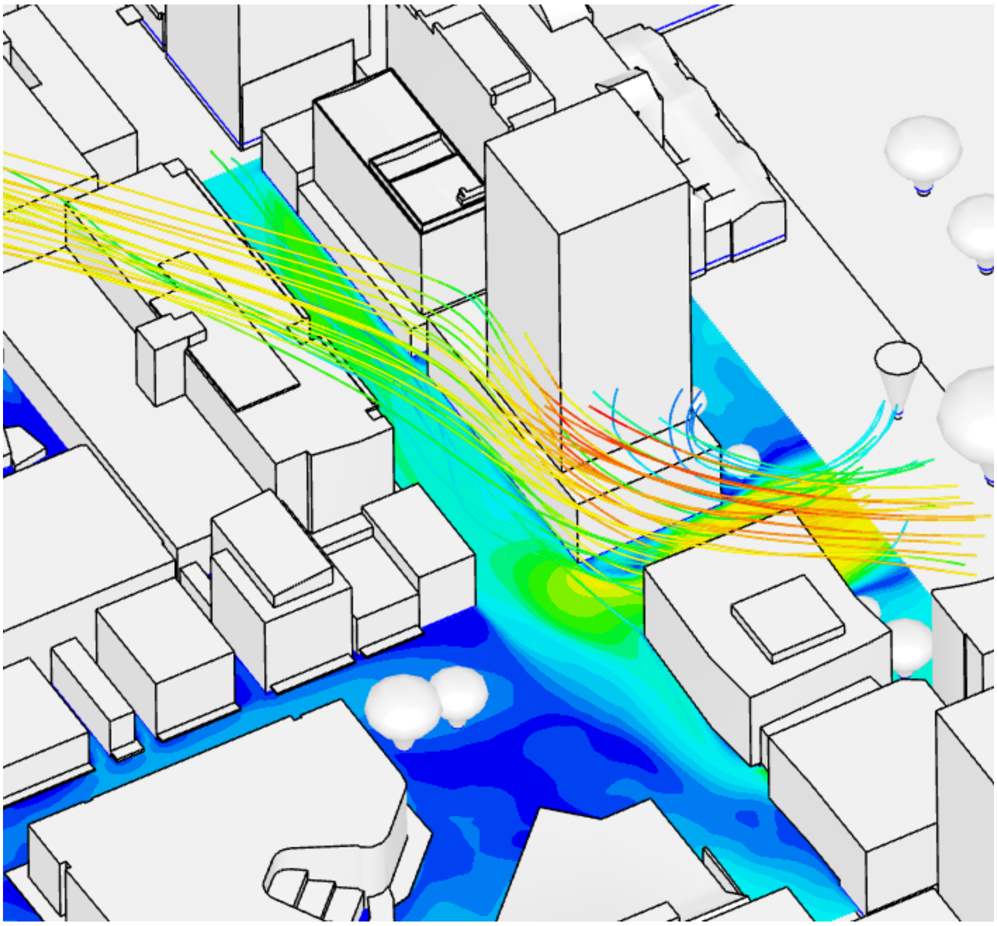
Technical Advice for Wind Assessments for Christchurch City

Meteorology Solutions

Using meteorology expertise to optimise engineering solutions

Mike Green, Engineering Meteorologist

8 June 2022



Contents

1. Introduction

Meteorology Solutions Ltd was commissioned by Christchurch City Council (CCC) for provision of technical advice to inform a package of rules and assessment matters for managing the impact of wind conditions caused by tall buildings in both residential and commercial areas. The scope includes advising CCC on new District Plan rules and may include suggesting rules and assessment matters to include in the Plan, as well as appropriate technical standards for wind conditions.

The scope also includes modelling of existing prevalent conditions in the City based on existing development, and further, demonstrating the likely impact of some future development scenarios. The purpose of the modelling is to identify impacts to inform potential mitigation options for challenging wind locations resulting from taller buildings. The wind modelling includes part of the city centre and an edge area to represent the High-Density Residential Zone.

A workshop was held on 6 May 2022 to discuss initial results. This report accounts for discussions in that workshop.

