Wind Control Regulations for The Pedestrian Level Wind Environment in Two New Zealand Cities

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ABSTRACT: In this paper the regulations pertaining to the wind environment in two New Zealand cities are presented. Wind tunnel testing methods developed by two laboratories which do essentially all of the wind environment testing in New Zealand are presented. It is shown that the city regulatory authorities become used to certain kinds of reports on the wind environment, and that it is helpful when the regulatory authorities work closely with the wind tunnel testing laboratory.

KEYWORDS: Australia, New Zealand, wind environment control, pedestrian level winds, wind comfort criteria, wind tunnel test, wind erosion test, hot-wire anemometer.

1 INTRODUCTION

New Zealand is located in the so-called "Roaring Forties" latitudes, and as such has relatively high average wind speeds. Wellington City is located on Wellington Harbour at the southern tip of the North Island at Cook Strait which lies between it and the South Island. The prevailing westerly winds are funnelled through Cook Strait, and so Wellington has very high winds. It is not uncommon for the peak gust at pedestrian level to exceed 20 m/s, which is at the dangerous level. Wellington is often referred to as "Windy Wellington". Hence Wellington has fairly strict wind control regulations, and tall buildings are almost always subjected to a wind tunnel test. The presence of high hills around Wellington means that the wind is funnelled, and so the prevailing winds are confined largely to the northerly and southerly directions. This is convenient when it comes to wind tunnel testing, as other directions with less frequent winds do not need to be tested.

Auckland City is the largest city in New Zealand. It also is a relatively windy location, but is not as windy as Wellington. Auckland is known as the "City of Sails". The prevailing winds in Auckland come from the southwest quarter, but winds from the northeast quarter can also be very strong, especially the tail ends of occasional tropical cyclones.

The Central Business District of Auckland City is built on the southern side of the Waitemata Harbour. This means that there is a sea fetch to the north, and so the city is more exposed to winds from the north than from the south.

In the 1960s a tall slab-like building was built at 1 Queen Street close to the harbour frontage, against the advice of some local architects who were concerned that it would cause strong winds at ground level. Indeed the building did produce strong winds in the adjacent Queen Elizabeth II Square. The very unpleasant wind environment in this large public space caused considerable embarrassment to the Auckland City Council (ACC), and so subsequently it began to seek advice concerning wind effects when tall buildings were proposed, and wind tunnel tests to investigate the pedestrian level wind environment became common from the late 1970s. Nowadays all "tall" buildings are wind tunnel tested, and lower buildings are often subjected to a "wind opinion" by a wind expert before the Auckland City Council will issue a Resource Consent for work to proceed.

2 WIND REGULATIONS FOR THE CITY OF AUCKLAND

2.1 *Development of wind control regulations for Auckland*

As mentioned above, following the problem of wind in Queen Elizabeth II Square after construction of the tall building at the bottom of Queen Street, the ACC began to require wind tunnel testing of proposed tall buildings prior to giving approval for construction. Generally if a building was taller than 55 m in height above ground, a wind tunnel test would be called for. During the 1980s there was a rapid increase in construction activity in Auckland, and the council decided that it was time to put some regulations into its District Plan. This began a relationship between the University of Auckland and Auckland City Council. The ACC funded a wind tunnel study of wind flow over Auckland. This work was carried out by a Master of Engineering student, Mr Richard Andrews [1], who built a 1:1000 scale model of the city and investigated the wind speeds at various locations and compared them to full scale measurements where they existed [2,3]. In addition, the University helped to frame some wind speed criteria[4] for the Proposed District Plan [5]. Further work and comparisons with existing criteria in other countries led to a refinement of the Auckland Criteria recommended for the proposed 1997 District Plan [6]. These criteria are in use today and are given in Appendix 1.

The wind comfort criteria have four levels proposed for different kinds of activities, and a dangerous level. The four levels correspond approximately to: sitting for a long time, sitting for a short time, walking slowly, and walking fast. Generally a lower wind speed limit is indicated for areas dedicated to long-term public usage (Cat. A) compared to areas intended only for passage (Cat. D). The limit Category is E, which is dangerous and undesirable for any type of location. Wind categories are specified in terms of the probability of exceeding certain hourly mean speeds. In order to be classified as Category A the hourly mean wind speed of the area must be less than 4.3 m/s for 99% of the time, whereas to be classified Category D the hourly mean wind speed needs to be less than 10.3 m/s for 99% of the time, indicating that a category D area can have a mean wind speed more than twice as strong as in category A areas (Appendix 1).

