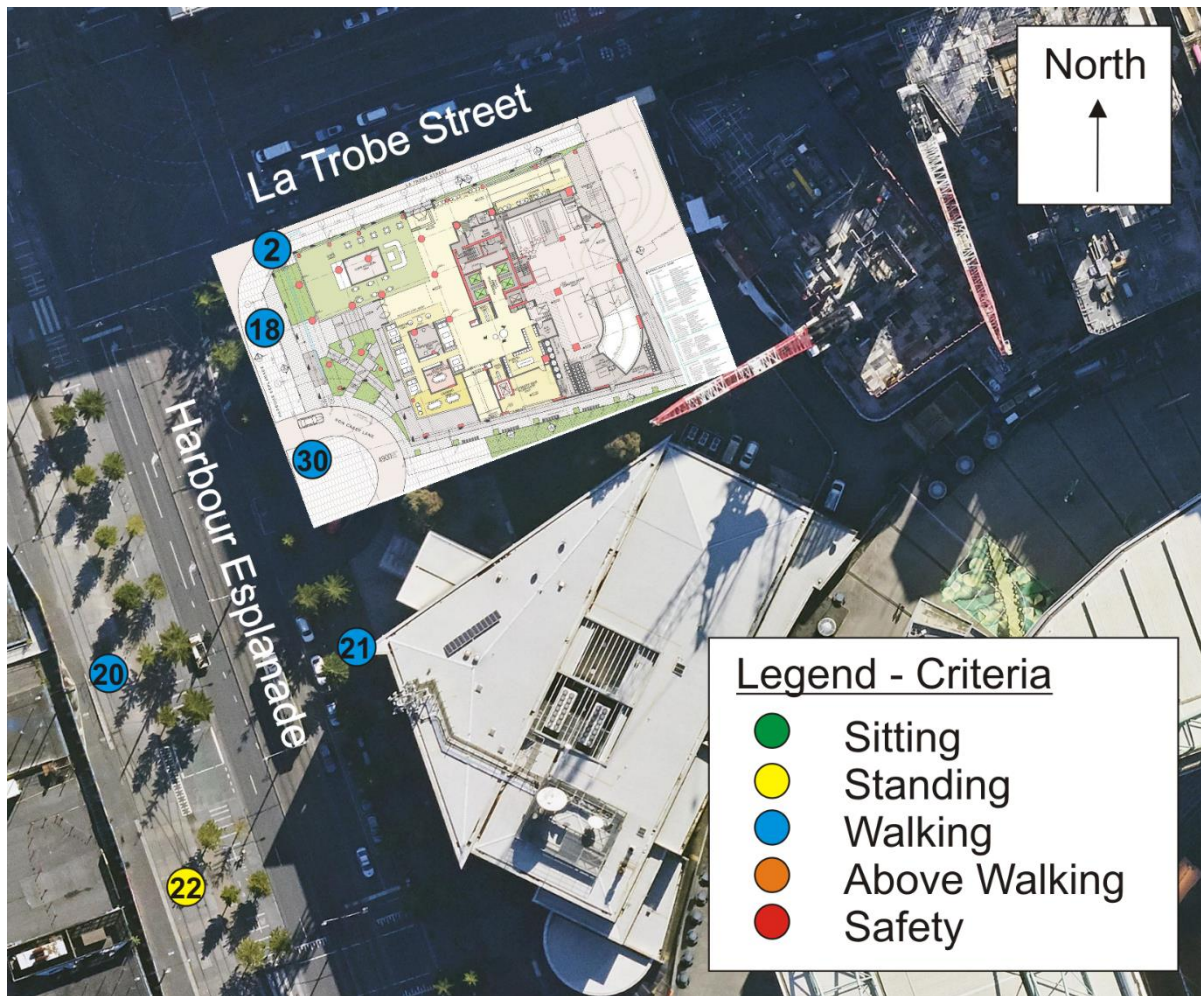


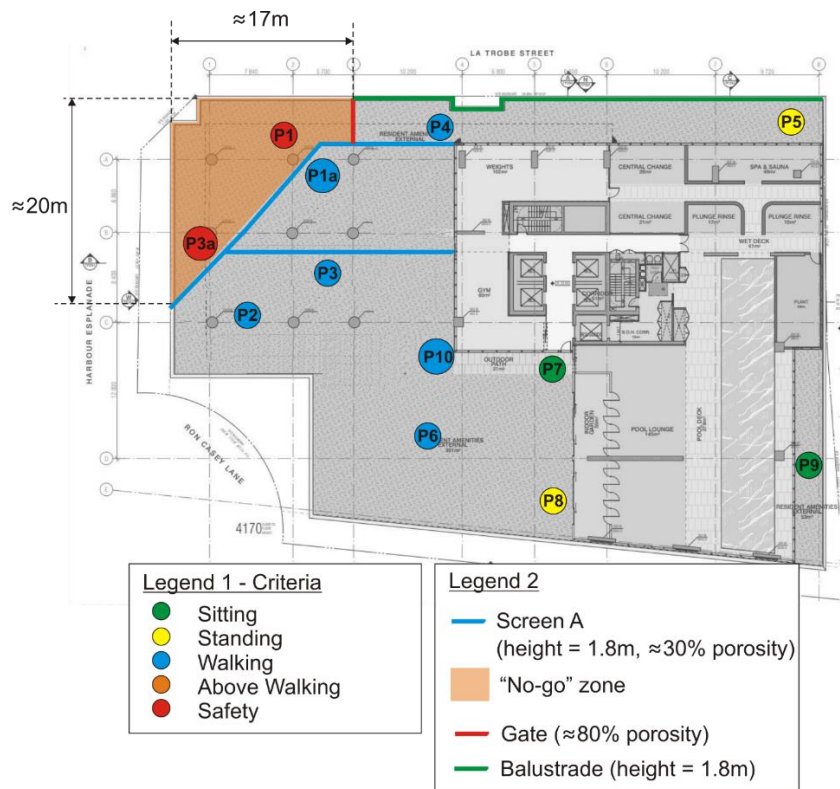
Figure 8a - Summary of satisfied wind criteria on the Ground Level for the Proposed Configuration with Mitigations A and B around the 699 La Trobe Street Development.

This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright



**ADVERTISED
PLAN**

Figure 8b - Summary of satisfied wind criteria on the Level 7 Podium Rooftop Terrace for the 699 La Trobe Street Development for the Proposed Configuration with Mitigations A.



This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright

Figure 8c - Summary of satisfied wind criteria on the Level 7 Podium Rooftop Terrace for the 699 La Trobe Street Development for the Proposed Configuration with Mitigations A and B.

APPENDIX A

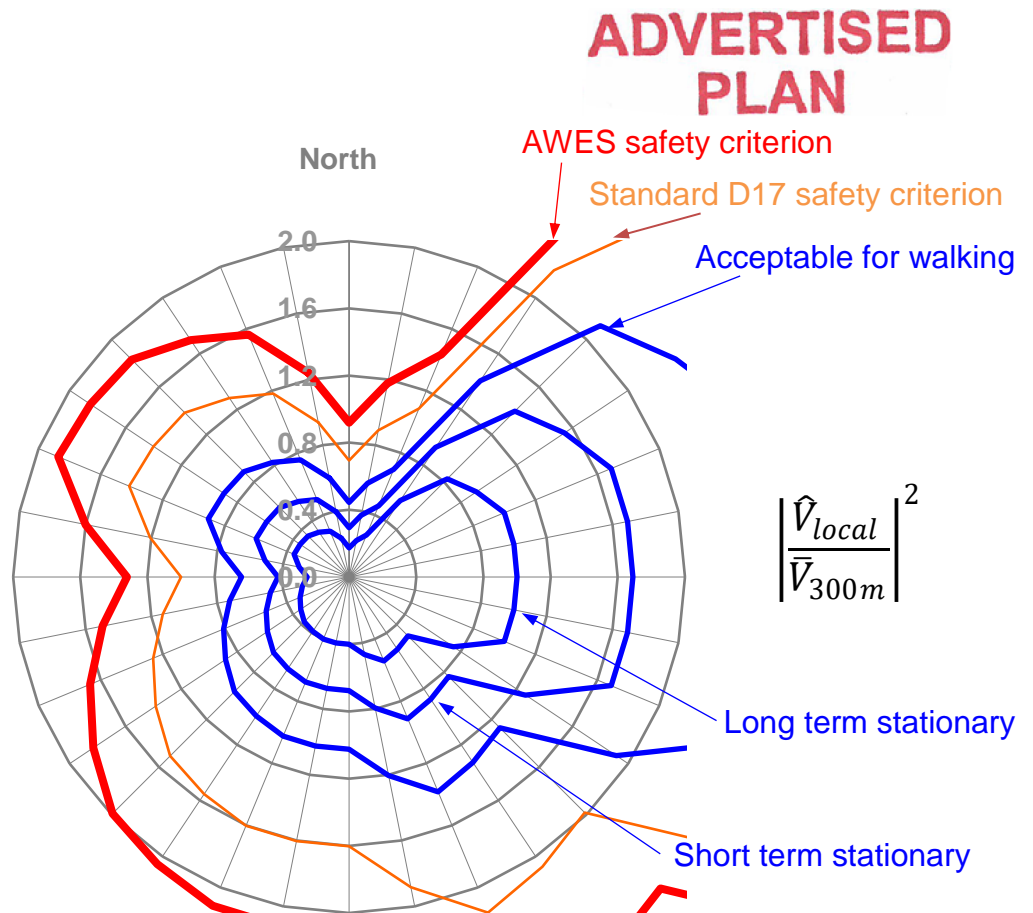
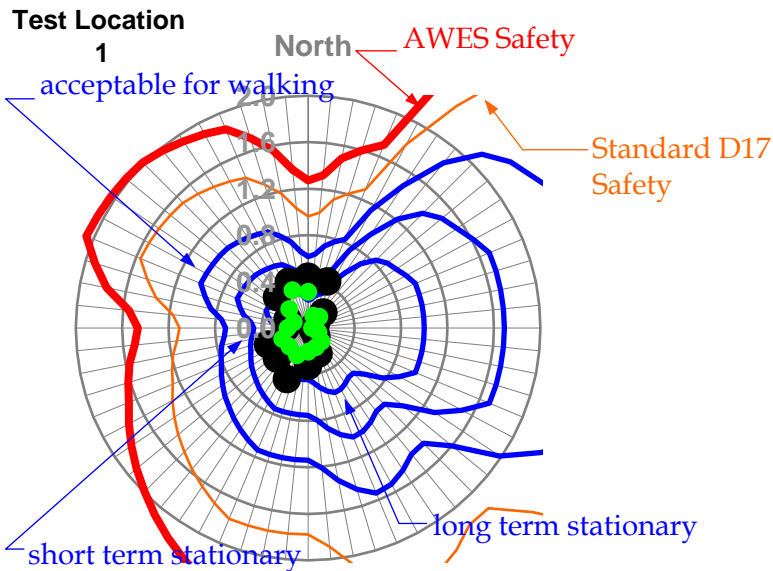


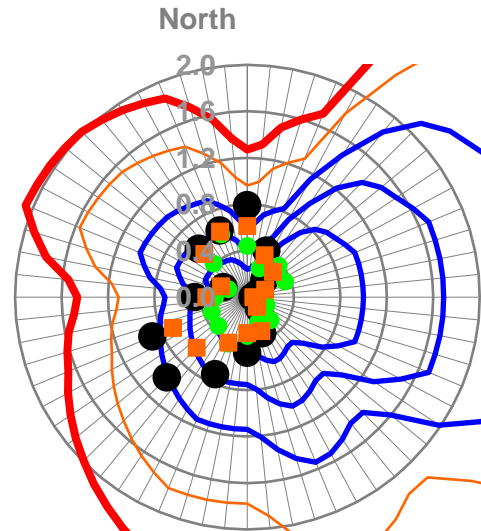
Figure A1 - Environmental wind criteria for Melbourne as a function of wind direction based on a 3 second gust

This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright

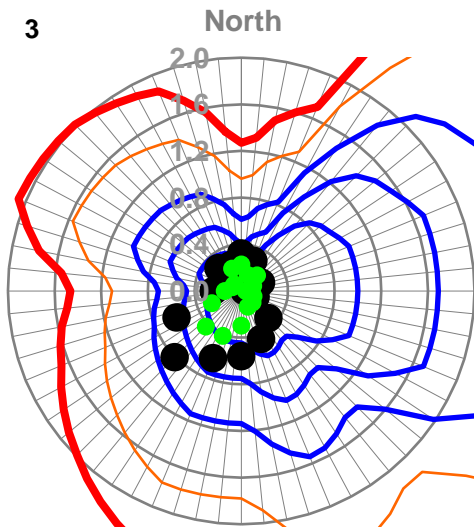
ADVERTISED PLAN



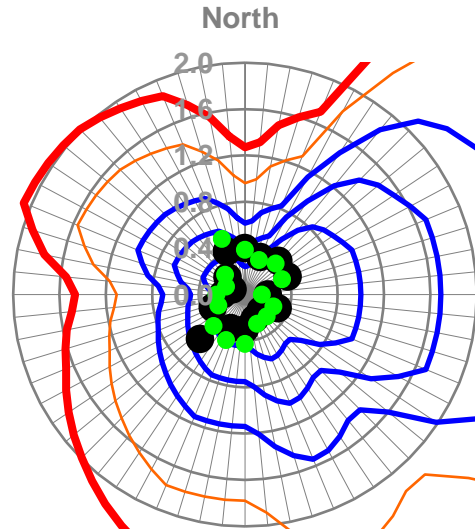
2



3



4



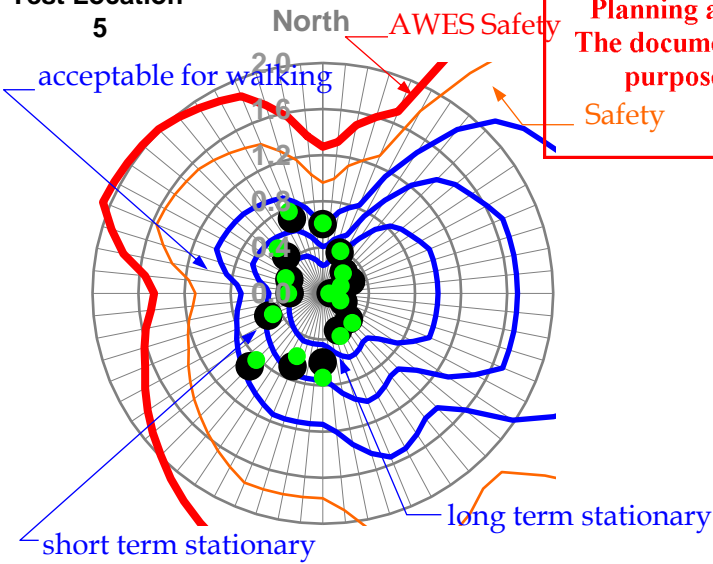
Peak velocity squared ratio $\left| \frac{\hat{V}_{local}}{\bar{V}_{300m}} \right|^2$ as a function of wind direction

Proposed Configuration	●
Existing Configuration	●
Proposed Configuration + Mitigations A and B	■

Appendix A2 - La Trobe Street

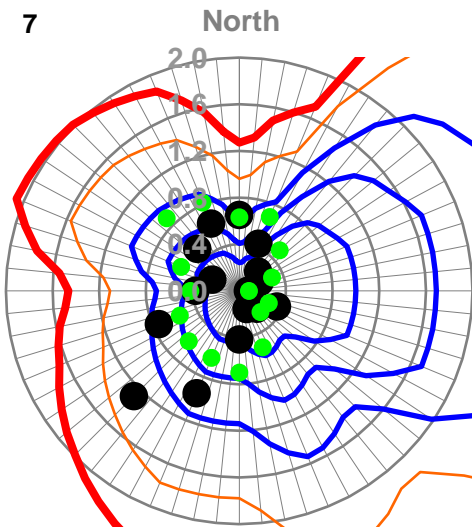
This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright

Test Location
5

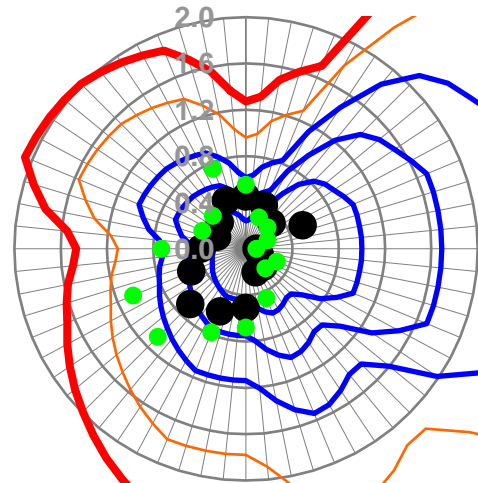


6

7



North



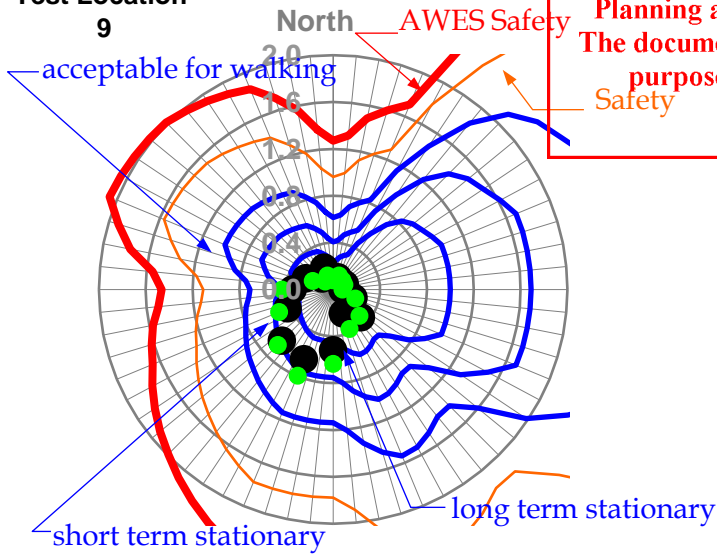
8

Peak velocity squared ratio $\left| \frac{\hat{V}_{local}}{\bar{V}_{300m}} \right|^2$ as a function of wind direction