2. Context

Christchurch is a relatively windy city with a background mean wind speed of about 4 m/s (at 10 m above the ground). At the airport for example, the mean wind speed exceeds 4 m/s about 45% of the time, exceeds 6 m/s about 21% of time, and exceeds 8 m/s about 11% of the time.

In general, the 'roughness' of a city, which is caused by buildings and trees/vegetation, results in a reduction of wind speeds. However, higher buildings can intercept and deflect stronger winds from higher levels towards the ground. Also, channeling of wind along street and across open areas (such as parks), can result in localised higher wind speed areas.

The modelling completed in this study for an existing CDB scenario showed that wind conditions in most places are reasonable (such as mean speeds exceeding 6 m/s less than 5% of the time) in most places, except at isolated locations where there is channeling/reinforcement of wind, or enhancement of wind speeds from deflection off taller buildings.

The CFD simulations with added 30 m high buildings added to the Christchurch CBD showed that there was only a small increase in adverse wind effects. However, for building heights above 30 m, there is evidence that there would be increasing potential for wind impacts at more locations, and over larger areas.

For residential areas, the CFD modelling showed that there is more potential for adverse wind conditions when higher buildings are added due to less sheltering in general by the absence of surrounding tall buildings, and due to more exposed areas around the added buildings. For this reason, it has been recommended that buildings above 20 m should require a wind impact assessment.

3. Review of other New Zealand city distrcit plan requirements for wind

Auckland City Council requires a wind assessment to be done for new buildings exceeding 25 m height. The plan requirements are the same for the city area and for surrounding local business centres. The council is flexible with the procedure to complete a wind assessment including a desk top study (from experience for areas outside of the CBD), CFD (computational fluid dynamics), or using a wind tunnel. The criteria refer to areas not exceeding environmental control limits (which is based around mean wind speed and probably of occurrence) which are aligned to pedestrian usage categories. There is also a requirement for safety around an annual 3-second wind gust not exceeding 25 m/s.

The Wellington plan is flexible in that a wind assessment can be in the form of a wind report (a desktop analysis by a wind expert referred to as a Wind Assessment Report) and modelling is not required. However, using CFD is not allowed, and modelling must use a wind tunnel, which is referred to as a Wind Tunnel Test Report. It is not clear from the district plan when a certain assessment type is suitable.

The Dunedin city plan requirements for wind assessments is brief. *Buildings and additions and alterations are required to maintain or enhance streetscape amenity by ensuring buildings and structures above 20m minimise as far as practicable adverse effects of shading and wind on pedestrian amenity*.

Wind assessments in all cities require a suitably qualified wind expert.

It is worth noting here that London city has very specific guidelines for wind such as at:
https://www.cityoflondon.gov.uk/assets/Services-Environment/wind-microclimate-guidelines.pdf

Table 1 provides a high-level summary of the Auckland, Wellington, and Dunedin rules and criteria in the relevant district plans.

Table 1: Summary of Auckland, Wellington, and Dunedin rules and criteria in city plans for wind

City	Building height limit for wind assessments	Flexibility around methodology of wind assessments	Criteria comments
Auckland	Above 25 m	Flexible methods allowed, but CFD or wind tunnel assessment is most likely required for CBD area.	• Wind criteria are based around recognised international standards (looks similar to the Davenport standard), but the criteria have difference that appear to be unique. • The annual 3-second second gust speed of 25 m/s is difficult to assess. Strong wind gusts are specific to a local environment, wind data is often some distance and in a different wind climate to the urban area, and extreme wind events often occur in localised weather events such as in thunderstorms. • To evaluate the gust criteria a wind tunnel or CFD would need to be required. The gust speed of 25 m/s represents gust equivalent mean speed (GEM) of 13.5 m/s.
Wellington	Above 18.6 m	Some flexibility, but CFD is not allowed	• Standard is based around safety and cumulative wind effects. • Safety criteria is based around maximum gusts speeds of 20 m/s. • Comfort/pedestrian/public space wind criteria are based around mean wind speeds of 2.5 and 3.5 m/s thresholds where occurrence of wind speeds cannot increase by more than 170 hours per year (or about 2% of the time). There are also criteria based around the existing windy environment with criteria in public spaces with mean wind speeds above 2.5 m/s 1700 hours per year (about 20% of the time) and with different rules if the existing scenario already exceeds this limit. • To assess these standards would require a wind tunnel assessment.
Dunedin	Above 20 m	Required method of assessment is not specified	• Criteria is limited to minimising as far as practicable adverse effects of wind.