The collaboration between ACC and the University of Auckland is still continuing, and recently 11 cup anemometers were installed above traffic light arms to record the wind speed at low level and compare them with wind tunnel results. Results to date have been reported in [7, 8].

2.2 *Wind tunnel testing technique used at the University of Auckland*

Pedestrian level wind investigations are carried out in the low speed test section of the de Bray wind tunnel located in the Aerodynamics Laboratory of the Department of Mechanical Engineering at The University of Auckland. Figure 1 shows the wind tunnel and a model viewed looking upstream. The model is built to a scale of 1:400, and the wind tunnel is 1.83 m wide, 9 m long with a roof height of about 1m. The roof height is adjustable, and it is always contoured to give zero pressure gradient over the wind tunnel model.

A standard layout of trip fence and roughness blocks is placed upstream of the model (as shown in Figure 1) to produce onset flow resembling that of the natural wind. In the present case, flow over Category 3 type terrain (residential housing), as set down in the New Zealand Wind Loading Code NZS4203:1992 is used as the target wind structure.

A bed of erodible material (bran flakes) is sprinkled over the area to be tested and the wind speed increased until the bran flakes move to form an eroded pattern. During testing, a computer acquires images of these patterns and determines the erosion patterns corresponding to different wind speeds. These are obtained for the predominant wind directions 0, 30, 60, 90, 210, 240, 270 and 300º (other directions being ignored because of their relatively low frequency).

Figure 1. General view of the proposed development embedded in model of surroundings looking upstream (westwards) showing roughness blocks and trip barrier.

2.3 *Analysis and Presentation of wind tunnel results*

Measurements have been made using a hot-wire anemometer to establish the wind speed, at a model scale height equivalent to 1.5 m in full scale, at which the bran flakes are eroded from under the wire. Having established this wind speed the ratio between wind speed at 1.5 m and the reference point at 200m (full scale equivalent) may be deduced by simply noting the velocity at 200m when erosion in a particular region occurs. A wind speed/probability density distribution has been deduced at 10 degree intervals for a height of 200 m based on full scale measurements. It is then assumed, in keeping with general wind engineering practice, that this ratio holds for all wind speeds from the particular direction.

In the present investigation, a computer image processing system, originally developed by Eaddy [9], is used to study each situation in detail. A digital camera is used to record the erosion images after the wind tunnel has been run at certain fixed wind speeds (starting from zero speed) for 90 seconds. It is then able to determine the additional area of erosion that has occurred for each increasing wind speed, and hence the local velocity ratios for this eroded area and wind direction. The system determines the velocity ratio for every pixel in the area under investigation for each of the eight test directions (maximum of 442368 points). These values, when combined with the reference climate data, give the wind speed frequency results that are used to categorise the area according to the ACC wind comfort criteria. This software automatically performs the analysis outlined by Flay [10], and produces colour images that contain the pedestrian level wind categories, for each test situation.

A typical coloured image resulting from this processing in the form which is given to the client is shown in Figure 2. Wind category A is shown as white, B is green, C is red, D is blue and category E is yellow. It should be noted that with this system erosion must occur for at least one wind direction for it to be categorised. Areas where no erosion occurs appear in the images in the background colour (dark grey) but are also category A.