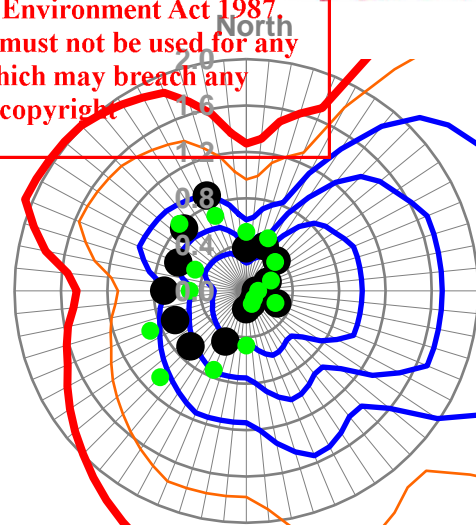


Appendix A3 - La Trobe Street (Continued)

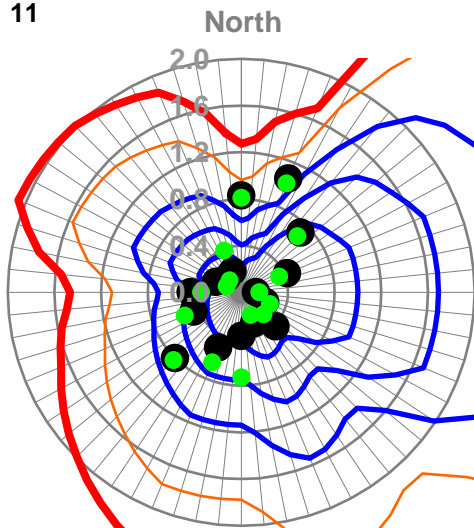
Test Location
9



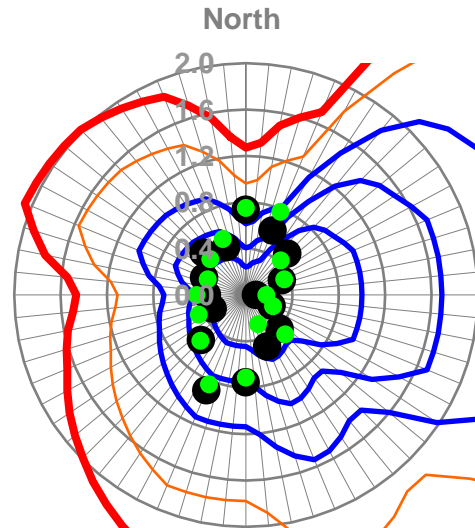
10



11



12

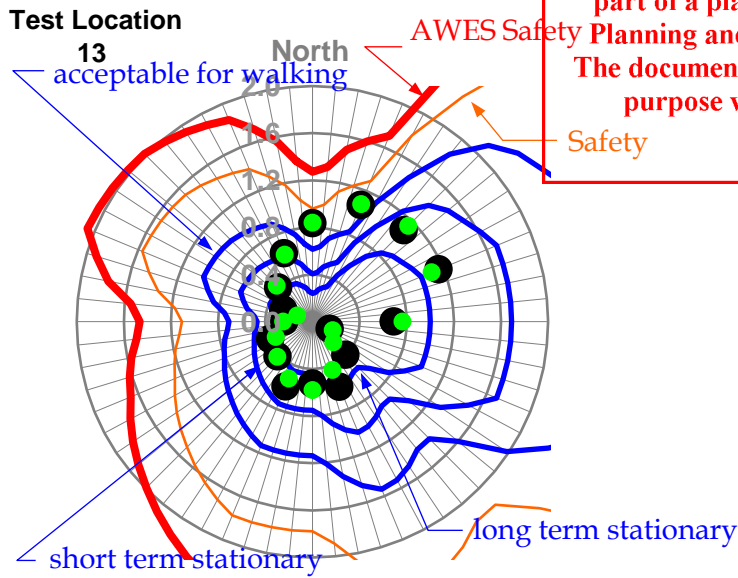


Peak velocity squared ratio $\left| \frac{\hat{V}_{local}}{\hat{V}_{300m}} \right|^2$ as a function of wind direction

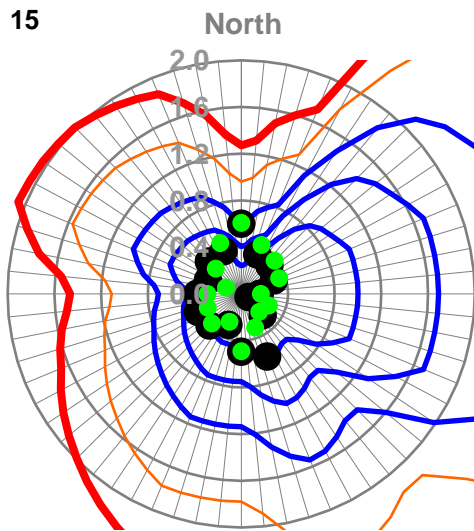
Proposed Configuration
Existing Configuration



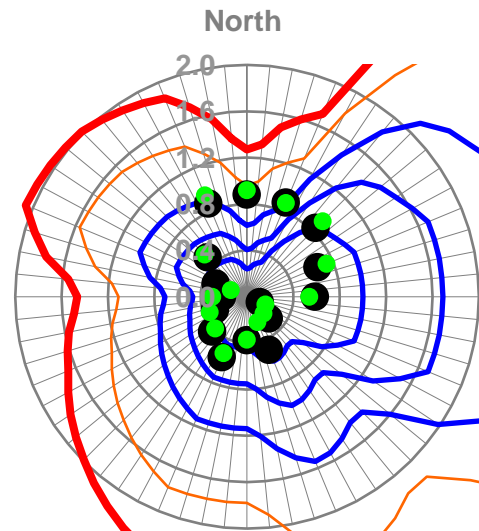
Appendix A4 - La Trobe Street (Continued)



14



15



16

Peak velocity squared ratio $\left| \frac{\hat{V}_{local}}{\bar{V}_{300m}} \right|^2$ as a function of wind direction

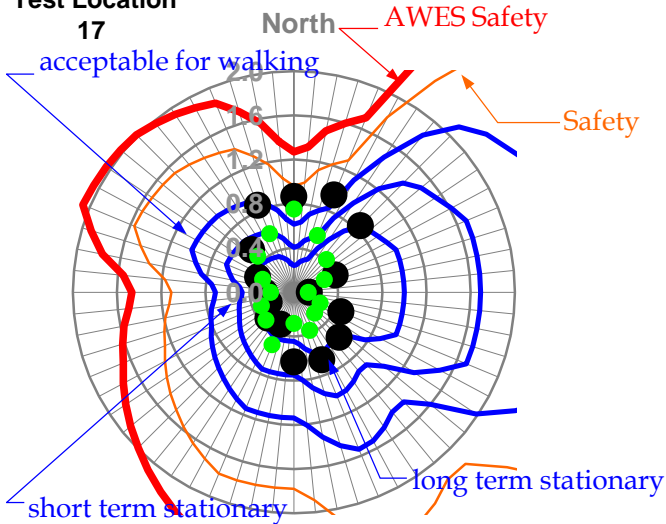
Proposed Configuration
Existing Configuration



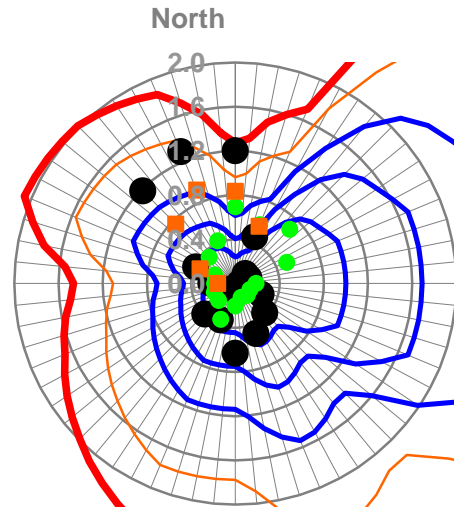
Appendix A5 - Harbour Esplanade

ADVERTISED PLAN

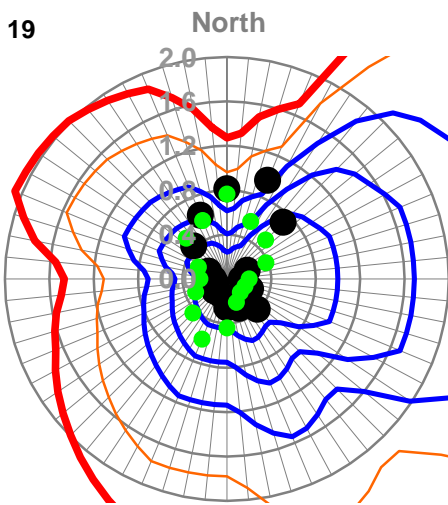
Test Location
17



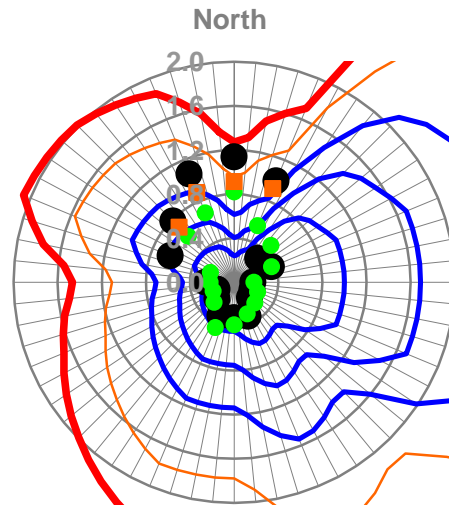
18



19



20



Peak velocity squared ratio $\left| \frac{\hat{V}_{local}}{\bar{V}_{300m}} \right|^2$ as a function of wind direction

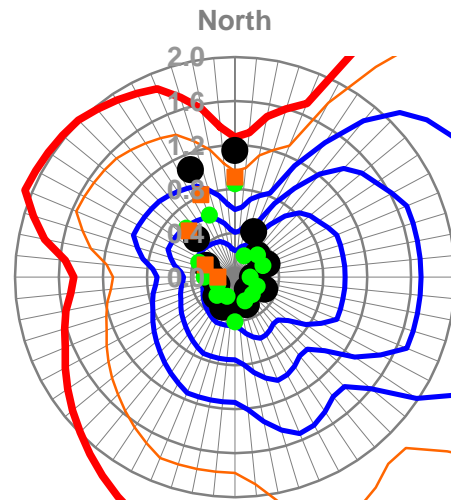
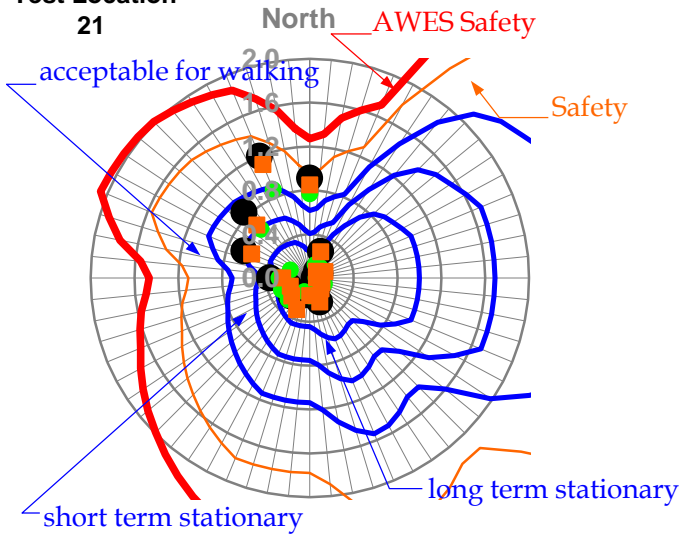
Proposed Configuration
Existing Configuration
Proposed Configuration + Mitigations A and B



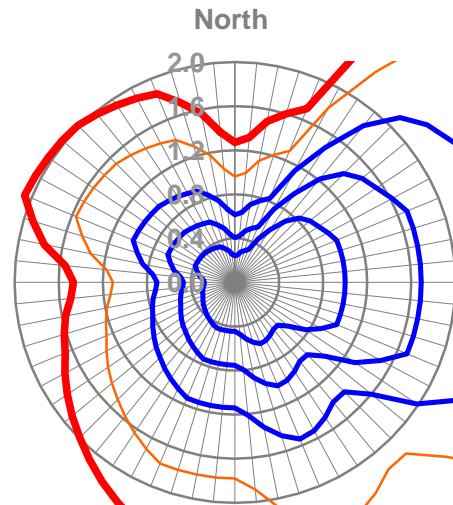
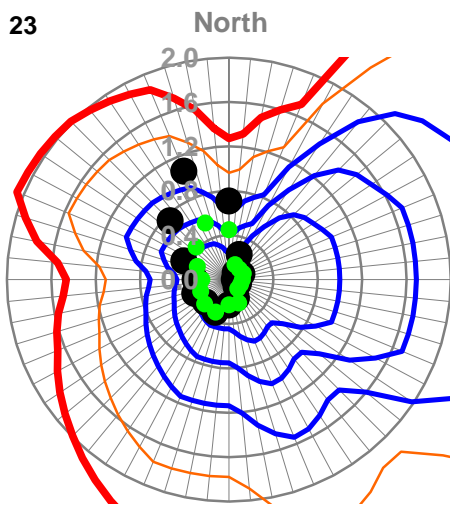
Appendix A6 - Harbour Esplanade (Continued)

This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright

Test Location
21



23



Peak velocity squared ratio $\left| \frac{\hat{V}_{local}}{\hat{V}_{300m}} \right|^2$ as a function of wind direction

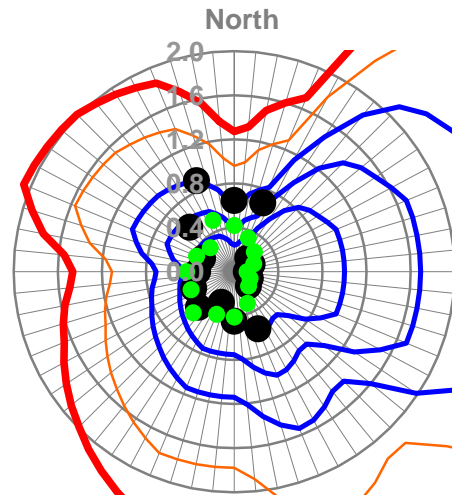
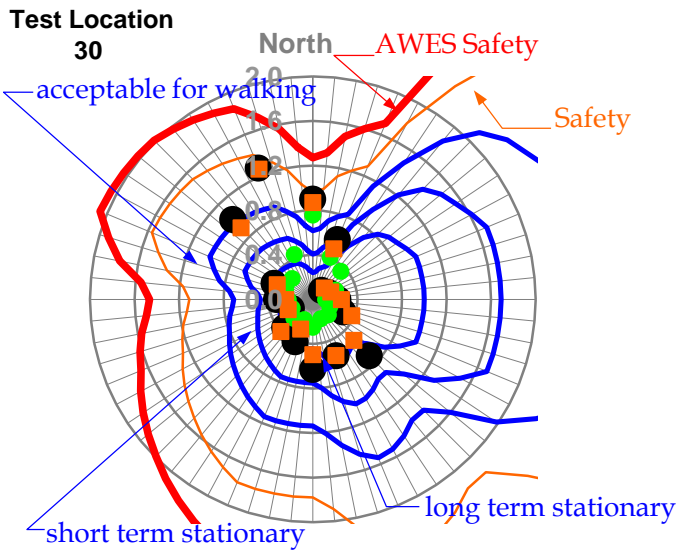
Proposed Configuration
Existing Configuration
Proposed Configuration + Mitigations A and B

Appendix A7 - Harbour Esplanade (Continued)

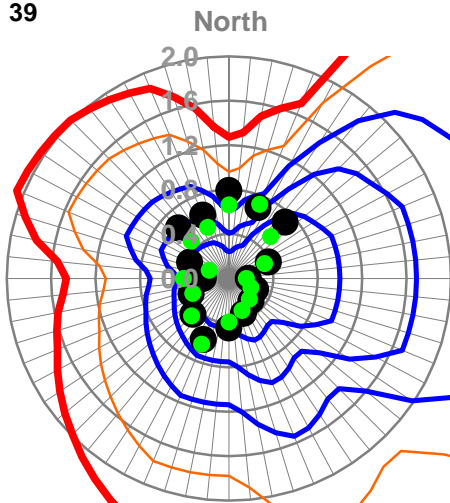
This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright

ADVERTISED PLAN

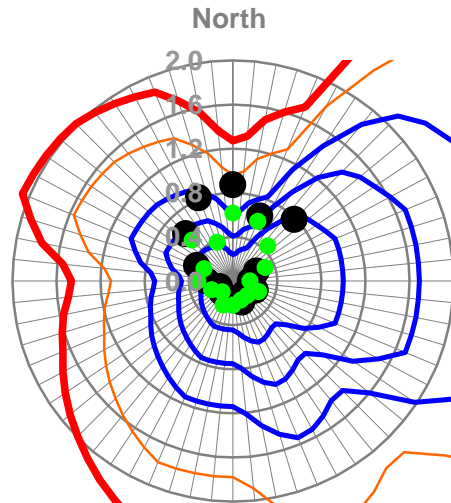
31



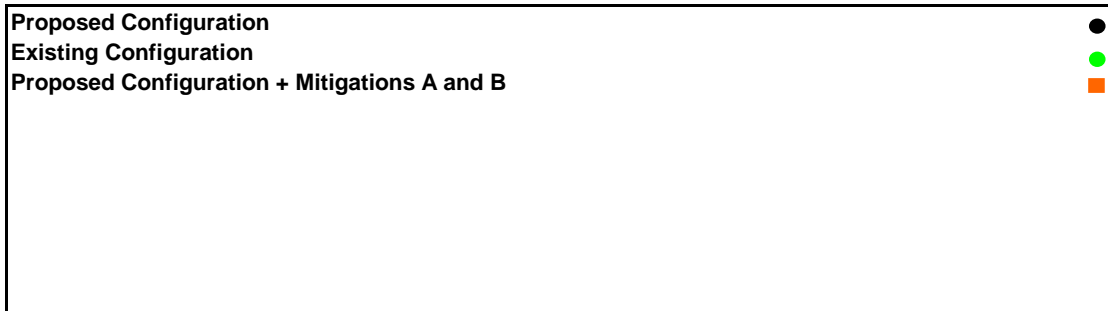
39



40

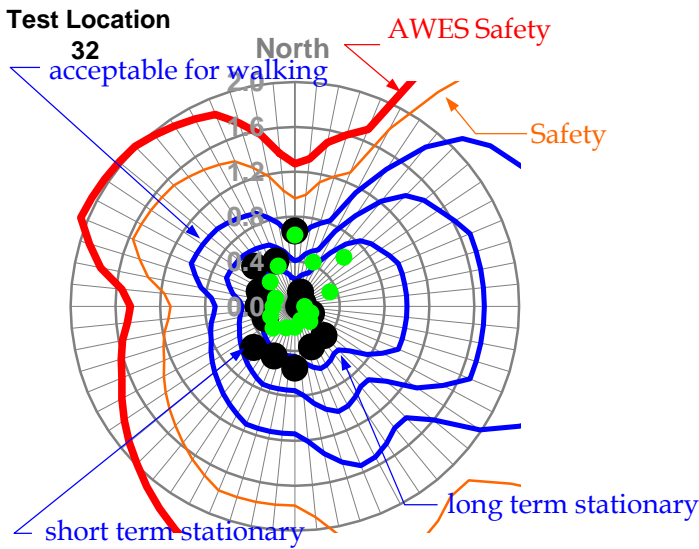


Peak velocity squared ratio $\left| \frac{\hat{V}_{local}}{\hat{V}_{300m}} \right|^2$ as a function of wind direction

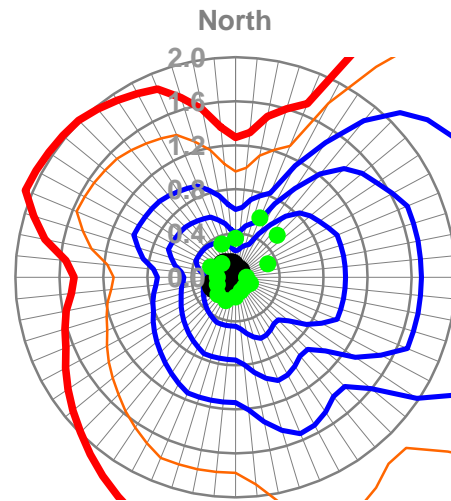


Appendix A8 - Harbour Esplanade (Continued)

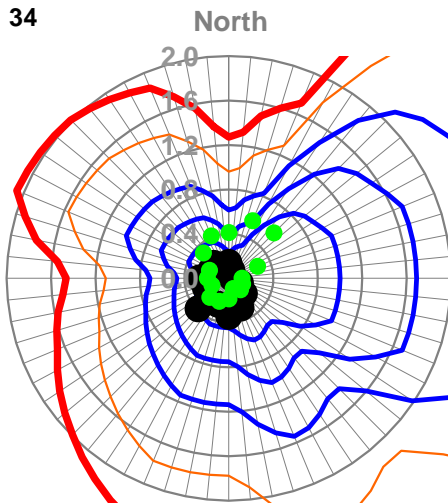
This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright



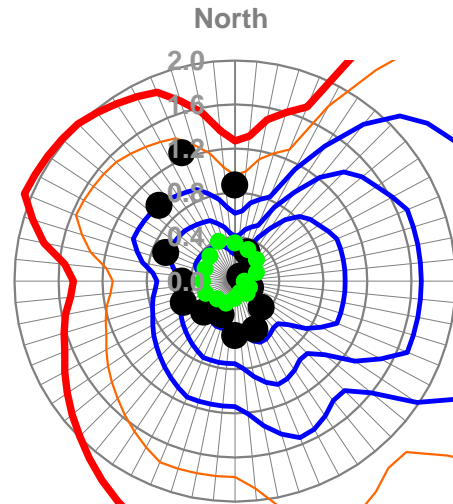
33



34



35



Peak velocity squared ratio $\left| \frac{\hat{V}_{local}}{\hat{V}_{300m}} \right|^2$ as a function of wind direction

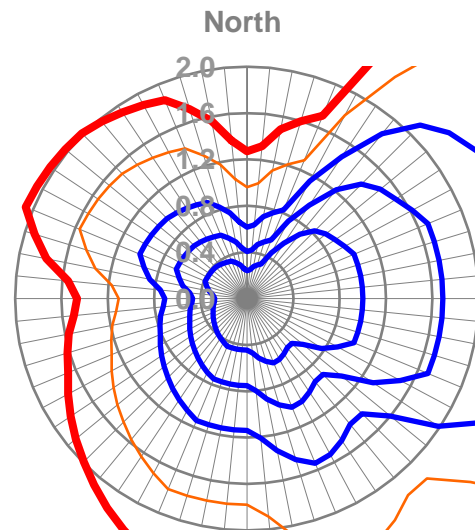
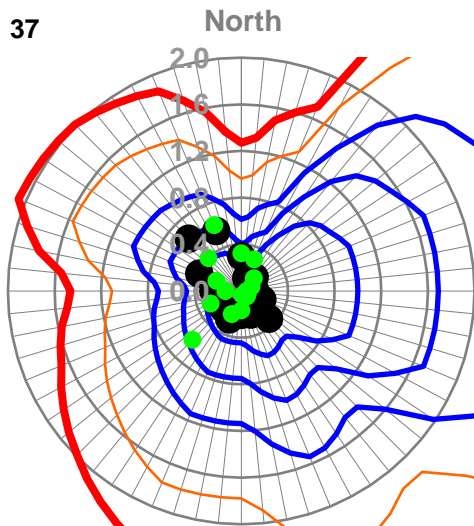
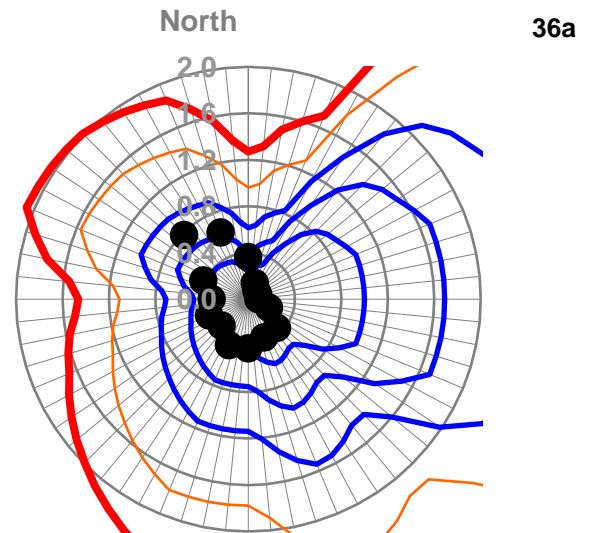
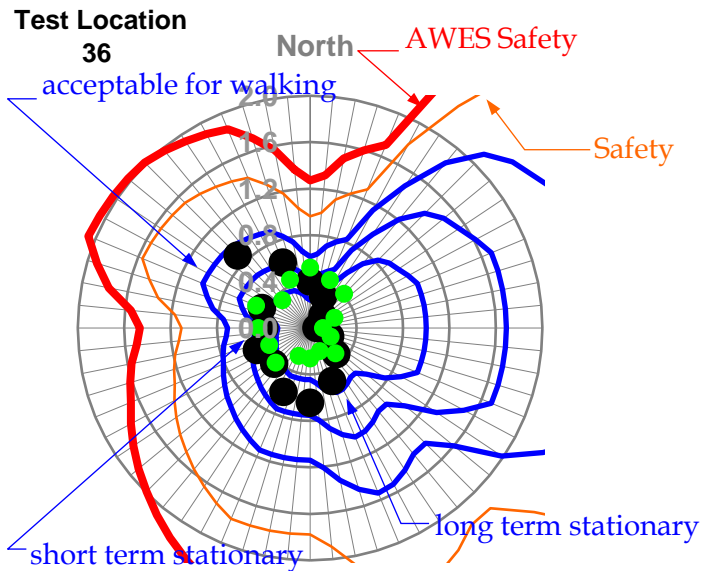
Proposed Configuration
Existing Configuration



Appendix A9 - West and South frontages of the Development

This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright

ADVERTISED PLAN



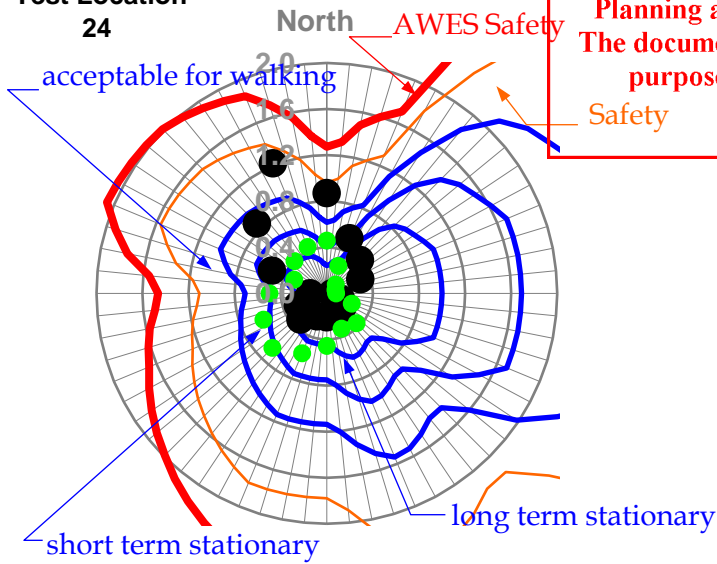
Peak velocity squared ratio $\left| \frac{\hat{V}_{local}}{\bar{V}_{300m}} \right|^2$ as a function of wind direction



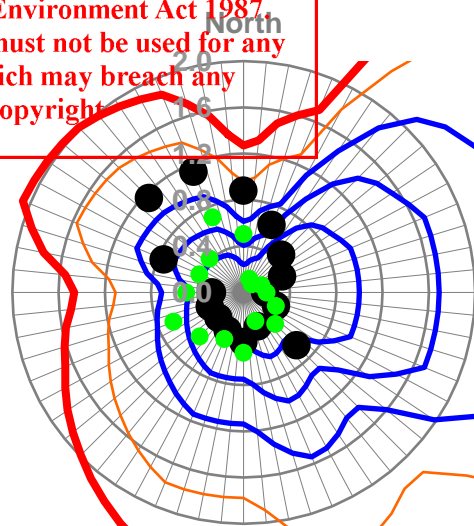
Appendix A10 - West and South frontages of the Development (Continued)

This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright

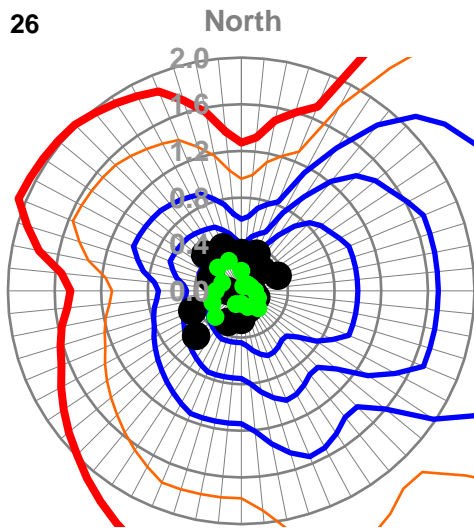
Test Location
24



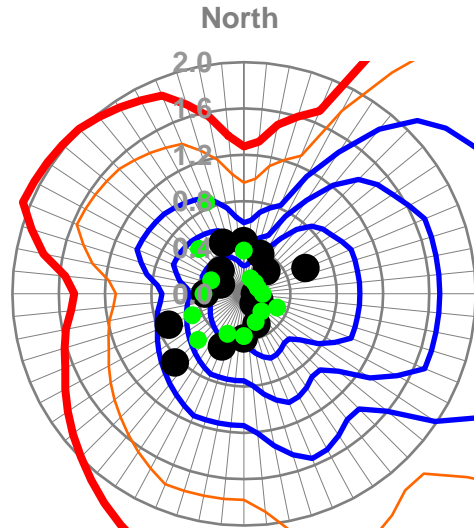
25



26



27



Peak velocity squared ratio $\left| \frac{\hat{V}_{local}}{\bar{V}_{300m}} \right|^2$ as a function of wind direction

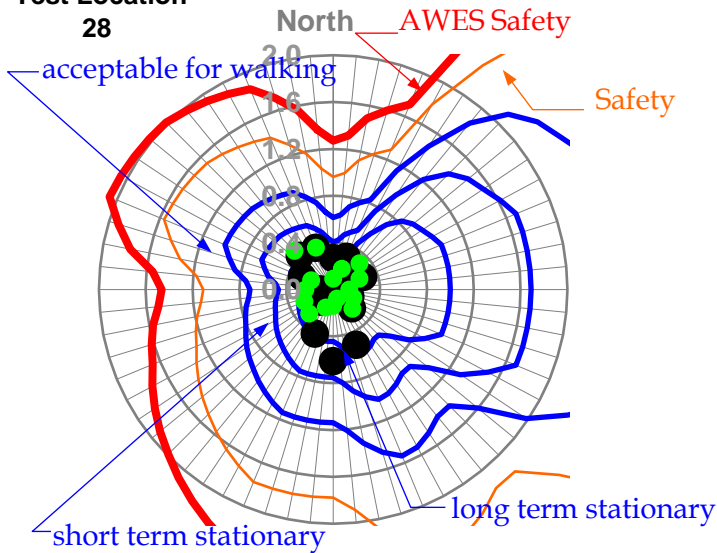
Proposed Configuration
Existing Configuration



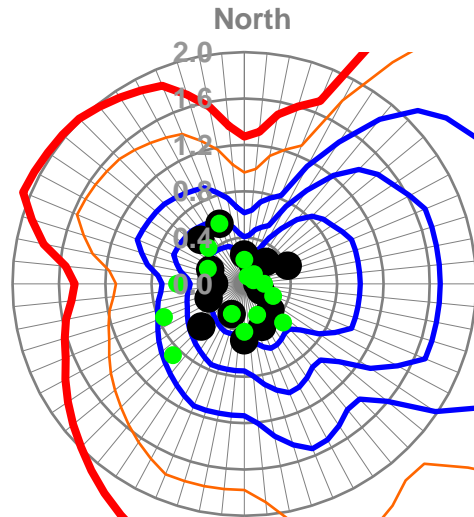
Appendix A11 - Laneway on the east side of Development

ADVERTISED PLAN

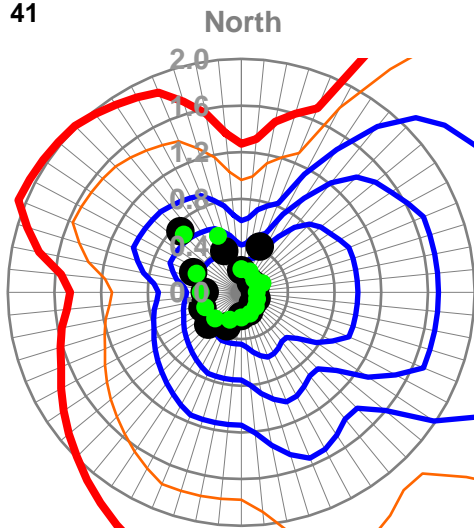
Test Location
28



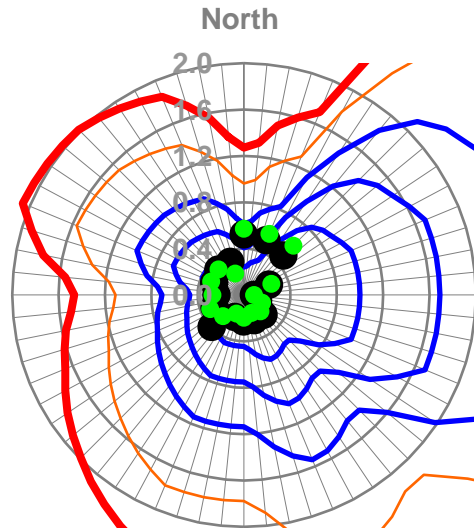
29



41



42



Peak velocity squared ratio $\left| \frac{\hat{V}_{local}}{\bar{V}_{300m}} \right|^2$ as a function of wind direction