4. Computation Fluid Dynamics (CFD) overview

This modelling for Christchurch utilised a new branch of the Computation Fluid Dynamics (CFD) model known as the Lattice Boltzmann Method (LBM) to evaluate wind speeds at 1.5 m above ground level. The LBM solver is provided by SimScale and used for complex fluid systems including wind flow around buildings and structures, and through porous objects such as trees and hedges. This form of CFD has been adapted and evaluated by SimScale for wind tunnel type applications such as wind loading on buildings, pedestrian wind safety analysis, automotive aerodynamics, and other external flow applications. SimScale allows for pedestrian comfort and safety results to be given in a number of internationally recognised standards, some of which are described below.

5. Modelling scenarios

The modelling consisted of two parts; part of the CDB centered around the Colombo St and High St intersection, and a residential area just northeast of the city around the Chester St. E and Barbados St area.

The CBD modelling comprised of three build scenarios including, existing, a scenario with added 30 m high buildings in the wider CDB area, and a scenario with added 90 m high buildings in the wider CDB area. Larger trees were included in the modelling. These building scenarios are shown in Appendix 1.

The two residential modelling scenarios were somewhat artificial including a model based around Chester St. E wit 6-story level buildings (18 m high) added, and then a model with a mix of 6 and 10-storey level buildings (30 m) added. Addition of these 6 and 10-story building meant that there were increased open areas such as car parking and public space areas between buildings compared to the existing conditions. Note that only trees in the vicinity of the Avon River were included in the modelling. These build scenarios are shown in Appendix 2.

6. Background wind conditions

Background wind conditions are a key input into the modelling. The wind rose uses was from Christchurch Airport for a 10-year period and is shown in Figure 1. While the airport is some distance from the Christchurch CDB, it is assessed to be representative of the background wind conditions.

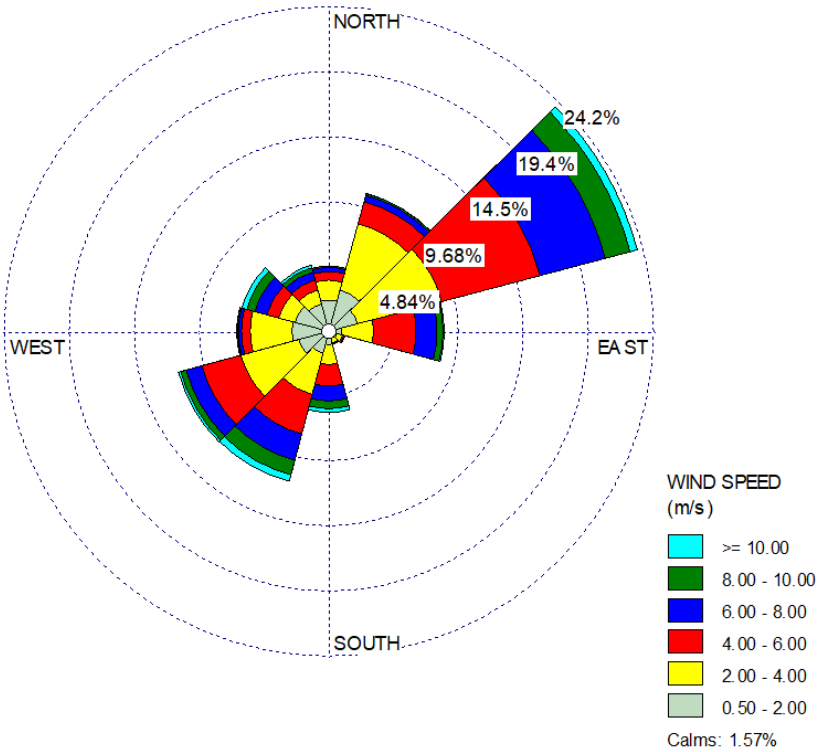


Figure 1: Wind rose for Christchurch Airport (showing the direction that the wind comes from)

Another required input for the CFD model is the surrounding surface roughness criteria which was assessed to be the 'urban' or 'suburban' categories. The surrounding surface roughness helps the model determine how wind speed changes with height which in turn affects how wind interacts with structures, especially taller buildings.