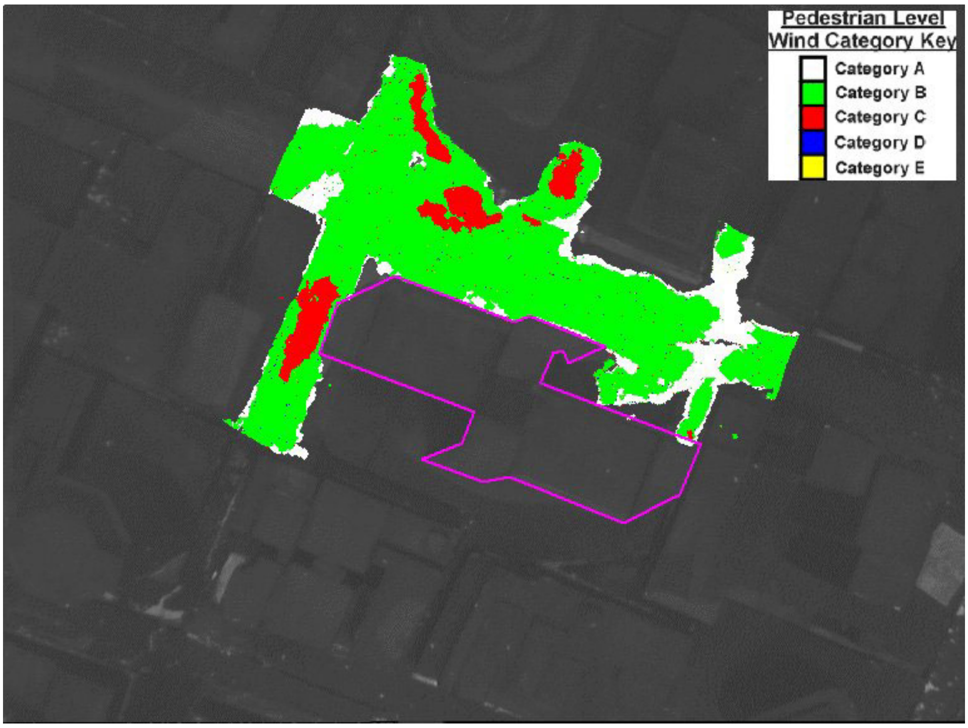

Figure 2. Wind categories in the vicinity of proposed modifications to a building in Auckland. (North is to the right of the figure.)

2.4 *Summary of Auckland Wind Environment Control*

It is evident that Auckland has developed a useful set of rules in its District Plan with regard to wind control. It has helped that the rules have been developed by a collaborative process between the University of Auckland and ACC. The University of Auckland has developed a quantitative method of assessing the wind environment using an erosion technique which results in diagrams which are easy to interpret by Architects and by the Council staff assessing submissions from Developers for Resource Consent.

3 WIND REGULATIONS FOR THE CITY OF WELLINGTON

3.1 *Description of Wellington City Council District Plan concerning Wind*

The wind control regulations for Wellington are contained in Appendix 2. The Appendix is fairly complete, and so only a brief description is given here.

The Wellington City District Plan requires that all buildings or structures above 4 storeys in height comply with specified wind speeds that are specified as peak annual 3-second gusts at a height of 2 m in daylight hours. Developers are required to commission wind tunnel tests which compare the wind environment in the vicinity of the existing building with that in the vicinity of the proposed building. It is known by the Wellington City Council (WCC) that the city is already too windy in many areas, and so the regulations are framed in such a way that they attempt to prevent public areas getting significantly worse than what they already are. Thus if the existing wind speed (peak annual 3-second gust) is less than 10 m/s, then the developer is not allowed to let the wind speed in the vicinity of the development exceed 10 m/s. If the existing wind speed is between 10 and 15 m/s, then the wind speed around the development must not exceed 15 m/s. If the existing wind speed is between 15 and 18 m/s, then the wind speed around the development must not exceed 15 m/s. If the existing wind speed exceeds 18 m/s then the wind speed around the development must not exceed 18 m/s.

However, it is not always possible for the developer to make changes to the proposed building to bring the wind speeds into compliance, and still have a commercially viable development. In such cases the WCC is able to use its discretionary powers, and approve non-complying developments, if it sees fit to do so in exceptional circumstances.

3.2 *Specification of wind tunnel tests for Wellington*

Wind tunnel tests for Wellington are usually carried out by Opus International Consultants, Central Laboratories in Gracefield, Lower Hutt, which is several kilometres north of Wellington.