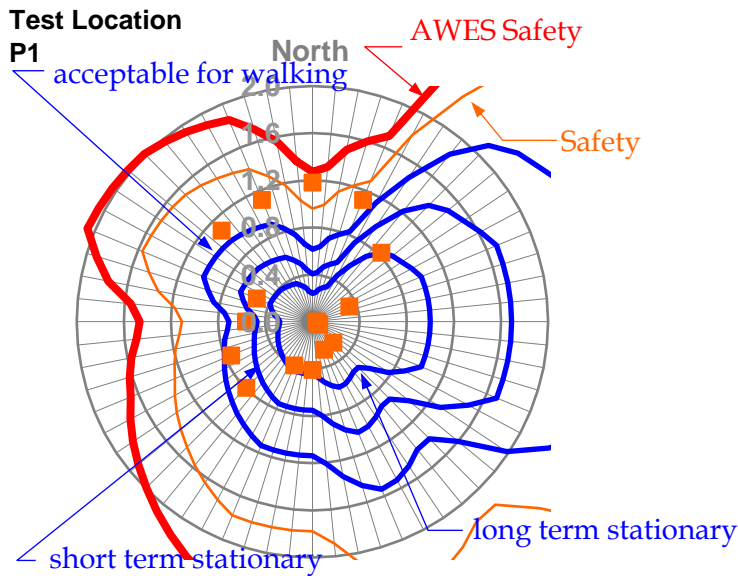
Proposed Configuration
Existing Configuration



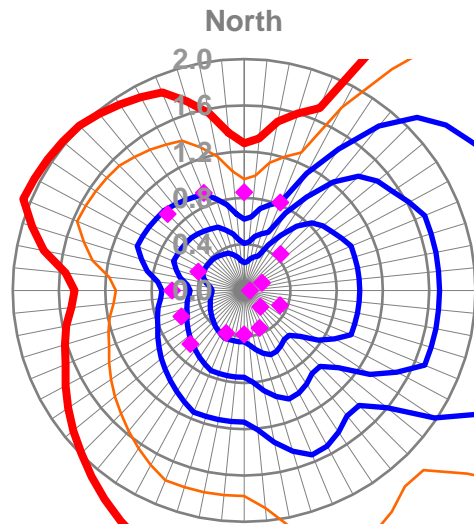
Appendix A12 - Marvel Stadium

This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright

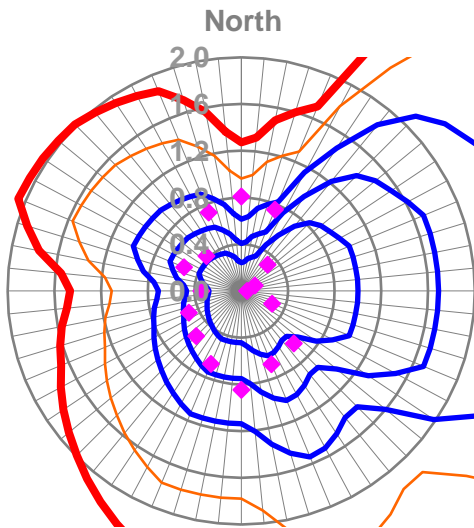
ADVERTISED PLAN



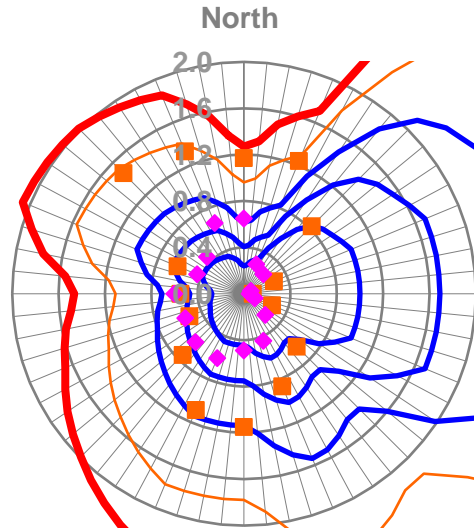
P1a



P2



P3



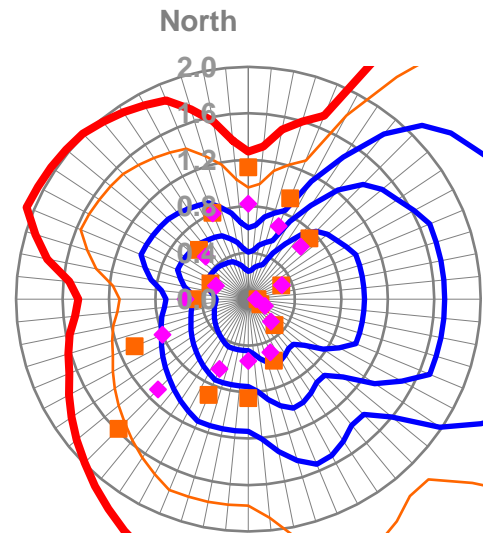
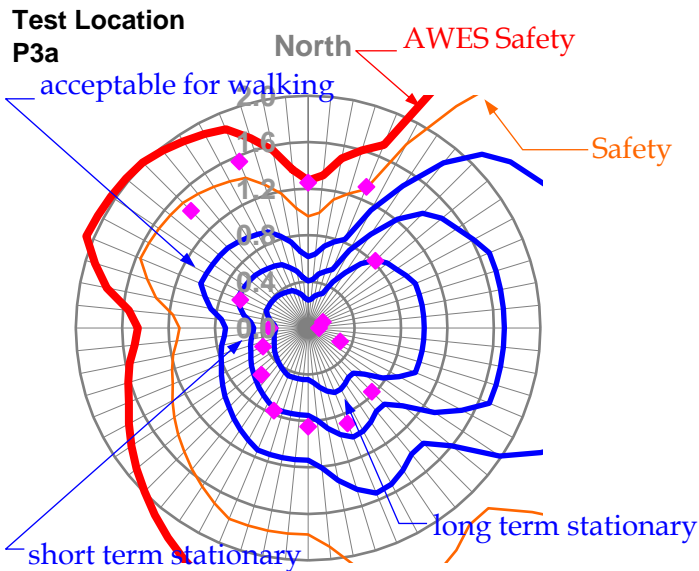
Peak velocity squared ratio $\left| \frac{\hat{V}_{local}}{\bar{V}_{300m}} \right|^2$ as a function of wind direction

Proposed Configuration + Mitigations A (Pavillion Removed + Serrated NW Corner) ■
 Proposed Configuration + Mitigations A + Mitigations B (Screens - height = 1.8m, 30% porosity) ◆

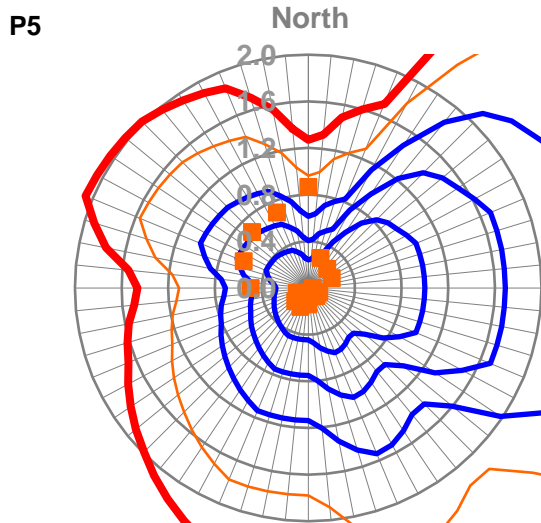
Appendix A13 - Level 7 Podium

This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright

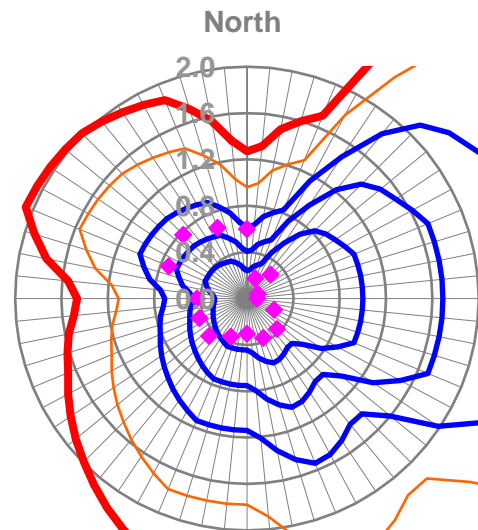
ADVERTISED PLAN



P4

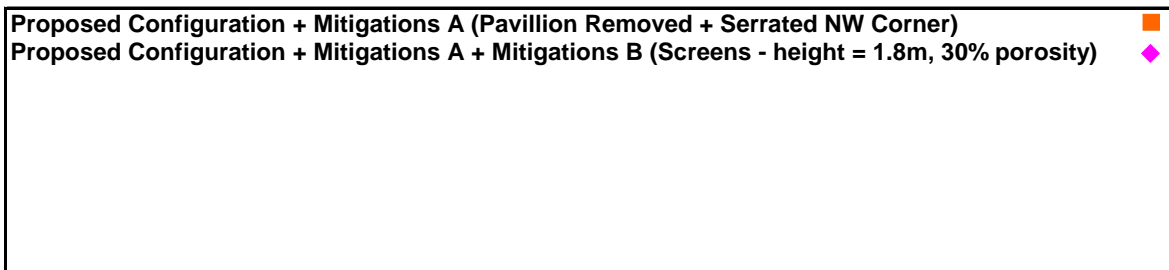


P5



P6

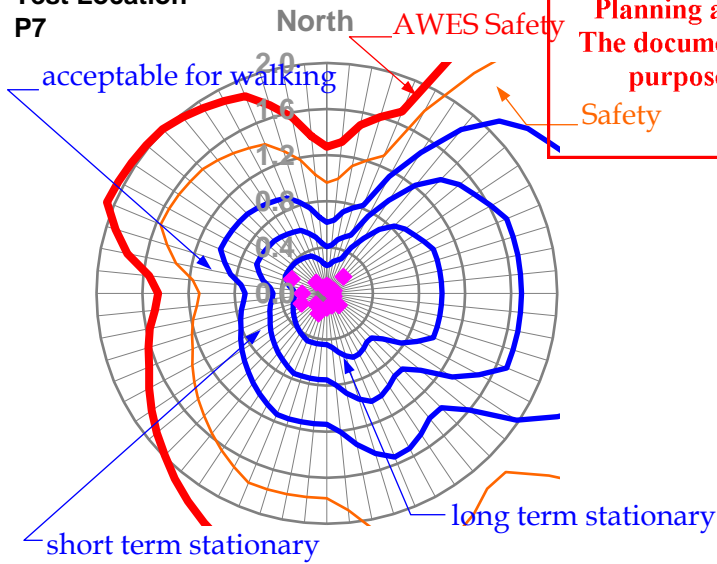
Peak velocity squared ratio $\left| \frac{\hat{V}_{local}}{\bar{V}_{300m}} \right|^2$ as a function of wind direction



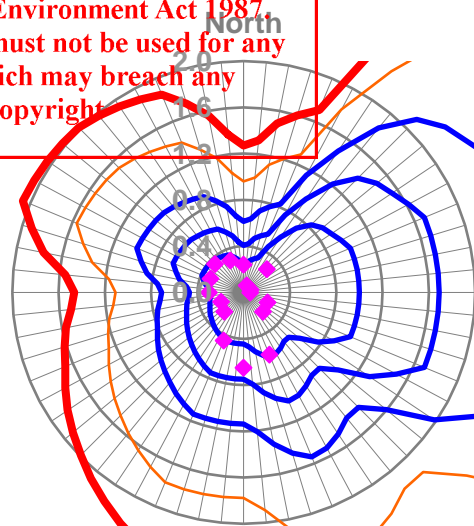
Appendix A14 - Level 7 Podium (Continued)

This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright

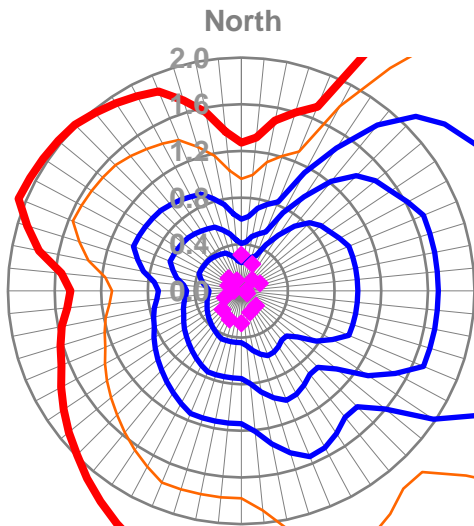
Test Location
P7



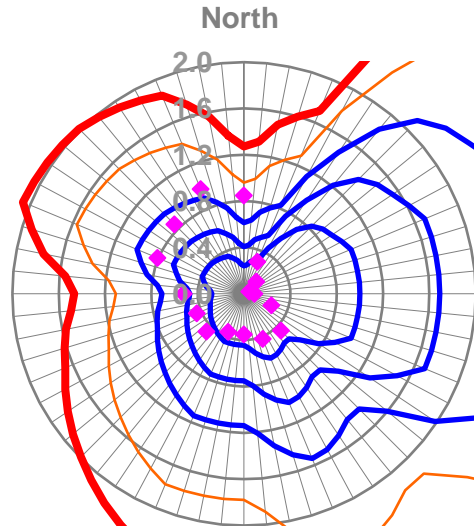
P8



P9



P10

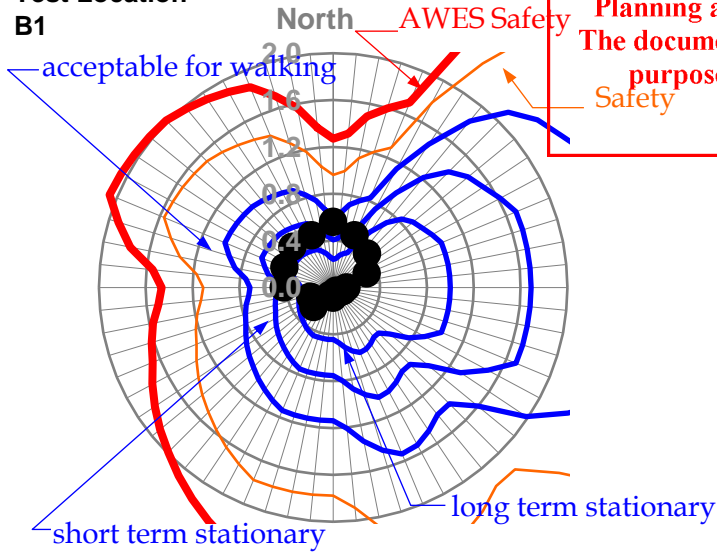


Peak velocity squared ratio $\left| \frac{\hat{V}_{local}}{\bar{V}_{300m}} \right|^2$ as a function of wind direction

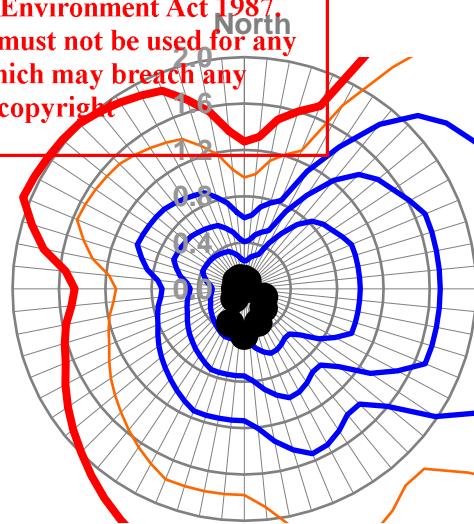
Proposed Configuration + Mitigations A + B

Appendix A15 - Level 7 Podium (Continued)

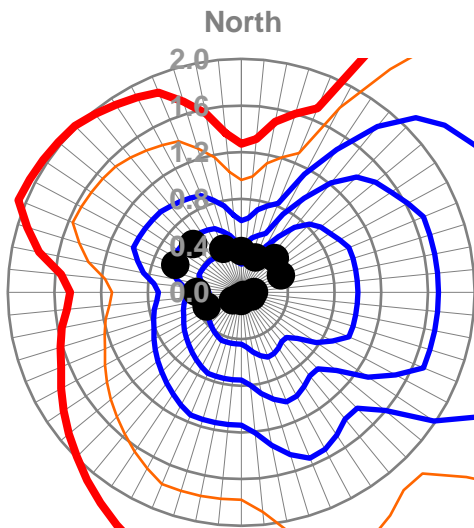
Test Location
B1



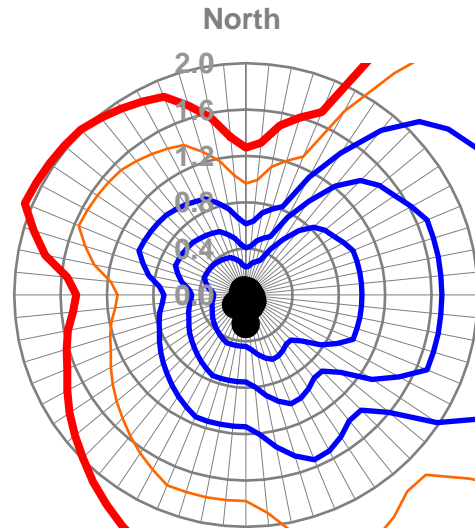
B2



B3



B4



Peak velocity squared ratio $\left| \frac{\hat{V}_{local}}{\hat{V}_{300m}} \right|^2$ as a function of wind direction