7. Wind Comfort Standards

Wind standards have been designed to give guidance around how wind conditions are suitable for intended pedestrian activities in urban settings. These standards use predicted spatial wind fields from the CFD modelling, and the frequencies of wind speeds, to give spatial pedestrian wind comfort and safety levels. Where the wind category exceed activity proposed in locations, this indicates the existence of an adverse effect of wind on pedestrians.

While there is no universal wind comfort/impact standard, there are a number that can be used to assess how a new building will impact on the surrounding wind environment. The criteria within standards range for example from 'sitting for long periods' (as would be suitable for outdoor cafes and restaurants) through to 'uncomfortable' and/or 'dangerous' levels. Standards that are often used are Lawson (and related variations such as London LDDC, Lawson 2001, and Lawson LDDC), Davenport, and NEN 8100. The NEN 8100 safety standard is an example of an index that is used to assess wind impacts on safety for pedestrians.

For pedestrian wind comfort, the typical approach can be to use mean wind velocity for the comfort calculations. However, it has been recognised that wind gusts often represent additional discomfort to the pedestrians, and the Gust Equivalent Mean (GEM) formulation is a way to account for such sudden wind accelerations. Some authorities around the world now require GEM to be considered. Note that while the GEM is given as mean wind speed, gust speeds can be estimated by multiplying the GEM by a (gust) factor of 1.85. For example, GEM of 13.5 m/s represents potential wind gusts speeds of about 25 m/s.

Wind standards are made up of a number of components including:

- Comfort and/or safety considerations
- Wind speed thresholds
- Percentage of wind speed occurrence
- Use of mean wind speed or GEM, or the maximum of both

Some standards combine both comfort and safety criteria, such as for the London LDDC criteria. This can result in the small exceedance percentages for safety criteria can supersede the comfort criteria, especially when GEM is being used. The Lawson LDDC standard is very similar to the London LDDC standard but does not include the safety criteria.

Based on the results of the Christchurch modelling, we recommend the following wind standard are used to assess wind comfort and safety for urban Christchurch:

For comfort:

1. Use either the London LDDC or Lawson LDDC standards as given in Tables 2 and 3.
2. Use 5% wind speed exceedance thresholds
3. Use maximum of mean wind speed and GEM (gust equivalent mean) wind speed.
4. Use all 24-hours of background hourly wind data.

For safety:

Use the NEN 8100 standard or London LDDC Pedestrian Safety Limit (which is more conservative than NEN 8100).

London Docklands Development Corporation (London LDDC) standard

Table 1 describes the six wind categories in the London LDDC standard. The London LDDC index is based around a version of a Lawson wind comfort classification and utilises the maximum of the mean and GEM wind speeds with exceedance levels of 5%, and using background wind data for all 24 hours. Note that for this standard, a safely wind speed criteria (F) is sometimes used as part of the comfort assessment criteria.

Table 1: London LDDC criteria to show spatial wind impacts

		Category	Maximum of mean and GEM wind speed (5% exceedance)	Possible adapted description for Christchurch
	A	Frequent Sitting	2.5 m/s	Acceptable for frequent outdoor sitting use such as outdoor restaurants and cafés.
	B	Occasional Sitting	4 m/s	Acceptable for occasional outdoor seating, such as general public outdoor spaces, balconies and terraces intended for occasional use.
	C	Standing	6 m/s	Acceptable for entrances, bus stops, covered walkways or passageways beneath buildings.
	D	Walking	8 m/s	Acceptable for external pavements and open walkways.
	E	Uncomfortable	Greater than 8 m/s	Not comfortable for regular pedestrian access.
	F	Pedestrian Safety Limit	15 m/s (0.022% exceedance)	Presents a safety risk for pedestrians, especially to the more vulnerable members of the public.