A photograph of the Central Laboratories wind tunnel can be seen in Figure 3. It is a rather long boundary layer wind tunnel of width 2.7 m and height 1.2 m. Spires, fences and blocks are used to generate the appropriate wind structure, typically for a model scale of 1:264, as is standard in boundary layer wind tunnels.

The wind tunnel testing technique used by Opus is to initially test a proposed building using an erosion technique to determine the areas of highest wind speed for the prevailing winds. Next hot-film anemometers are used to measure the instantaneous wind at a number of locations, typically 25 to 50. The hot-film is positioned at a height equivalent to 2 m in full scale above the ground, with its axis vertical. Appropriately filtered data are recorded (so that the response is equivalent to a peak 3-second gust) for a period of 60 seconds, and the statistics determined – mean wind speed, maximum and minimum speeds, and standard deviation. A representative maximum gust speed is determined by the mean plus two standard deviations scaled appropriately. These effective peak wind speeds are measured for eight wind directions: 320°, 335°, 350°, 005°, 170°, 185°, 200°, and 215°, and the results are tabulated from the existing and proposed building. “Hot spots”, or locations that are close to the criteria limits are re-measured for a period of 120 seconds. The wind tunnel engineer works with the developer and architect to attempt to mitigate the effects of non-complying wind conditions, if they exist for a particular development.

The developer is required to submit a Wind Report to the WCC for review. It is quite common for WCC to seek the advice of an independent wind specialist to help it to review the report, and to make recommendations on the course of action required.

Figure 3. Photograph of the Central Laboratories wind tunnel looking downstream. There is a compliant “Parkinson-type” slotted roof over the turntable area.

3.3 *Summary of Wellington Wind Environment Control*

Wellington City Council has developed a comprehensive set of rules in its District Plan for the Central Area to require developers to take the impact of wind into account. If proposed buildings do not comply with the WCC rules with regard to wind, then the council has in its power the ability to withhold the consent being requested. This is a very powerful position, and has meant that architects that design tall buildings for Wellington have become educated with regard to wind effects, and to the effect of tall buildings on the wind environment in the built environment, and they now try to take this into account in their design. This means that for example they will tend to specify the largest canopy that can fit above the footpath, they build towers above a podium where possible, and they try to round the corners of buildings. However, even with the best efforts, if the building still does not comply with the Central Area Rules, then the WCC can waive them if it is in the best interests of the City when all aspects of the development are taken into account.

4 DISCUSSION AND CONCLUSIONS

The paper has described the rules concerning wind environment control for two cities in New Zealand and pointed out differences. These differences are very significant. The wind comfort criteria for Auckland are framed in terms of the mean wind speed, whereas for Wellington they are framed in terms of the peak annual 3-second gust speed at a height of 2 metres.

It has been shown that in the case of Auckland, the rules were developed by collaboration between the Auckland City Council and the University of Auckland, and that this has been a successful collaboration.

A description of the erosion method used in wind tunnel tests at the University of Auckland to determine wind speeds in a quantitative manner has been described, and the advantages in the presentation of the simple coloured diagram showing the various wind comfort categories for developers, architects and the Council staff have been mentioned.

In the more windy Wellington, the regulations concerning wind control are more prescriptive, and the style and content of the wind tunnel report is specified in some detail.

It is evident that New Zealand has recognised the problems that can arise in cities when the wind environment is unpleasant and/or dangerous to the public, and it has made considerable efforts to try to mitigate the problems resulting from too much wind in public spaces by placing controls in place which affect the developers of tall buildings.

5 ACKNOWLEGEMENTS

The senior author acknowledges the assistance of Mr Alan Kirk, Auckland City Council, in obtaining details of the District Plan pertaining to wind control. Furthermore, the senior author acknowledges the discussions with Mr George Farrant at Auckland City Council over many years in developing the regulations regarding to Wind Environment Control.

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7 APPENDICES

7.1 *Appendix 1 Extracts from Auckland City Council District Plan*

CITY OF AUCKLAND – DISTRICT PLAN
CENTRAL AREA SECTION – OPERATIVE 2004
updated 09/06/04

PART 6 – DEVELOPMENT CONTROLS

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6.12 WIND ENVIRONMENT CONTROL

a) New buildings or structures must be erected in such a manner that:

- i) does not cause the mean wind speed around them to exceed the category for the intended use of the area as set out in Appendix 10
- ii) does not cause the average annual maximum peak 3 second gust to exceed the dangerous level of 25 metres per second
- iii) does not cause an existing wind speed which exceeds the standards of (i) or (ii) to be increased.