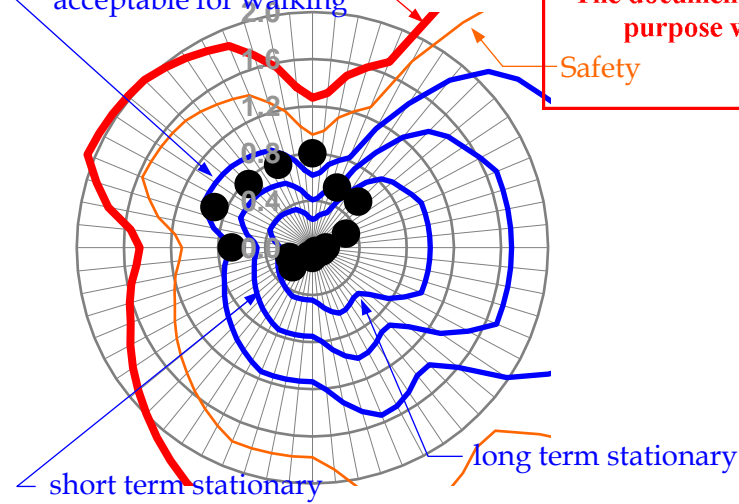
Proposed Configuration

Appendix A16 - Level 19 Balconies

Test Location
B5

acceptable for walking

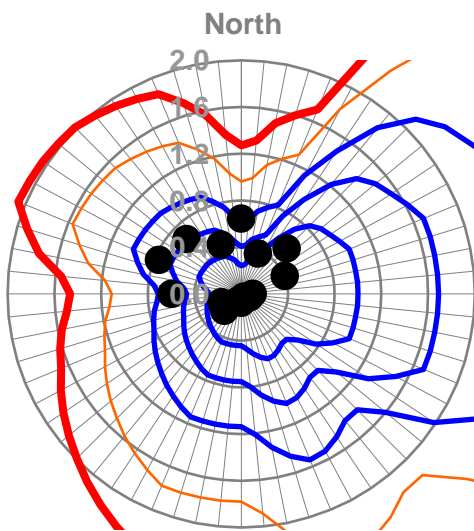
AWES Safety
Safety



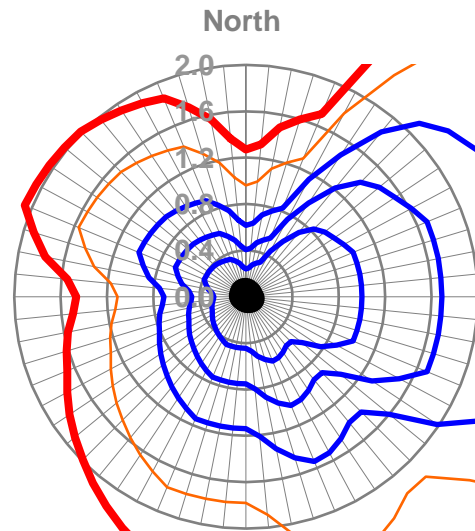
B6



B7



B8



Peak velocity squared ratio $\left| \frac{\hat{V}_{local}}{\bar{V}_{300m}} \right|^2$ as a function of wind direction

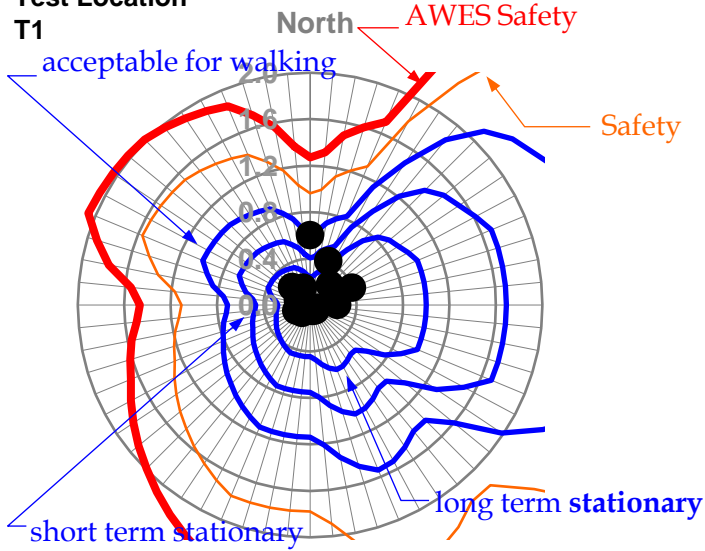
Proposed Configuration

Appendix A17 - Level 29 Balconies

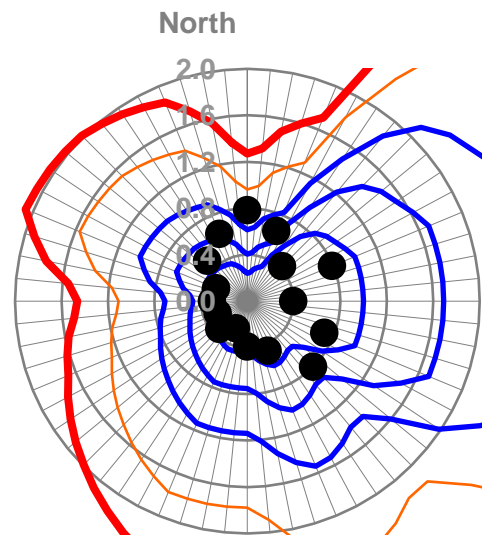
ADVERTISED PLAN

Test Location

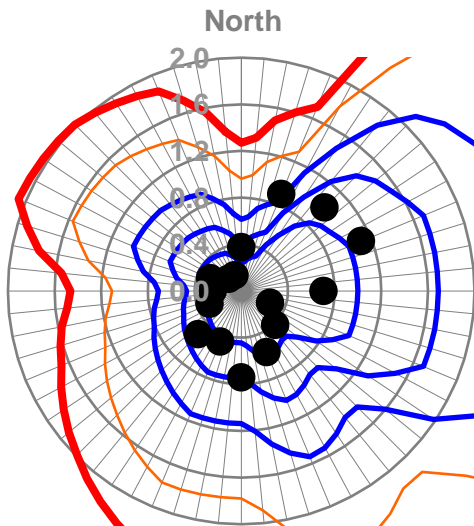
T1



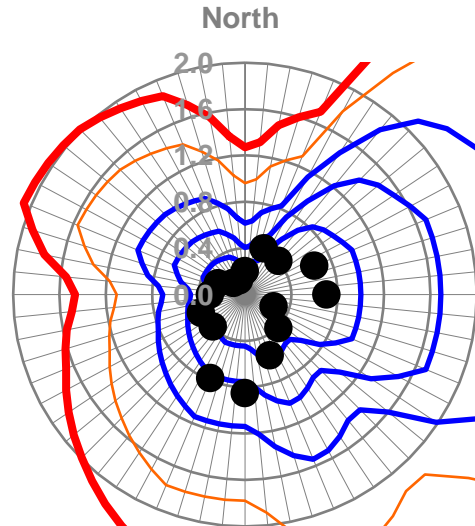
T2



T3



T4



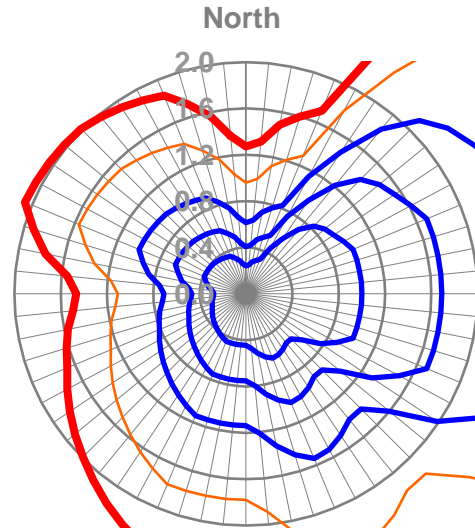
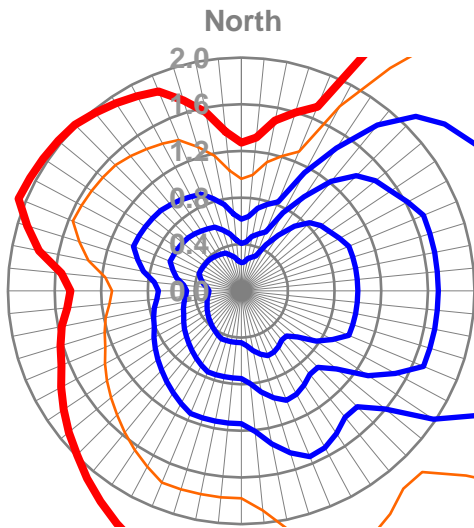
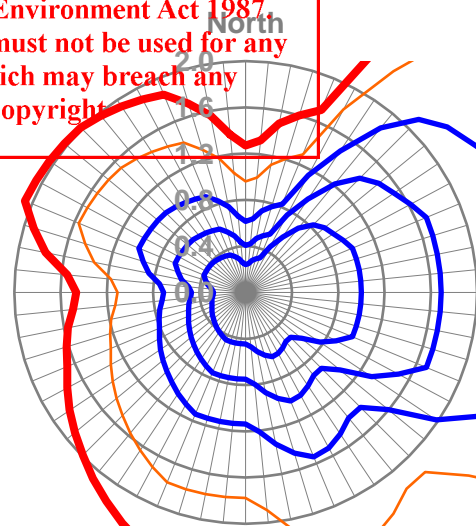
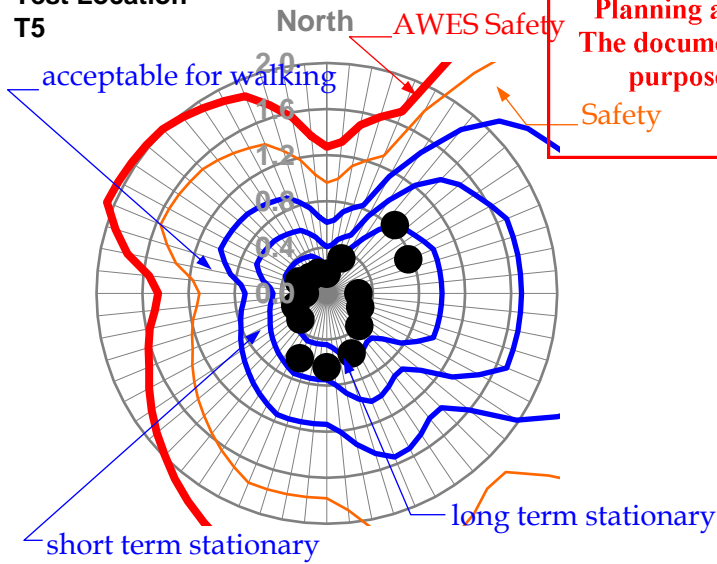
Peak velocity squared ratio $\left| \frac{\hat{V}_{local}}{\bar{V}_{300m}} \right|^2$ as a function of wind direction

Proposed Configuration

Appendix A18 - Level 40 Rooftop Terrace

This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright

Test Location
T5



Peak velocity squared ratio $\left| \frac{\hat{V}_{local}}{\bar{V}_{300m}} \right|^2$ as a function of wind direction

Proposed Configuration

Appendix A19 - Level 40 Rooftop Terrace (Continued)

This copied document to be made available
for the sole purpose of enabling
its consideration and review as
part of a planning process under the
Planning and Environment Act 1987.
The document must not be used for any
purpose which may breach any
copyright

Paper 12

CRITERIA FOR ENVIRONMENTAL WIND CONDITIONS

W.H. MELBOURNE

*Department of Mechanical Engineering, Monash University, Clayton, Victoria 3168
(Australia)*

(Received October 18, 1977)

**ADVERTISED
PLAN**

Summary

Since 1971 a number of authors have published criteria for the acceptability of environmental wind conditions for human comfort for a range of activities.

This paper notes that it is the forces caused by peak gust wind speeds and associated gradients which people feel most and discusses the relation between peak gust and mean wind speeds. Melbourne's criteria, which have been stated in terms of maximum gust speeds per annum, are shown to define a range of wind-speed probabilities, in particular, the frequency of occurrence of mean wind speeds, which then facilitates comparison between the various published criteria.

It is shown that, in spite of the apparent numerical differences in published wind speed criteria and the various subjective assumptions used in their development, there is remarkably good agreement when they are compared on a proper probabilistic basis.

1. Introduction

In recent literature and at the 4th International Conference on Wind Effects on Buildings and Structures, London, 1975, there has been some debate as to the quantitative values of wind speed to be used in criteria for environmental conditions around new building developments. It was noted by several of the authors at the above-mentioned conference, that in spite of the seeming numerical differences in wind-speed criteria quoted by a number of authors, the differences were, in fact, relatively small [1]. The problem is that the phenomenon of wind and frequency of occurrence is very complex and the numerical values developed for these criteria depend on the statistical framework in which they are set.

It is the purpose of this paper to discuss the physical nature and effect of wind on people in respect of the relationship between mean wind speeds and peak gusts produced in turbulent conditions and the statistical inference of the various ways of expressing the frequency of occurrence of given wind speeds, and hence to permit a comparison of the various published environmental wind criteria.

2. The reason for needing environmental wind-speed criteria
The document must not be used for any
purpose which may breach any
copyright

Whilst involved in the technical argument about criteria, it is important to remember the reason for trying to establish environmental wind-speed criteria.

Briefly, the need has arisen because unacceptable wind speeds can be induced around building developments and one way of avoiding these problems is to conduct wind-tunnel tests from which wind speeds around a proposed development can be estimated. Having obtained the facility for predicting likely wind conditions in a given area, it becomes necessary to develop some criteria as to the frequency of occurrence of wind speeds which are acceptable and unacceptable for a variety of activities.

3. How people feel the effects of wind

There seems little doubt that wind speed and rate of change of wind speed are the primary parameters in any assessment of how wind affects people, Melbourne [2], Hunt et al. [3]. There are, of course, other factors such as temperature, humidity, degree of shade and mode of dress, which are also significant; however, these are factors which can be superimposed on or used to modify the effects of wind speed and as such will not be dealt with here.

Wind gustiness, or fluctuation of wind speed with time, is a random process and whilst the mean wind speed is a meaningful and simple parameter to obtain, the rate of change of wind speed is not. Fortunately, the effect of rate of change of wind speed can be covered generally by the parameter of turbulence intensity of wind speed, that is the standard deviation over the mean of wind speed. Further, in terms of what people feel, it is often convenient to talk in terms of a gust wind speed, that is a wind speed averaged over the smallest periods of time to which a person can respond, of the order of seconds. The mean 2- or 3-second-gust wind speed has become a useful reference in this respect, because it is roughly equivalent to the peak gust speed recorded by the Dines anemometer and the larger cup anemometers.

The wind force felt by a person is related to dynamic pressure. Hence, whilst it may be convenient in one sense to relate criteria directly to wind speed, it must be appreciated that the force felt by a person is proportional to wind speed squared. For this reason a more rational feel for the problem is gained if comparative data are presented in terms of velocity pressures rather than velocities. However, the referring of criteria to wind speed has gained popular acceptance and values of wind speed are more easily remembered than numbers based on the square of wind speed, hence, criteria will be discussed in terms of wind speed.

In concluding this section, it is worth re-casting the opening sentence by now saying that it is the peak gust wind speeds and associated gradients which people feel most.

4. Relationships between peak gust and the mean wind speeds

The peak gust wind speed \hat{u} is dependent on turbulence intensity and can be given in terms of the mean \bar{u} and standard deviation σ_u as

$$\hat{u} = \bar{u} + 3.5 \sigma_u \quad (1)$$

For example, for a turbulence intensity (σ_u/\bar{u}) of 15%, $\hat{u} = 1.5 \bar{u}$, and for 30%, $\hat{u} = 2.0 \bar{u}$, etc.

As noted, it is the peak gust wind speeds and associated gradients which people feel most and as such it is of interest to know under what conditions they occur. The observations of Melbourne and Joubert [4] indicated that the areas in full scale which have been classed as having unpleasant or unacceptably high wind speeds were all associated with high mean wind speeds. Later, model- and full-scale measurements by Isyumov and Davenport [5] and Melbourne [6] continued to show that the windiest areas were associated with high mean wind speeds, but that the turbulence intensity was important in determining the peak gust wind speeds. In the case of the former, the ratio of peak gust wind speed over mean wind speed \hat{u}/\bar{u} for the three windiest conditions respectively were 1.5, 2.7 and 2.8 and for the latter 1.9, 1.9 and 2.4. For areas and wind directions with lower wind conditions, and obviously for much greater turbulence intensities, this ratio was typically as high as 5.0. This means that to get an accurate prediction of peak gust wind speeds from wind-tunnel model tests, it is essential that mean and rms or peak values for a given probability level be actually measured.