Lawson LDDC criteria

Table 2 identifies the six wind categories in the Lawson LDDC standard which is also based around a version of a Lawson wind comfort classification scheme. This standard utilises the maximum of the mean and GEM wind speed levels with exceedance levels of 5% (using wind data from 24 hours in a day). The Lawson LDDC standard does not include the lower percentage exceedance safety criteria - which can be beneficial for not masking other higher wind level criteria areas which can occur with the London LDDC standard.

It is recommended that it is up to the discretion of a wind specialist to include the F criteria level in the London LDDC standard for a wind comfort assessments. In our opinion both the London LDDC and Lawson LDDC standards provide a rigorous level of assessment and have similar wind speed thresholds except at the lowest level, and with an added comfort level for the Lawson LDDC standard for higher wind speeds.

Table 2: Lawson LDDC criteria to show spatial wind impacts

		Category	Maximum of mean and GEM wind speed (5% exceedance)	Possible adapted description for Christchurch
	A	Outdoor dining	2 m/s	Acceptable for frequent outdoor sitting use such as outdoor restaurants and cafés.
	B	Pedestrian Sitting	4 m/s	Acceptable for occasional outdoor seating, such as general public outdoor spaces, balconies and terraces intended for occasional use.
	C	Pedestrian Standing	6 m/s	Acceptable for entrances, bus stops, covered walkways or passageways beneath buildings.
	D	Pedestrian Walking	8 m/s	Acceptable for external pavements and open walkways.
	E	Business walking	10 m/s (less than 5%)	Not comfortable for regular pedestrian access.
	U	Uncomfortable	10 m/s (more than 5%)	Not comfortable for regular pedestrian access (and potentially dangerous for some people)

Lawson 2% exceedance criteria

The Lawson 2% exceedance standard is another version of a Lawson standard. The 2% exceedance criteria means that wind comfort levels are exceeded at more locations and for lower frequency than for the 5% exceedance criteria.

Table 3: Lawson 2% exceedance criteria to show spatial wind impacts

		Category	Maximum of mean and GEM wind speed (2% exceedance)	Possible adapted description for Christchurch
	A	Sitting long	1.8 m/s	Acceptable for frequent outdoor sitting use such as outdoor restaurants and cafés.
	B	Sitting short	3.6 m/s	Acceptable for occasional outdoor seating, such as general public outdoor spaces, balconies and terraces intended for occasional use.
	C	Walking leisurely	5.3 m/s	Acceptable for entrances, bus stops, covered walkways or passageways beneath buildings.
	D	Walking fast	7.6 m/s	Acceptable for external pavements and open walkways.
	E	Uncomfortable	Above 7.6	Not comfortable for regular pedestrian access.

NEN 8100 Wind Danger Criteria

The NEN8100 index is based on a Dutch wind nuisance standard adapted to advise on danger caused by wind as set out in Table 2 below. Using the danger criteria, mean wind speeds of 15+ m/s occurring less than 0.05% of the time are regarded as being 'No Risk', while mean speeds 15+ m/s occurring more than 0.3% of the time are regarded as 'Dangerous'. For a hospital environment where there is more likely to be vulnerable people in outdoor areas, the more conservative 'Limited Risk' criteria (or green category) was used to assess wind speed risk.

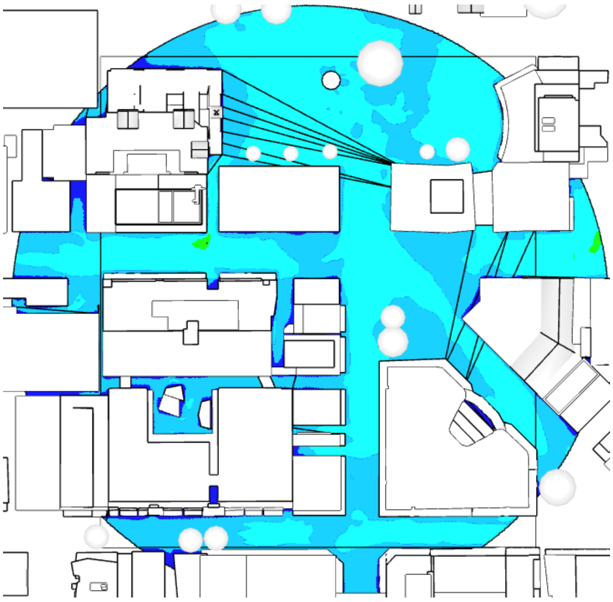
Table 3: NEN 8100 standard adapted to identify 'dangerous' locations