Explanation

The purpose of the control is to avoid excessive wind velocity and turbulence in outdoor pedestrian spaces. The performance categories set tolerable wind levels for various pedestrian environments depending on the likely frequency and type of usage of those environments. They are designed to ensure that a development does not make the existing wind conditions significantly worse.

Compliance with this rule may either be demonstrated by a wind report including the results of a wind tunnel test or appropriate alternative test procedure to show that the proposed development complies with the above standards. Alternatively a report from a suitably qualified expert that a building or addition meets the requirements of this rule may be accepted, without the need for a wind tunnel test, depending on the nature of the proposal, its design and scale and the sensitivity of the receiving wind environment.

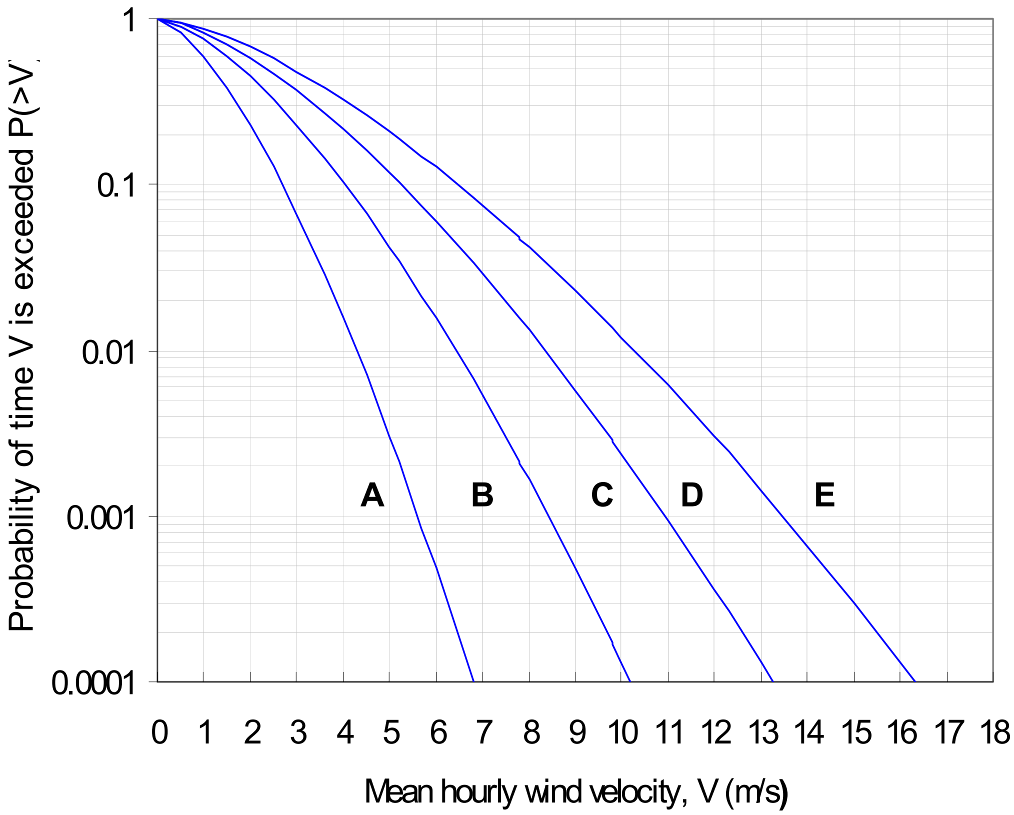
APPENDIX 10

WIND CONTROL

Figure 10.1 Performance Categories

Category A:	Areas of pedestrian use containing significant formal elements and features intended to encourage longer term recreational or relaxation use, i.e., major and minor public squares, parks and other public open spaces - e.g. Aotea Square, Queen Elizabeth Square, Albert Park, Myers Park, St Patricks Square, Freyberg Place.
Category B:	Areas of pedestrian use containing minor elements and features intended to encourage short term recreation or relaxation, i.e., minor pedestrian open spaces, pleasance areas in road reserves, streets with significant groupings of landscaped seating features e.g. Khartoum Place, Mayoral Drive pleasance areas, Queen Street.
Category C:	Areas of formed footpath or open spaces pedestrian linkages, used primarily for pedestrian transit and devoid of significant or repeated recreational or relaxational features, such as footpaths where not covered in Categories A – B above.
Category D:	Areas of road, carriage way, or vehicular routes, used primarily for vehicular transit and open storage, such as roads generally where devoid of any features or form which would include the spaces in Categories A – C above.
Category E:	Category E represents conditions which are dangerous to the elderly and infants and of considerable cumulative discomfort to others. Category E conditions are unacceptable and are not allocated to any physically defined areas of the city.
Note: All through-site links and other private land given over to public use as bonus features, or subject to public access easements, shall be subject to the Wind Environmental Categories.	

Figure 10.2 Wind Environmental Categories



Derivation of the Wind Environment Control Graph

The curves on the graph delineating the boundaries between the acceptable categories (A – D) and unacceptable (E) categories of wind performance are described by the Weibull expression:

$$P(>V) = e^{-\left(\frac{V}{C}\right)^{k}}$$

where V is a selected value on the horizontal axis, and P is the corresponding value of the vertical axis:

and where:-
P(>V) = Probability of a wind speed V being exceeded;