Although it is possible to have unpleasant areas with low mean wind speeds and high turbulence intensities, the evidence to date does seem to indicate that for areas likely to have unacceptably high wind conditions, such as near corners, in narrow alleys and in arcades, the turbulence intensity is relatively low and that in these areas it would be reasonable to assume that the peak gust wind speeds will be about twice the mean wind speed. This means that wind-tunnel investigations, in terms of exploring and improving likely areas of high wind conditions, can often be reasonably based on very simple and inexpensive model measurements of mean wind speed. However, this does not mean that the need to model the turbulence characteristics of the incident wind stream can be overlooked, as a low turbulence stream would produce quite different flow fields and erroneous information.

5. Melbourne's criteria for environmental wind speeds

Notwithstanding the usefulness of the above very simple tests, to maintain flexibility in the application of environmental wind-speed criteria to all levels of turbulence, the author believes it is necessary to frame the definition in terms of gust wind speeds related to some meaningful return period or frequency of occurrence. Criteria which are defined only by mean wind speeds need to be qualified with respect to turbulence to have any general application.

Melbourne's criteria [2, 7] were based on two levels of wind speed, an unacceptable level at which wind gusts would be strong enough to knock people over and a level generally acceptable in main public access-ways based on conditions which had existed in the main Australian cities during the first half of the 20th century, when building was dense but heights restricted to about 30 m. Temperatures are typically between 10° C and 30° C with people appropriately dressed for the outside temperature conditions. These criteria simply state that in main public access-ways wind conditions are

- (a) completely unacceptable if the annual maximum gust exceeds 23 m/s (the gust speed at which people begin to get blown over),
- (b) generally acceptable if the annual maximum gust does not exceed 16 m/s (which results in half the wind pressure of a 23 m/s gust). Along the lines of Davenport's [8, 9] suggestions for comfort for activities less than walking in a main public access-way, two additional comfort criteria have been added to the original criteria as follows:
- (c) generally acceptable for stationary short-exposure activities (window shopping, standing or sitting in plazas), if the annual maximum gust does not exceed 13 m/s,
- (d) generally acceptable for stationary, long-exposure activities (outdoor restaurants, theatres), if the annual maximum gust does not exceed 10 m/s.

From these basic criteria a probability distribution, or frequency of occurrence, can be developed to suit any turbulence conditions. An example of such a distribution is given in Fig.1, for a turbulence intensity of 30%, where the distributions of the maximum gust speeds per annum, of 23 m/s, 16 m/s, 13 m/s and 10 m/s are shown as normal distributions back to the maximum hourly mean wind speed per annum (i.e. $\hat{u} = 2.0 \bar{u}$ for $\sigma_u = 0.3 \bar{u}$, which as discussed in Section 4 is a very typical situation). The upper part of Fig.1 shows the distribution of hourly mean wind speeds for these conditions using a Rayleigh distribution, and the expected maximum wind speeds for periods of a day, week, month and year have been calculated using a method by Davenport [10].

Davenport showed that the number of storms, on occasions during which a wind speed \bar{u} is exceeded, can be expressed as

$$N_u = \sqrt{2\pi} \nu T \left[\Gamma \left(1 + \frac{2}{k} \right) - \Gamma^2 \left(1 + \frac{1}{k} \right)^{\frac{1}{2}} k \{ -\ln P_{(>\bar{u})} \} \right]^{(k-1)/k} P_{(>\bar{u})} \quad (2)$$

where $P_{(>\bar{u})}$ is the probability of exceeding the mean wind speed \bar{u} (based on the Weibull distribution), k is one of the Weibull parameters, Γ is the Gamma function and νT is the number of independent events per annum. The value of k varies about 1.5 to 2 and νT varies between 500 and 1000, depending on the local wind climate. From an evaluation of Davenport's eq. (2) [5] the ranges given in Table 1 can be obtained which express the relation between probability of exceeding a certain hourly mean wind speed and the number of storms per annum during which that mean wind speed is exceeded. Apart from

This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright

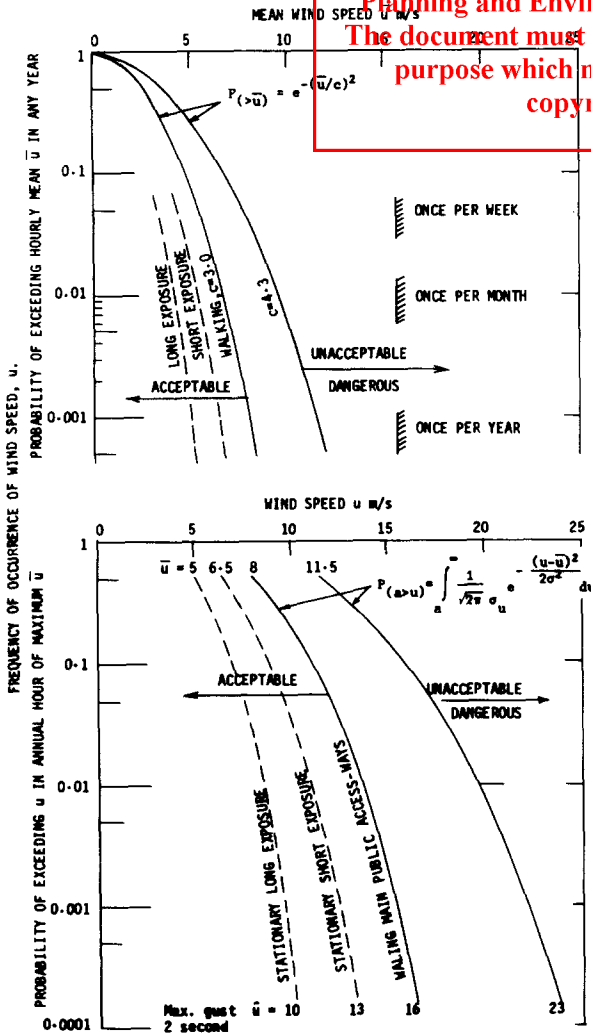


Fig.1. Probability distributions of Melbourne's criteria for environmental wind conditions for daylight hours, for a turbulence intensity of 30%. $\sigma_u = 0.30\bar{u}$, $\hat{u} = 2.0\bar{u}$.

providing a very important link to give information about the maximum wind speeds likely to occur on average for various periods, such as once per year, once per month, etc., this also provides the necessary link to enable the various environmental wind speed criteria to be compared.

One other complication arises in respect of the number of storms per annum which are relevant to the assessment of environmental wind conditions for human comfort. It is obviously conservative to include winds which blow for all hours of the year, day and night, when most areas under consideration will only be occupied for half of the time or less. Although it does not make

This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any

ADVERTISED PLAN

TABLE 1

Relationship between probability of exceeding a mean wind speed and the average number of storms per annum during which that mean wind speed is exceeded

Number of storms per annum during which \bar{u} is exceeded ($N_{\bar{u}}$)	Probability of exceeding an hourly mean wind speed \bar{u} ($P(>\bar{u})$)	
	All hours	Daylight hours
1, once per annum on average	0.00025–0.0005	0.0005–0.001
12, once per month on average	0.003–0.006	0.006–0.012
52, once per week on average	0.015–0.03	0.03–0.06

a great deal of difference, the author prefers to relate criteria and assessment to approximately half the total time, by relating the probability of exceedence to half the yearly cycling rate (i.e. 250–500 independent events per annum) and calling this procedure an assessment of environmental wind conditions relating to “daylight hours”; these ranges are also given in Table 1. Strictly speaking, the cycling rate and evaluation of the wind speed probability distributions should be related to the relevant occupancy times (i.e. daylight hours, afternoon hours, etc.), and in many parts of the world seasonal distributions are also significant. However, for the purposes of this comparison of criteria the simplistic assumptions above described as relating to “daylight hours” will be used in this paper.

6. Comparison of various criteria

Since 1971 several forms of criteria for environmental wind conditions have been published. The criteria developed by Wise [11], Penwarden [12, 13] Davenport [8,9], Lawson [14] and one by Hunt, Poulton and Mumford [3] are given in terms of mean wind speed at some stated or implied level of turbulence intensity between 15% and 20%. Comparison of these criteria can be made in Fig.2 with Melbourne’s criteria which have been plotted for a turbulence intensity of 15%, i.e. for $\sigma_u/\bar{u} = 0.15$ and from eqn. (1) $\bar{u} = \hat{u}/1.5$.

Wise [11], in 1971, commented in relation to the Beaufort scale “that wind speeds much above about 5 m/s are likely to give unpleasant disturbance to clothing and hair” and “making reasonable assumptions about metabolic rate, and the thermal resistance of body layers and clothing, speeds of some 5 m/s appeared tolerable at 10° C in normal winter clothing”. Penwarden [12] in 1973 and again in collaboration with Wise [13] in 1975 prepared a summary of wind effects on people based on a modified version of the Beaufort Scale from which the following three points can be extracted

discomfort begins $\bar{u} = 5 \text{ m/s}$
unpleasant $\bar{u} = 8-10 \text{ m/s}$
dangerous $\bar{u} = 15-20 \text{ m/s}$

The document must not be used for any
purpose which may breach any
copyright

ADVERTISED
PLAN

Penwarden and Wise [13] quoted a criterion which they had used at the Building Research Station, that conditions were regarded as acceptable, or no remedial action was required, if $\bar{u} < 5 \text{ m/s}$ for 80% or more of the time and vice versa, that remedial action would be taken if $\bar{u} > 5 \text{ m/s}$ for more than 20% of the time. In probability terms this criterion is interpreted as being acceptable if $P(\bar{u} > 5) \leq 0.2$.

Davenport [8, 9] in 1972 amalgamated work by Wise, Melbourne and Joubert and suggested criteria for a range of activities; these were related to a Beaufort scale for open-country mean wind speeds at 10 m. These criteria also noted that the relative comfort level might be expected to be reduced by one Beaufort number for every 20°C reduction in temperature. In particular Davenport nominated the following hourly mean wind speeds (converted to 2 m) conditions as being tolerable if not exceeded more than once per week, which in probability terms are interpreted as being acceptable for

walking fast	if $P(\bar{u} > 10) \leq 0.05$
strolling, skating	if $P(\bar{u} > 7\frac{1}{2}) \leq 0.05$
standing, sitting, short exposure	if $P(\bar{u} > 5\frac{1}{2}) \leq 0.05$
standing, sitting, long exposure	if $P(\bar{u} > 3\frac{1}{2}) \leq 0.05$

Lawson [14] in 1973 used the same Beaufort scale as Penwarden and developed a figure to take into account the effects of turbulence. A value of $\hat{u} = 1.7 \bar{u}$ was used, which from eq. (1) implies a turbulence intensity of about 20%. Lawson quotes Beaufort 4 wind speeds (6–8 m/s) as being tolerable if not exceeded for more than 4% of the time; and Beaufort 6 wind speeds (11–14 m/s) as being unacceptable if exceeded for more than 2% of the time. In probability terms these criteria are interpreted as being

acceptable	if $P(\bar{u} > 6-8) \leq 0.04$
unacceptable	if $P(\bar{u} > 11-14) \geq 0.02$

Hunt, Poulten and Mumford [3] in 1976 described a range of wind-tunnel tests which were conducted to show how wind affects people's abilities to perform simple tasks, including a simulation of turbulence. Two criteria were developed, firstly that if wind conditions are to be tolerable and for most kinds of performance to be unaffected

$$\bar{u} < 9/(1 + 3 \text{ turbulence intensity})$$

for turbulence intensity of 15% this becomes $\bar{u} < 6.2 \text{ m/s}$, and secondly, for safe and sure walking that there must be a low probability (say 1%) of a gust lasting over a few paces (say 5–10 m) exceeding 13 m/s. For a turbulence intensity of 15% the 13 m/s gust becomes a mean wind speed of $13/1.5 = 8.7 \text{ m/s}$. (Hunt used a conversion from Durst to give 9 m/s.) In probability terms

This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright

ADVERTISED PLAN

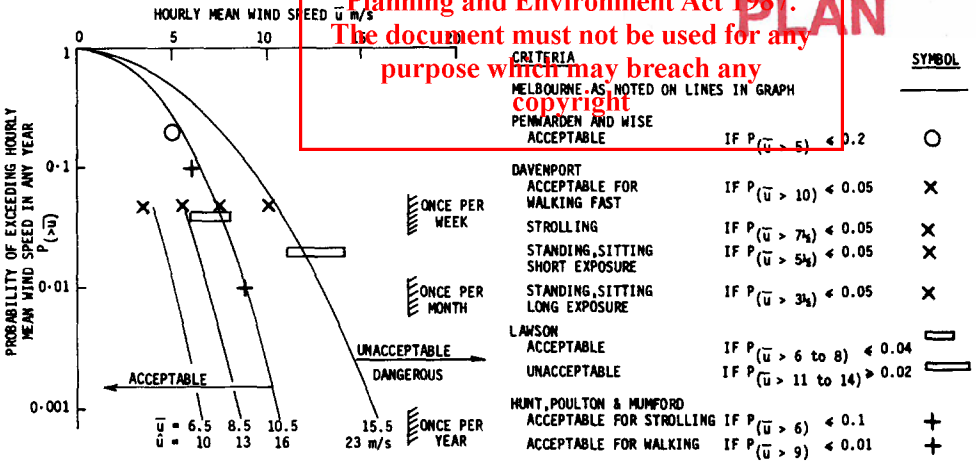


Fig. 2. Comparison of various criteria for environmental wind conditions for daylight hours for a turbulence intensity of 15%. $\sigma_u = 0.15\bar{u}$, $\hat{u} = 1.5\bar{u}$.

for 15% turbulence intensity, this is interpreted as being

- acceptable for strolling if $P(\bar{u} > 6) \leq 0.1$
- acceptable for walking if $P(\bar{u} > 9) \leq 0.01$

These criteria in probability terms have been compared in Fig.2 with Melbourne's criteria plotted for a turbulence intensity of 15%.

7. Conclusions

It remains to conclude that the degree of agreement between the criteria when presented in probabilistic terms is quite remarkable for a phenomenon which relies almost completely on subjective assessment. This is particularly so for the earlier attempts by Wise, Melbourne and Penwarden where the criteria were developed entirely independently and in quite different ways. The agreement of the later published criteria, whilst supportive, is not quite so remarkable as there has been a certain amount of influence from the earlier attempts. It seems reasonable to conclude that assessments based on any of these criteria could be said to be made with some consensus of international opinion. However, assessment of the viability of any area in terms of wind environment still relies heavily on the assessment of the use to which the area is to be put and the cost-effectiveness of providing protection from the wind.

References

- 1 Discussion Session 7, Proc. 4th Int. Conf. Wind Effects on Buildings and Structures, Cambridge University Press, London, 1975, pp. 665–666.
- 2 W.H. Melbourne, Ground level winds caused by large buildings, Monash University, Dept. Mech. Eng., MMER 4, 1971.
- 3 J.C.R. Hunt, E.C. Poulton and J.C. Mumford, The effects of wind on people; new criteria based on wind tunnel experiments, Building and Environment, II (1976) 15–28.
- 4 W.H. Melbourne and P.N. Joubert, Problems of wind flow at the base of tall buildings, Proc. 3rd Int. Conf. Wind Effects on Buildings and Structures, Tokyo, 1971, pp. 105–114.
- 5 N. Isyumov and A.G. Davenport, The ground level wind environment in built up areas, Proc. 4th Int. Conf. Wind Effects on Buildings and Structures, Cambridge University Press, London, 1975, pp. 403–422.
- 6 W.H. Melbourne, Wind effect measurements on the BHP Building, Melbourne and full scale wind measurements below tall buildings, Symp. Full Scale Measurements of Wind Effects on Tall Buildings, University of Western Ontario, London, Canada, 1974.
- 7 W.H. Melbourne, Wind tunnel test expectations, Int. Conf. Planning and Design of Tall Buildings, Lehigh University, ASCE, Vol. DS, 1972, pp. 301–304.
- 8 A.G. Davenport, An approach to human comfort criteria for environmental wind conditions, Colloquium on Building Climatology, Stockholm, 1972.
- 9 A.G. Davenport, Approaches to the design of tall buildings against wind, Theme Report at Int. Conf. on Planning and Design of Tall Buildings, Lehigh University, Vol. 1b-7, 1972, pp. 1–22.
- 10 A.G. Davenport, On the statistical prediction of structural performance in the wind environment, Preprint 1420 ASCE National Structural Eng. Meeting, Baltimore, Maryland, 1971.
- 11 A.F.E. Wise, Wind effects due to groups of buildings, Philos. Trans. R. Soc. (London), A269 (1971) 469–485.
- 12 A.D. Penwarden, Acceptable wind speeds in towns, Building Sci., 8 (1973) 259–167.
- 13 A.D. Penwarden and A.F.E. Wise, Wind environment around buildings, Building Research Establishment Report, H.M.S.O., 1975.
- 14 T.V. Lawson, The wind environment of buildings: a logical approach to the establishment of criteria, University of Bristol, Dept. of Aeronautical Engineering, Report No. TVL 7321, 1973.

**ADVERTISED
PLAN**

**This copied document to be made available
for the sole purpose of enabling
its consideration and review as
part of a planning process under the
Planning and Environment Act 1987.
The document must not be used for any
purpose which may breach any
copyright**

This copied document to be made available
for the sole purpose of enabling
its consideration and review as
part of a planning process under the
Planning and Environment Act 1987.
The document must not be used for any
purpose which may breach any
copyright

Paper 9

WIND ENVIRONMENT STUDIES IN AUSTRALIA

W.H. MELBOURNE

*Department of Mechanical Engineering, Monash University, Clayton, Victoria 3168
(Australia)*

(Received November 30, 1977)

ADVERTISED
PLAN

Summary

The assessment of prospective environmental wind conditions about proposed building developments in Australia has been discussed. Assessment techniques, making use of wind tunnel studies, have been illustrated with examples from a study of two possible building configurations for a very exposed site on the north side of the City of Melbourne.