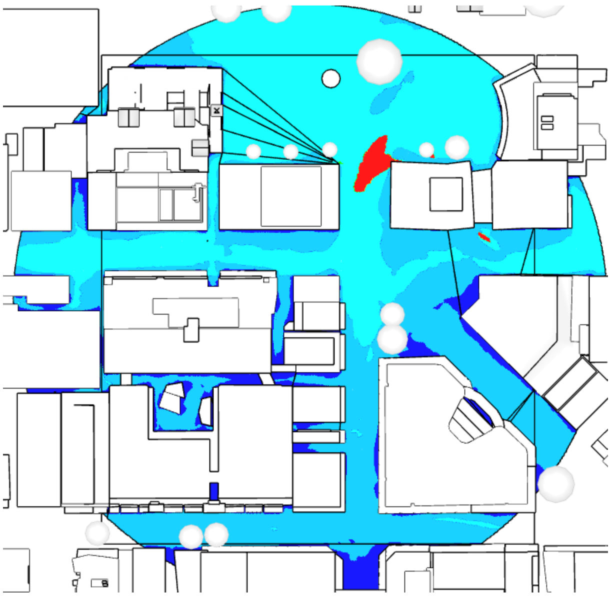
		Wind speed	Frequency	Description
(blue)	**A**	15 m/s	Less than 0.05%	No Risk
(yellow)	**B**	15 m/s	Less than 0.3%	Limited Risk
(red)	**C**	15 m/s	Greater than or equal to 0.3%	Dangerous

8. CBD wind modelling results

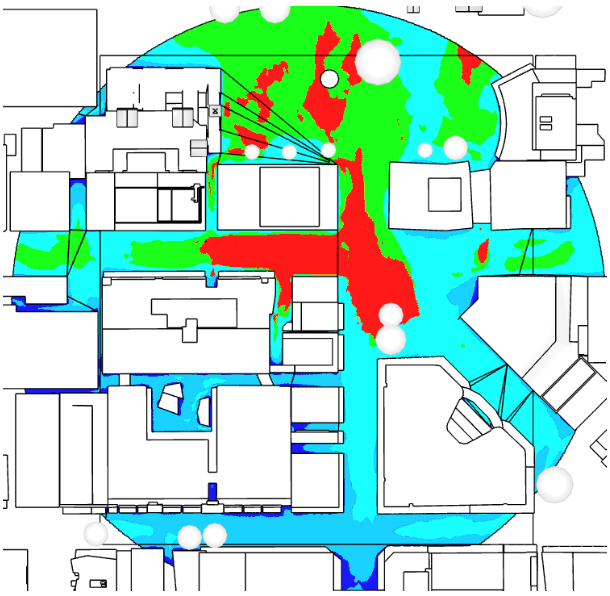
Below are results for the three proposed wind impact standards for the CBD area including for the existing building scenario and for the two scenarios including added 30 m and 90 m high buildings (as shown in Appendix 1). For comparison the Lawson 2% exceedance standard has been included in the results to compare with the 5% exceedance standards. Note that the results have a truncated version of the wind criteria key. Also note that the colour scale for the Lawson 2% exceedance criteria has a different colour scale to the other comfort criteria.