E = The Napierian base 2.718281…..;
V = the velocity selected;
k = the constant 1.5; and
c = a variable dependent on the boundary being defined:

A/B	c = 1.548
B/C	c = 2.322
C/D	c = 3.017
D/E	c = 3.715

7.2 Appendix 2 Extracts from Wellington City Council District Plan

WELLINGTON CITY DISTRICT PLAN

The sections of the Wellington City District Plan, which make specific reference to wind are listed below. These include descriptions of the general principles and also the specific requirements of the wind ordinances.

12. CENTRAL AREA

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12.2 Central Area Objectives and Policies

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OBJECTIVE

12.2.2 To maintain and enhance the amenity values of the Central Area and any nearby Residential Areas.

POLICIES

To achieve this objective, Council will:

…

12.2.2.4 Ensure that the buildings are designed to avoid, remedy or mitigate wind problems that they create.

METHODS

- Rules
- Information (Wind design guide)

Tall buildings can induce wind changes at ground level. This can make activities on the ground uncomfortable, difficult and even dangerous. Wind rules will therefore be enforced to ensure that adverse effects are avoided or reduced.

The environmental result will be that the adverse effect of wind around buildings are avoided, remedied or mitigated.

13. CENTRAL AREA RULES

13.1 Permitted Activities

Note: The Lambton Harbour area remains subject to the provisions of the Lambton Harbour Combined Scheme (Operative: 1 November 1989) and the Proposed District Plan (Notified on 27 July 1994).

Section 13.1 describes which activities are permitted in the Central Area provided that they comply with any specified conditions and the payment of any financial contributions (refer to rule 3.4).

Where Residential or Open Space Areas are situated within the Central Area Boundary as defined on the Planning Maps, the relevant Residential or Open Space objectives, policies or rules will apply to those Residential and Open Space Areas as the case may be (refer to Parts 5 and 6 and Parts 16 and 17 respectively).

Note: In the Central Area and Suburban Centre Areas the definition for sensitive activities and uses includes residential activities.

…

…

13.1.2.11 Wind (except in the Operational Port Area)

13.1.2.11.1 New buildings or structures above 4 storeys in height shall be designed to comply with the following standards:

Existing wind speeds	Wind speeds resulting from development proposal	Requirements on developer
Up to 10 m/sec	If exceeding 10m/sec in any public space	Reduce to 10m/sec in the public space
Up to 15m/sec	If exceeding 15m/sec	1. Reduce to 15m/sec 2. Although other directional speeds may be increased towards 15m/sec, overall impact is to be no worse than existing
15-18m/sec	If exceeding 15m/sec	Reduce to max 15m/sec
Above 18m/sec	If more than 18m/sec	Reduce to max 18m/sec

13.1.2.11.2 To show that a proposed development complies with these standards, a wind report must be supplied which includes the results of a wind tunnel test.