A method of predicting the probability of occurrence of a given wind speed at a particular location has been detailed, and examples have been given of the integration of model measurements of local velocities with the wind speed probability distribution for the geographic area. The comparisons of these probabilistic estimates with environmental wind speed criteria have been discussed and illustrated.

A method of measuring peak gust wind speeds at model scale in situations of high turbulence intensity has been given and a comparison is given with a full scale situation.

1. Introduction

An assessment of prospective environmental wind conditions is now carried out for virtually all major building developments in Australia; for several of the major cities it is a mandatory requirement of the licensing authority. Some of the proposed developments become the subject of wind tunnel studies because of their size and particular exposure to strong wind directions, or when the architect wants an evaluation of several possible schemes, or where the development of a particularly well protected recreational area or shopping precinct is required. Because of a steady build-up of experience in architects' offices of how to design to avoid undesirable environmental wind conditions, there has been a significant reduction in the number of wind tunnel studies required and most are now occasioned by an architect or client wanting to create configurations with better than average environmental wind conditions.

Feedback from developments which have been the subject of wind tunnel tests, and some full scale studies, have permitted the development of the criteria discussed by Melbourne [1]. Much of the techniques used in conducting these wind tunnel tests in Australia by Melbourne at Monash University and Vickery at the University of Sydney have been reported in the text *Architectural Aerodynamics* [2]. This text concentrated more on examples for archi-

tests, in particular how environmental wind problems are caused and how they can be avoided. Hence it would seem to be more appropriate in this paper to discuss the probabilistic techniques used in Australia to assess prospective environmental wind conditions about a proposed development from wind tunnel tests. To illustrate these techniques, examples will be drawn from an investigation carried out at Monash University on the relative merits of two possible configurations for a very exposed site on the north side of the City of Melbourne, one proposal was made up of rectangular building towers and the alternative proposal was based on towers with a circular planform.

2. Wind tunnel techniques

As discussed in both Refs. [1] and [2], it is the wind pressures caused by peak gust wind speeds and associated gradients which people feel most. Although it is possible to have unpleasant areas with low mean wind speeds and high turbulence intensities, the evidence to date does seem to indicate that in areas likely to have unacceptably high wind conditions, such as near corners, in narrow alleys and in arcades, the turbulence intensities are relatively low (20 to 30%) and that in these areas it is reasonable to assume that the peak gust wind speeds will be about twice the mean wind speed. In many cases these problems can be assessed adequately through measurements of local mean wind speeds referenced to a probability distribution of wind speeds for the area. Measurements of mean wind speeds can be simply made with either small pitot static tubes or hot wire anemometers. The exception can occur when assessment is required of an area, such as a recreational plaza for long exposure, which is surrounded by buildings. The turbulence intensity in these situations can be high and the criteria for comfort very strict and in these cases it is necessary to measure peak gust wind speed with a hot wire anemometer.

The measurement of mean velocity pressures with a pitot static tube and the measurement of mean wind speeds with a hot wire both have advantages and disadvantages. The hot wire technique has problems in that the measurement of mean and standard deviation in turbulence intensities above 20% become increasingly suspect and eventually meaningless. However, if only peak gust wind speeds without local directional information are required, then the hot wire technique is relatively satisfactory. The peak gust wind speeds can be obtained from an on line probability analysis of the signal from the hot wire equipment. If the equivalent to a 2 to 3 second gust, as measured by a cup or Dines anemometer in full scale is required, the signal must be appropriately filtered and the velocity with a probability of exceedance of about 2×10^{-4} (i.e. 3.5 standard deviations above the mean for a normally distributed process) taken as the equivalent gust wind speed.

For the majority of wind tunnel investigations the author prefers to use the technique of measuring mean velocity pressures with pitot static tubes as shown diagrammatically in Fig.1. The mean velocity pressure can be simply

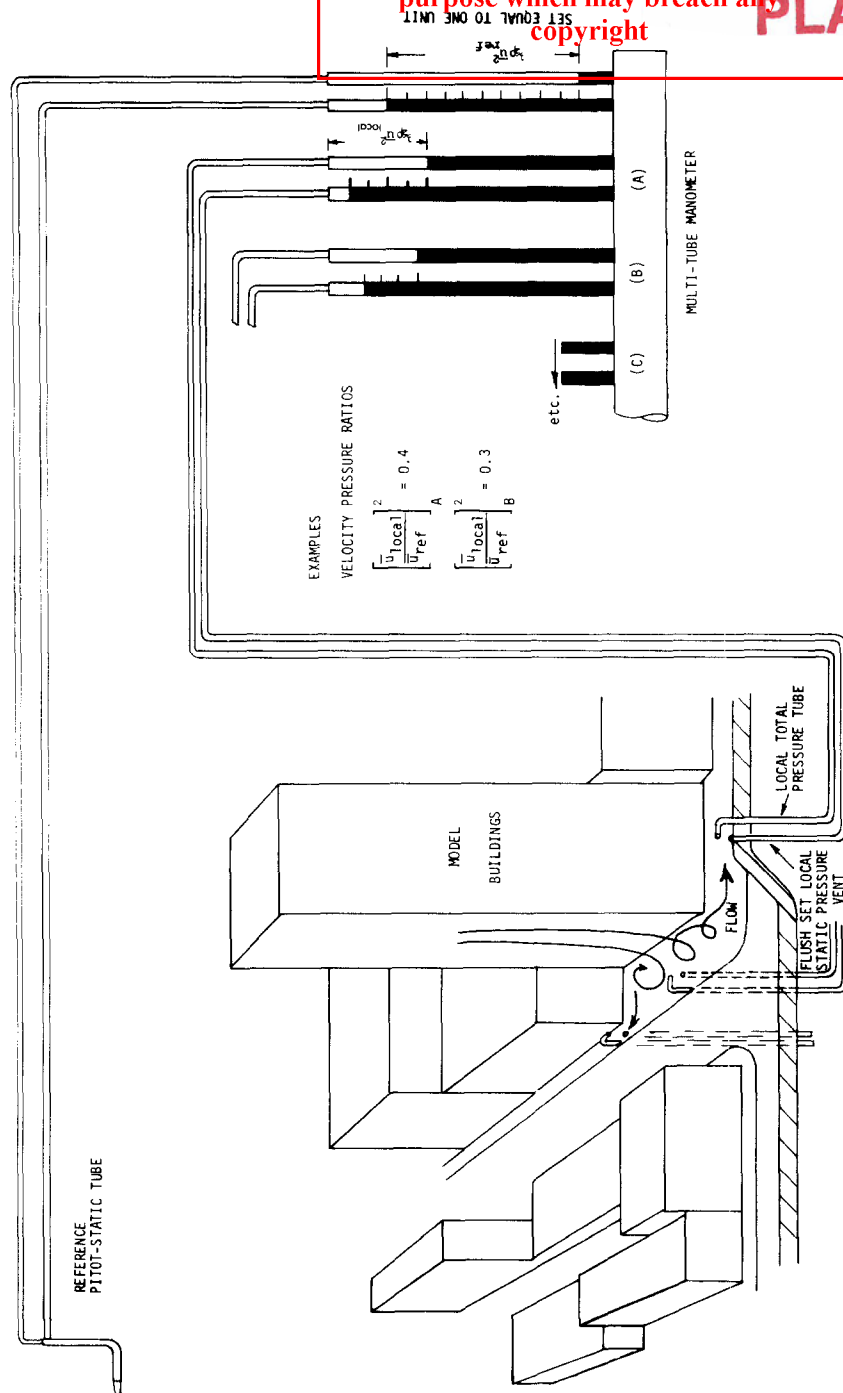


Fig.1. Experimental arrangement for measuring mean velocity pressure ratios.

measured by using a length of small diameter tubing bent in the horizontal plane to measure total pressure in conjunction with a surface static vent. The mean velocity pressures at a number of stations can be measured at the same time by displaying the velocity pressure on a multitube manometer. The disadvantage of this technique is that the total pressure tubes have to be aligned to face directly into wind to get the maximum reading (which does have the benefit of indicating the local wind direction), and peak gust wind speed readings cannot be satisfactorily obtained even if a pressure transducer is used. It is more satisfactory to use a hot wire anemometer to measure peak gust wind speed.

Both techniques require that measured local velocity pressures or wind speeds be referred as a ratio to some reference velocity pressure or wind speed, such as at or near gradient height, which can in turn be related to a full probability distribution of wind speeds for the area. These techniques and probabilistic analysis will be illustrated in the following example.

3. Assessment of prospective environmental wind conditions

The assessment of prospective environmental wind conditions about a proposed development in Australia goes through a series of stages of which the following are typical:

- (i) The client and architect discuss broad principles with a number of specialist consultants, one of whom is the wind engineer or aerodynamicist.
- (ii) Several configurations or themes on one configuration are developed for the assessment of environmental wind conditions.
- (iii) A probability distribution of wind speeds with direction, relative to the site, is compiled.
- (iv) Wind tunnel tests are made on the various configurations and modifications developed at the time the models are in the wind tunnel.
- (v) The wind tunnel data are integrated with the wind speed data to facilitate a final assessment of the environmental wind conditions.

In practice, the integration of the wind tunnel and wind speed data is done continuously throughout the wind tunnel test programme, to facilitate continuous assessment and decisions by the client and architect to dictate the direction of the test programme. The author will only conduct wind tunnel tests of this type when senior client and architect representation at the wind tunnel can be guaranteed. There are some very simple ways in which the wind tunnel data can be assessed with respect to the wind speed data and these will be illustrated in the following example.

3.1 Example of wind tunnel testing and initial assessment procedure

The example chosen is that of a major development proposal to be located on the northern edge of the Central Business District of the City of Melbourne. The architects were particularly aware of the fact that such a development would be exposed to the wind directions from which come the strongest and

most frequent winds. Similarly, they were aware that there was little likelihood of any significant shielding being developed for these directions in the foreseeable future. Accordingly, they developed two proposals for assessment of environmental wind conditions. The first was based on three rectangular tower buildings with extensive canopy arrangements near ground level and the second was based on three circular towers of similar size and arrangement with the ground level area left completely open. Photographs of these two models are shown in Fig.2.

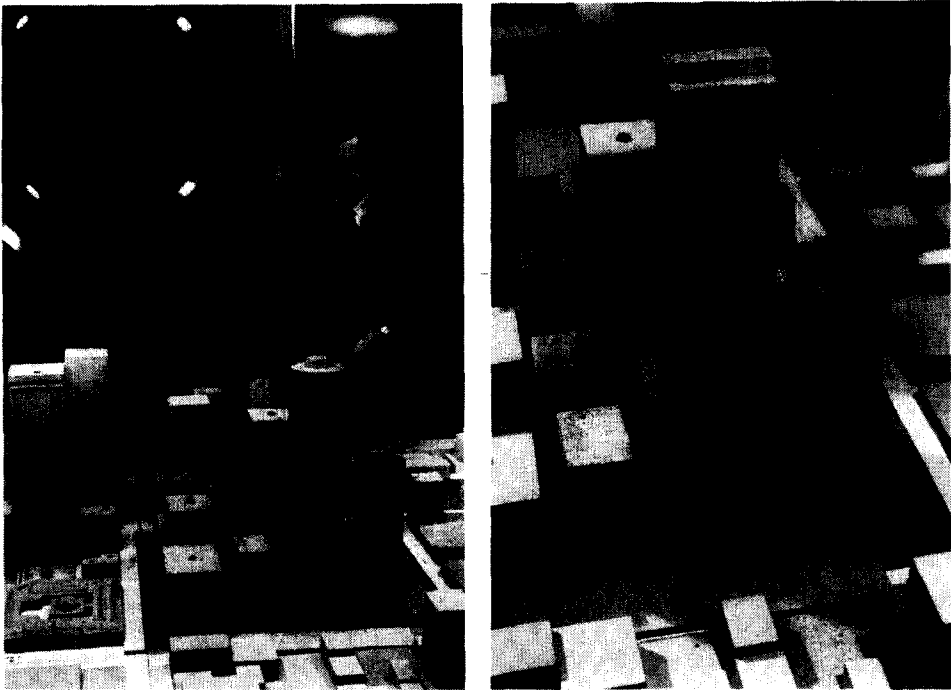


Fig.2. 1/400 scale models of a development proposed for the City of Melbourne.

Before the commencement of the wind tunnel test, it is necessary to prepare a probability distribution of wind speeds. An example of such a distribution is given in the first part of Table 1 in the form of the raw data as were obtained from records of measurements made with a Dines anemometer located at a height of 10 m at Essendon Airport some 10 km north of the City of Melbourne. The cumulative probability distribution for each of the 16 wind directions (θ) can be fitted to a Weibull distribution, which takes the form,

$$P(>\bar{u})_{\theta} = A_{\theta} \exp(-(\bar{u}/c_{\theta})^k) \quad (1)$$

which then can be presented in a polar plot with lines of constant probability

This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright.

TABLE 1

Probability distribution of hourly mean wind speeds measured at 10 m height in open country terrain at Essendon Airport, Melbourne, Australia, 1955-71 for daylight hours 0730 to 1930, and environmental wind criteria per 22½° sector

\bar{u} at 10 m over open country terrain	Band of wind speeds, \bar{u} (m/s)					
	0.5 to 2.1	2.1 to 3.6	3.6 to 5.65	5.65 to 8.75	8.75 to 11.3	11.3 to 14.4
\bar{u} at 300 m over suburban terrain*	0.8 to 3.2	3.2 to 5.5	5.5 to 8.6	8.6 to 13.4	13.4 to 17.3	17.3 to 22.0
Wind direction	Probability of being in band $\times 10^4$					
N	11973	15323	37400	64368	31085	15543
NNE	3900	4340	8238	12468	4943	2800
NE	6535	3185	2855	1538	440	110
ENE	5218	1813	660	165	55	
E	7800	2800	1098	330		
ESE	4340	2690	2088	1318	330	
SE	9008	7745	9720	7635	1593	440
SSE	8733	11698	16423	12138	933	165
S	18948	32898	64753	68543	9063	933
SSW	9338	10490	18180	17630	3680	1043
SW	11080	12633	20485	18508	6205	2418
WSW	5823	6700	11588	14280	5548	2965
W	9555	11040	7963	21968	7690	2528
WNW	4558	5273	7963	7360	1703	715
NW	6480	7853	10215	12578	7223	1868
NNW	5878	8073	12633	17025	7280	2418
Calm	88788					
Total	1000000					

$$\bar{u}_{300, \text{suburban}} = \bar{u}_{10, \text{open country}} \left[\frac{400}{10} \right]^{0.15} \left[\frac{300}{500} \right]^{0.25} = 1.53 \bar{u}_{10, \text{open country}}$$

**For a lower turbulence intensity of $\sigma_u = 0.15\bar{u}$, $\hat{u} = 1.5\bar{u}$, the numerical criteria become Unacceptable/dangerous, annual maximum $\bar{u} > 15.5$; Acceptable/walking, annual maximum $\bar{u} < 10.5$.