The test or tests must examine the effects of the proposed building upon areas open to the public, such as adjacent roads, parks, malls, plazas, public carparks, the immediate forecourt area and entranceways to proposed buildings.

The tests must also be operated on the following basis:

• maximum annual occurrence within daylight hours

• simulated 3 second gusts at a 2 metre height

- the proposed development must be tested against the existing situation except where the site is currently cleared. If the latter is the case, the proposal must be tested against the building which previously existed.

For the form and content of reports on wind tunnel tests, refer to Appendix 7.

The wind rules are designed to encourage a safe and pleasant environment by decreasing the worst effects of wind. The standards work to ensure that no development makes the environment around buildings dangerous or makes the existing wind environment significantly worse.

For information, the effects of wind at various speeds are:

10 metres/second -	*Generally the limit for comfort when standing or sitting for lengthy periods in an open space*
15 metres/second -	*Generally the limit of acceptability for comfort whilst walking*
18 metres/second -	*Threshold of danger level*
23 metres/second -	*Completely unacceptable for walking*

…

13.3 Discretionary Activities (Restricted)

Section 13.3 describes which activities are Discretionary Activities (Restricted) in the Central Area. Consent may be refused or granted subject to conditions. Grounds for refusal and conditions will be restricted to the matters specified in rules 13.3.1 to 13.3.5. The decision on whether or not a resource consent application will be notified will be made in accordance with the provisions on notification in the Act.

…

13.3.2.15 Wind

Whether a proposed development makes the environment dangerous or makes the existing wind environment significantly worse. Under this rule any reduction in the specified standard will only be considered where it can be shown that every reasonable alternative building design has been explored. A full wind report must be supplied in support of the application.

Council aims is to encourage a safe and pleasant environment by ameliorating the worst effects of wind. In some limited cases, some reduction in the standards may be justified.

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Appendix 7. Wind

This Appendix details the form and content of reports on wind tunnel tests as required by Rule 13.1.2.11.

1. Aims of the Wind Tunnel Test

The aims of a standard wind tunnel test are:

1.1 to examine a building proposal in order to quantify any wind problems and to test alternative solutions to them; and

1.2 to provide documentary evidence, of the proposed building's positive effect on the wind environment emphasising measures taken to improve the wind environment, and describing other options for development that have been tested.

2. Form of the Wind Tunnel Test

A standard wind tunnel test must meet these conditions:

2.1 The wind tunnel used in this procedure must reproduce the wind speed variation with height observed in the atmospheric boundary layer, at the model scale used for the model of the building proposal to be tested. A simple power law relationship may be used for this variation, such that:

Velocity at height $H = V_G (H/H_G)^{\phi}$

where H_G is the height above the city at which the shear forces of the atmospheric boundary layer give way to the pressure forces driving the wind; where V_G is the (gradient) velocity of the wind above this gradient height; and where ϕ has a value between 0.3 and 0.45 in Wellington.

Other expressions for the relationship between height and wind speed may be accepted if their derivation is adequately documented in each wind report.

2.2 The wind tunnel model of the velocity profile of the atmosphere must model the turbulence at scale heights between 0 and 200 metres in the wind tunnel, namely:

- between 30 percent and 40 percent at a scale height of 10 metres; and
- between 10 percent and 25 percent at a scale height of 100 metres.

2.3 The model scale used in the wind tunnel test must not produce models that are smaller than those obtained using a 1:500 scale.

3. Wind Tunnel Procedure

The following checklist is offered as a guide to the steps to be followed in order to produce the material needed to complete the WCC standard wind tunnel test report described in Section (4) of this Appendix.

The checklist is divided into phases which it is expected will be sequential. However, the points within each phase may well be performed in a different order from that listed, depending on the type of building project to be investigated.

Is the criteria of acceptability only to be pedestrian safety or are there other considerations of comfort to be applied to particular areas? What parts of the proposed building are fixed in bulk/size and what parts may be changed, moved or added to improve the wind environment?

Phase I

Book time at a wind tunnel facility capable of making the detailed measurements required in a wind tunnel test report. As the test itself could take at least a week to complete, book well in advance.

It is important to ensure that the wind tunnel is capable of meeting the requirements set out in Section (2) above.

Phase II - The Model

3.1 Provide model details and/or model(s) of the proposed and existing buildings to the wind tunnel facility which is to perform the test.

Phase III - The Wind Tunnel Test

3.2 Identify the areas around the proposed building which experience the highest wind flows. Measure and record the wind speed at these locations for wind from the following points of the compass (degrees clockwise with respect to true North) 340°, 360°, 20° (Northerlies); 160°, 180°, 200° (Southerlies).

3.3 Measure and record the wind speeds occurring in the high wind areas around the existing buildings for the 340° and 200° directions, and for other directions identified as problematic for the proposed building.

3.4 Assess the need for alterations to the form of the proposed building. If alterations would be useful, test those that would be acceptable to the proposer of the building. If no alterations are needed, examine other alternatives for improving the ground level wind environment, such as wind-breaks, trees, walls, canopies and verandahs. The recording and measurement of wind speeds here should only be for those areas on the proposed building causing problems and for the problem plus the 340° and 200° directions.

3.5 Summarise the physical measurements and qualitative observations made during the tests in a way which clarifies:

3.5.1 the cause(s) of the observed problems;

3.5.2 the ways in which these problems might be avoided; and

3.5.3 the ways in which shelter against these wind problems might be provided.

At its simplest this might mean stating (for example):

- that the root cause is the downwash caused by the building being very much bigger in scale than its neighbours;
- that reducing the size of the proposed building would remove this root cause (but may have certain practical or financial difficulties);
- that large canopies around the building could provide shelter from the downwash in the immediate vicinity of the entry ways, although this may result in the carparking area beyond the canopy being made uncomfortable.

4. Form of Wind Report

Each wind tunnel test must contain:

4.1 A technical appendix outlining measured data on:

4.1.1 the relationship between wind speed and height in the model of the atmospheric boundary layer used in the test; and

4.1.2 the variation with height of the turbulence of the wind tunnel model of the atmospheric boundary layer used for the test.

4.2 A calibration section. This must contain photographs of the erosion of flow visualisation granular material like polystyrene bubbles, from around an isolated building model subjected to the same model of the atmospheric boundary layer as is used in the test. The model shall be of a 60 metres high, 15 metres square plan, simple rectangular tower at the scale used in the test. The photographs shall be taken at least four and preferably six different times. The last time should be determined by the length of time the wind tunnel must run at a particular maximum speed in order to clear an area of diameter 50 metres (at the scale of the model) centred on the back face of the model by over 80 percent of the original coverage. The intermediate speeds will be chosen to divide this maximum speed into equal quarters (sixths). The times of exposure corresponding to each intermediate speed will be such that the product of wind speed and time for each is a single constant value. The photographs should show the time allotted for each selected wind speed and the value of the wind speed itself.

4.3 An appendix which describes:

4.3.1 the model of the atmospheric turbulence that is used in the wind tunnel;

4.3.2 the relationship of this model to reality (as far as it is known);

4.3.3 the likely error limits in the peak gust speeds which are listed in the body of the report, given that this model has been used;

4.3.4 the precision achievable with the particular means chosen for estimating the ground level gust speed.

4.4 A table for each wind direction, listing the likely peak annual gust at the locations on the model identified as in the pre-design test, is critical to the success of the building. This table should list for comparison:

4.4.1 the wind speeds at these locations for existing buildings;

4.4.2 the wind speeds at these locations for the proposed buildings; and

4.4.3 where appropriate to illustrate the success of particular modifications to the proposed building, wind speeds at the worst locations prior to the introduction of the modification.

4.5 A table for each wind direction of parenthetical entries in the table listed under Point 4.4 above, which lists the ratios between ground level and reference level wind speeds that have been used to derive the peak gust predictions of Point 4.4.

4.6 An analysis by the wind consultant of the 3-dimensional wind flows around the proposed building indicating the way in which its effect on the air flow affects pedestrian-level winds.