ADVERTISED PLAN

		Average annual hourly maximum wind speed at 300 m for each sector from line with $P(>\bar{u}) = 0.001$ in Fig.3	Environmental wind criteria based on Melbourne's criteria for $\sigma_u = 0.3\bar{u}$, $\hat{u} = 2.0\bar{u}^{**}$			
14.4 to 17.5	17.5 to 21.1		Unacceptable/ dangerous annual maximum $\bar{u} > 11.5$ m/s		Acceptable for walking annual maximum $\bar{u} < 8.0$ m/s	
			For $\bar{u}_{\text{local}} = 11.5$ $\frac{\bar{u}_{\text{local}}}{\bar{u}_{300}} \quad \left[\frac{\bar{u}_{\text{local}}}{\bar{u}_{300}} \right]^2$	For $\bar{u}_{\text{local}} = 8.0$ $\frac{\bar{u}_{\text{local}}}{\bar{u}_{300}} \quad \left[\frac{\bar{u}_{\text{local}}}{\bar{u}_{300}} \right]^2$		
22.0 to 26.7	26.7 to 32.3					
2910 330	275	24	0.48	0.23	0.33	0.11
		20	0.58	0.33	0.40	0.16
		12	0.96	0.91	0.67	0.44
		6	1.9	3.7	1.3	1.8
		6	1.9	3.7	1.3	1.8
		10	1.2	1.3	0.8	0.64
		14	0.82	0.67	0.57	0.33
		14	0.82	0.67	0.57	0.33
55		18	0.64	0.41	0.44	0.20
110		17	0.68	0.46	0.47	0.22
165		19	0.61	0.37	0.42	0.18
605	55	20	0.58	0.33	0.40	0.16
440		20	0.58	0.33	0.40	0.16
165		18	0.64	0.41	0.44	0.20
165	55	19	0.61	0.37	0.42	0.18
330		20	0.58	0.33	0.40	0.16

level as shown in Fig. 3. In this particular plot the mean hourly wind speed has been factored to refer to a height of 300 m over suburban terrain by the relationship,

$$\begin{aligned} \bar{u}_{300, \text{suburban}} &= \bar{u}_{10, \text{open country}} \left[\frac{400}{10} \right]^{0.15} \left[\frac{300}{500} \right]^{0.25} \\ &= 1.53 \bar{u}_{10, \text{open country}} \end{aligned} \quad (2)$$

In the wind tunnel model tests, the local velocity pressures, or local wind

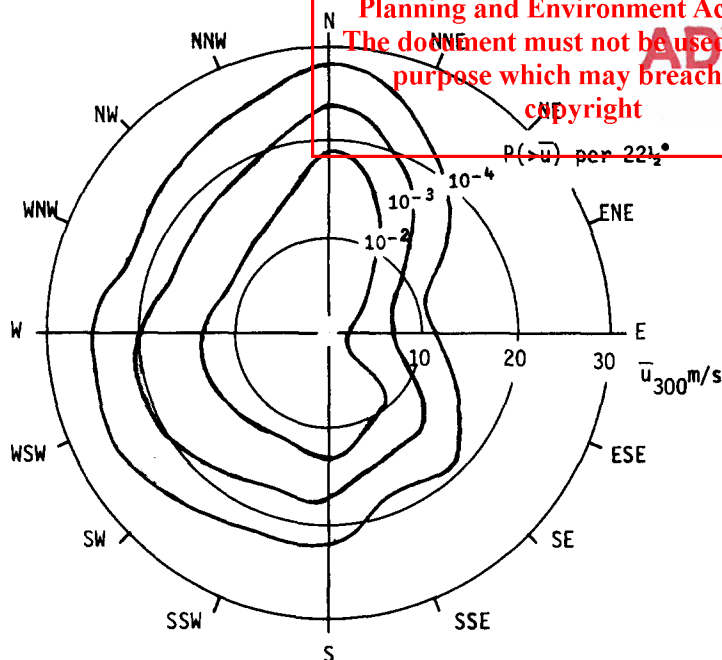


Fig.3. Probability distribution of hourly mean wind speeds at 300 m over suburban roughness at Essendon Airport Melbourne for daylight hours 0730 to 1930.

speeds, will be measured as a ratio with the similar measurement at 300 m over the model suburban approaches. Hence, if the annual maximum hourly wind speeds at 300 m can be obtained for each wind direction sector, then Melbourne's criteria [1] can be expressed for each sector as a ratio against which any measurements can be directly compared at the time of measurement. The annual maximum hourly wind speed for each sector can be obtained using the probabilities given in [1] and in this case, where the distribution is for daylight hours, the average maximum hourly wind speed can be approximated by reading around the contour with a probability $P(>\bar{u}) = 10^{-3}$ in Fig.3 as tabulated in Table 1. With this information the criteria, in ratio form, can be calculated as shown in the last part of Table 1 for the most general case of the peak gust wind speed equal to twice the hourly mean wind speed ($\hat{u} = 2\bar{u}$) for two levels as defined in [1] as being

- (a) unacceptable/dangerous if the annual maximum gust wind speed, $\hat{u} > 23$ m/s;
- (b) acceptable/for walking if the annual maximum gust wind speed, $\hat{u} < 16$ m/s.

The curves of these two criteria can then be plotted as background information on the data sheets on which the wind tunnel measurements are directly recorded as shown in Fig.4. Obviously this information forms the background for any test series and once it has been obtained for an area, it serves for tests

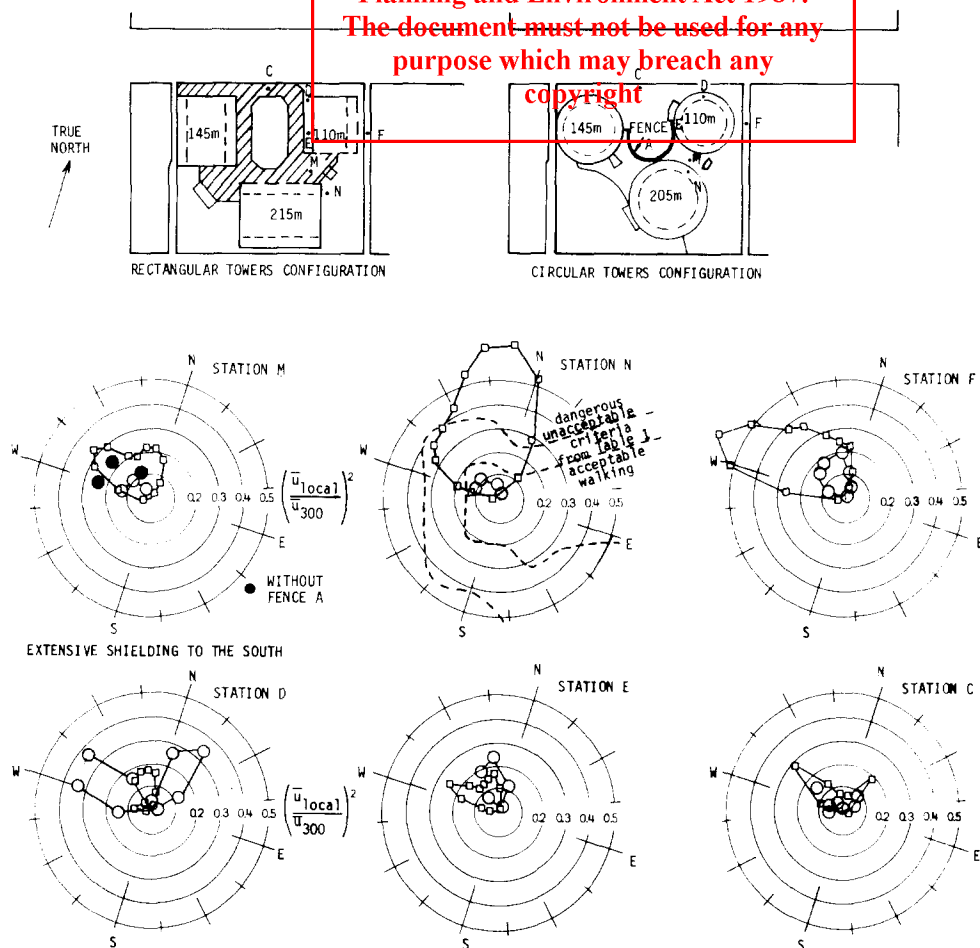


Fig. 4. Mean velocity pressure ratios from wind tunnel model tests.

on all projects in that area. In this particular case, some small modification has to be made to reduce the effect of topographical funnelling which peaks the distribution for northerly wind directions at Essendon Airport, but the effect of which reduces further south over the downtown area of the City of Melbourne and southern suburbs.

Examples of polar plots of velocity pressure ratio as a function of wind direction are given in Fig. 4, for 6 of about 30 stations, at which measurements were made to facilitate the assessment of environmental wind conditions for these two configurations. At Stations M, N and F, the very adverse effects of the rectangular buildings inducing flow down to ground level is shown to result in quite unacceptably high velocity pressure ratios (for this geographic region) in critical points of public access. These adverse effects can be offset to some extent by the use of local wind break fences or overcome completely by pro-

viding air locked connections under the canopy between the main towers at ground level. The circular tower configuration is shown to induce much less wind flow at ground level and to provide conditions within the "acceptable criterion" at Stations M and N. However, in the absence of surrounding buildings over 30 m height to the north and west, there is still a need for the local protection provided by the 50% porous Fence A shown in Fig.1 and 4. Similarly, wind conditions at Stations D, E and C, for the completely open circular tower configuration, are shown to border on unacceptable levels (and certainly are well in excess of acceptable levels). These very local conditions can be ameliorated with the use of porous wind breaks (planter boxes of shrubs and trees) or by the planned layout of architectural features and main access-ways which keep pedestrian traffic away from local regions where high wind speeds are likely to occur.

In concluding this example of how, during wind tunnel testing, a very quick assessment can be made of prospective environmental wind conditions for various configurations, a word of caution must be made in respect of interpreting the measurements.

First of all, the criteria shown in Fig.4 are for each 22½ degree sector; that is if the velocity pressure ratio (or wind speed ratio, whichever approach is being used) reaches, for example, the criterion for unacceptable/dangerous conditions for one sector, it means that once per annum, on average, the peak gust wind speed of 23 m/s will be exceeded. If the criterion is reached for two sectors, it means the probability of exceeding the criterion will double and so on. To make a proper assessment of the probability of exceeding certain wind speeds for all wind directions, a full analysis for all wind directions must be compiled, as shown in Section 3.2.

Secondly, an assessment has to be made by the experimenter as to when the local turbulence intensity reaches a level which invalidates the use of mean velocity pressures or mean wind speeds, whichever technique is being used. If this stage is reached, the simple technique of relying on mean measurements has to be abandoned and the more sophisticated technique of measuring peak gust wind speeds has to be used. A further word of warning here is that it is not sufficient to rely on mean and standard deviation readings from a hot wire anemometer to indicate when a turbulence level of say 25% is reached, because the errors inherent in the hot wire tend to increase the mean and reduce the standard deviation, hence lulling the unwary into thinking that the turbulence intensity is not all that high. A much safer way to determine whether high turbulence, low mean velocity conditions are present, is to observe the signal on a cathode ray oscilloscope and run out a probability distribution to check on the peak values. One consolation, in a sense, of relying on mean wind speeds measured with a hot wire anemometer to higher turbulence intensities is that the mean wind speeds measured are high, and in most cases excessively conservative decisions are more likely to be made on the basis of this incorrect information. An example of the measurement of peak gust wind speeds will be given in Section 3.3.

3.2 Probability distributions of wind speed for all wind directions

In the majority of situations, high wind speeds induced at a particular station are confined to a relatively narrow band of wind directions and an assessment can be made on the basis of criteria for a given sector as described in Section 3.1. For situations where either a more accurate assessment is required (perhaps for a marginal situation), or high wind speeds occur for a broad range of wind directions, it becomes necessary to prepare a full probability distribution of wind speeds which accounts for all, or all the significant, wind directions. Such a distribution can be prepared as follows:

(a) From a distribution such as given in Table 1, a cumulative probability distribution of wind speeds at the reference point (in this case 300 m over suburban terrain) can be prepared which expresses the probability of exceeding a given wind speed for a given wind direction sector, $P(> \bar{u})_{\theta, \text{reference}}$. One convenient method of doing this is to use the Weibull distribution noted previously.

(b) For each station an average value of the wind speed ratio, $\bar{u}_{\text{local}}/\bar{u}_{\text{ref}}$, can be obtained from the model tests for each wind direction sector. Using this wind speed ratio, the cumulative probability distribution can be prepared expressing the probability of exceeding a given wind speed for a given wind direction sector at the local station, $P(> \bar{u})_{\theta, \text{local}}$.

(c) The value of $P(> \bar{u})_{\theta, \text{local}}$ must be obtained for all or all significant wind directions and integrated to give the total probability of exceeding a given mean wind speed for all directions, i.e.

$$P(> \bar{u})_{\text{all directions, local}} = \int_0^{360} P(> \bar{u})_{\theta, \text{local}} d\theta \quad (4)$$

(d) The whole process can be done conveniently with a digital computer, but it is not a particularly long task to do it manually for a few stations, simply because if the relatively coarse $22\frac{1}{2}^\circ$ sectors are used, it is very unusual in practice to have to do the integration of more than three or four sectors. An example of the final stages of this process is given in Table 2 for Station M of the previous example.

(e) Finally, a graph of the probability of exceeding a given wind speed can be superimposed on criteria expressed in the same probabilistic form such as given in [1] and an example of which is given in Fig.5, for several of the stations from the previous example. Whilst such a presentation confirms just how unacceptable conditions would be at Stations M and N for the Rectangular Towers proposal, it is more useful in quantitatively indicating how acceptable the conditions at Station C are likely to be, which can only be very generally assessed from observing the information in Fig.4.

3.3. Measurement of peak gust wind speeds

If, as described in Section 3.1, it is deemed necessary to make an assessment of an area subjected to wind flows with high turbulence intensities, a

This copied document to be made available for the sole purpose of enabling its consideration and review as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright.

TABLE 2

Example of last part of the development of the probability distribution of mean wind speeds at Station M, Rectangular Towers Configuration (Fig.4)

Wind direction	\bar{u}_{local} (m/s)	4	6	8	10	12
	$\frac{\bar{u}}{\bar{u}_{300}}$ frim Fig.4	Probability of being greater than \bar{u} for 22½° sectors of wind direction $P(>\bar{u})_{\theta} \times 10^6$				
N	0.42	80,000	45,000	11,000	1,300	100
NNW	0.47	20,000	12,000	3,000	500	50
NW	0.47	20,000	12,000	3,000	500	50
WNW	0.57	13,000	6,000	2,000	600	150
W	0.40	18,000	7,000	1,000	50	
All other wind directions	< 0.2	Not significant				
Total $P(>\bar{u})^*$		0.15	0.082	0.020	0.0029	0.00035

*These values are plotted in Fig.5.

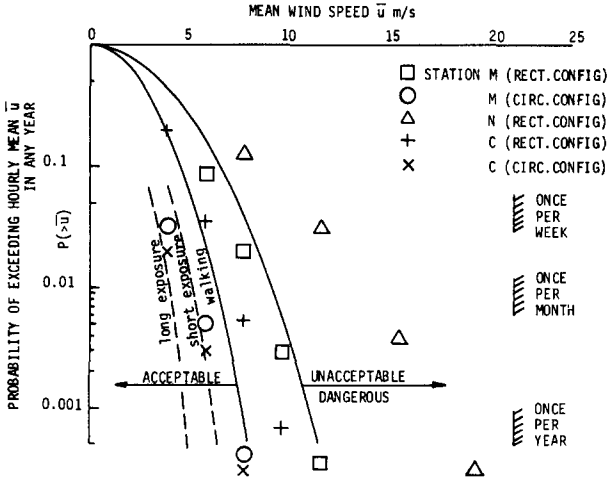


Fig.5. Probability distributions of mean wind speeds at several stations compared with Melbourne's criteria for environmental wind conditions (Daylight hours, $\sigma_u = 0.3 \bar{u}$, $\hat{u} = 2 \bar{u}$).

measurement of the peak gust wind speeds can be made using a hot wire anemometer as follows:

- (a) If it is required to compare model scale peak wind speed measurements with criteria [1] based on peak gusts measured over two to three seconds in

full scale, it is first necessary to low-pass filter the hot wire anemometer linearised output, so that it looks like the scaled down version of the output from a typical cup or Dines anemometer.

(b) The next step in the process is to obtain a probability distribution of the filtered hot wire anemometer signal; this can be conveniently obtained using on-line digital analysis techniques.

(c) It is then necessary to determine the probability level equivalent to 2–3 second peak gust in full scale. Many observers of wind data collected from cup or Dines anemometers in open country situations have observed that the peak gust wind speeds are between 1.5 and 1.8 times the mean, and from a knowledge of the turbulence intensities in these situations, it is possible to deduce that the 2–3 second mean wind gust wind speed is approximately 3.5 standard deviations above the mean, i.e.

$$\hat{u}_{2-3 \text{ sec}} = \bar{u} + 3.5 \sigma_u \quad (4)$$

For a normally distributed process, the probability of exceeding 3.5 standard deviations above the mean is 2.3×10^{-4} . It is suggested that the value of the velocity with a probability of exceedance of 2.3×10^{-4} is an appropriate approximation to use as being equivalent to a 2–3 second mean maximum gust wind speed.

(d) The gust wind speed so obtained can then be expressed as a ratio with the reference mean wind speed and compared with the environmental wind criteria as previously outlined.

The measurement of peak gust wind speeds can be illustrated by the following comparison of a full scale measurement at a city corner, at an intersection near, but not directly adjacent, to tall buildings, and a model measurement for the same situation. The model measurements were made using a hot wire anemometer and the procedure as outlined above.

		Full scale	Model scale
local peak gust wind speed	\hat{u}		
local mean wind speed	\bar{u}	4.1	1.8
local mean wind speed	\bar{u}		
reference mean wind speed	\bar{u}_{300}	0.21	0.50
local peak gust wind speed	\hat{u}		
reference mean wind speed	\bar{u}_{300}	0.8	0.9

It can be seen that the model measurement of the mean wind speed is a very significant overestimate and on its own would be quite misleading. The reason is apparent when one observes that the ratio of local peak to mean wind speed is over four, indicating very high turbulence, and which the hot wire anemometer records at less than two. However, when only the peak gust wind speed is used from a hot wire anemometer in this situation, the comparison between peak and reference mean wind speed ratios compares relatively well.

ADVERTISED PLAN

4. Conclusions

The assessment of prospective environmental wind conditions about a typical proposed building development in Australia has been discussed. Measurement techniques have been described and illustrated with examples. In particular, examples of the probabilistic assessment of local wind speeds and comparison with environmental wind speed criteria have been given in detail. A method of measuring peak gust wind speeds in situations of high turbulence intensity has been given.

Acknowledgements

The author wishes to acknowledge the kind permission of Meldrum and Partners to include examples from studies on one of their projects. The author is indebted also to the Australian Bureau of Meteorology for the full scale wind data made available, not only for this report, but for countless studies of a similar kind in various Australian locations.

References

- 1 W.H. Melbourne, Criteria for environmental wind conditions, J. Ind. Aerodyn., 3 (1978) 241—249
- 2 R.M. Aynsley, W.H. Melbourne and B.J. Vickery, Architectural Aerodynamics, Applied Science Publishers, Barking, 1977.

This copied document to be made available
for the sole purpose of enabling
its consideration and review as
part of a planning process under the
Planning and Environment Act 1987.
The document must not be used for any
purpose which may breach any
copyright