The London LDDC standard for existing building scenario, added 30 m buildings, and added 90 m buildings (using maximum of mean and GEM wind speeds)

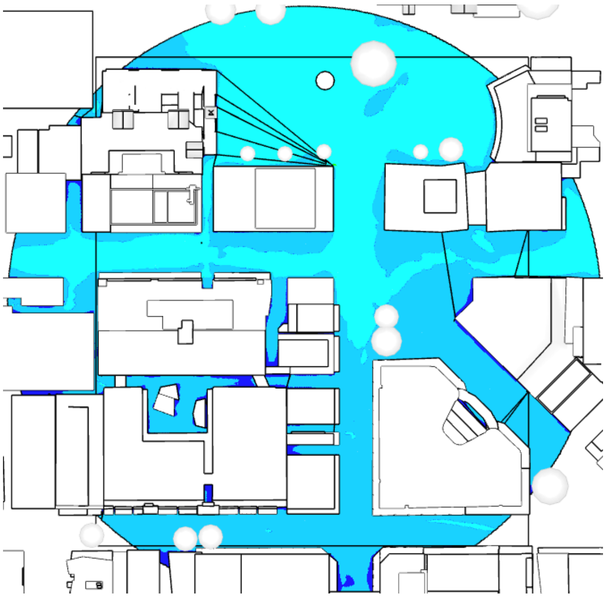




A	2.5 m/s	< 5%	Frequent Sitting
B	4 m/s	< 5%	Occasional Sitting
C	6 m/s	< 5%	Standing
D	8 m/s	< 5%	Walking
E	8 m/s	> 5%	Uncomfortable
S	15 m/s	> 0.022%	Unsafe

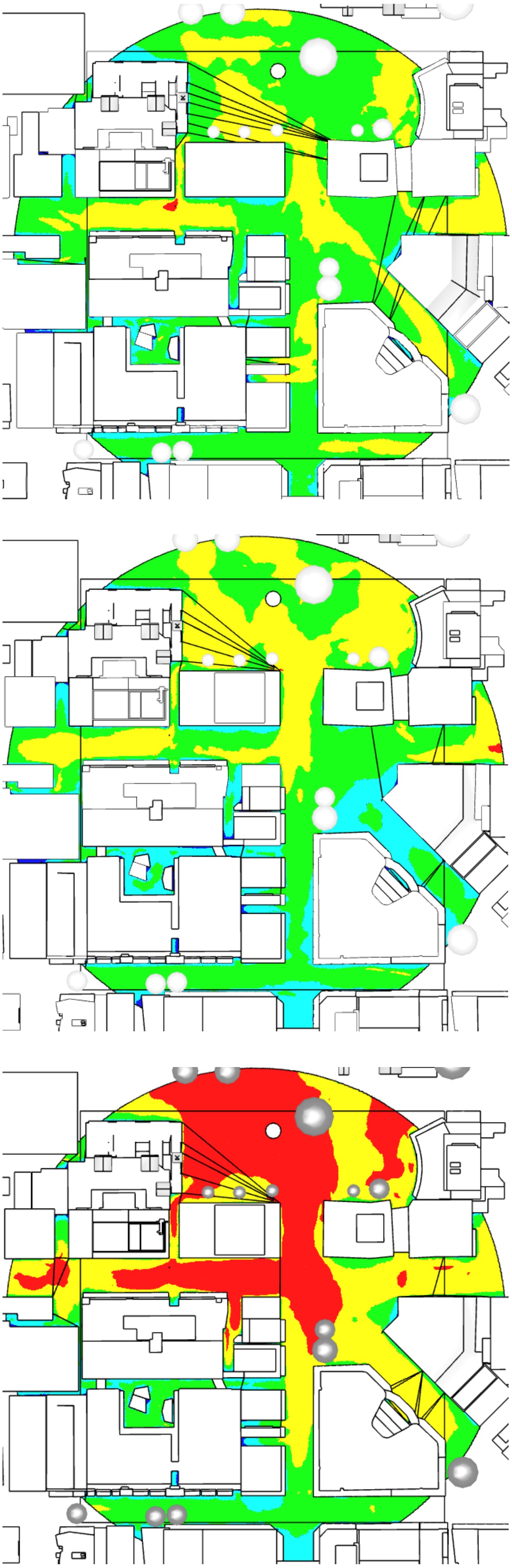


The Lawson LDDC standard for existing building scenario, added 30 m buildings, and added 90 m buildings (using maximum of mean and GEM wind speeds)



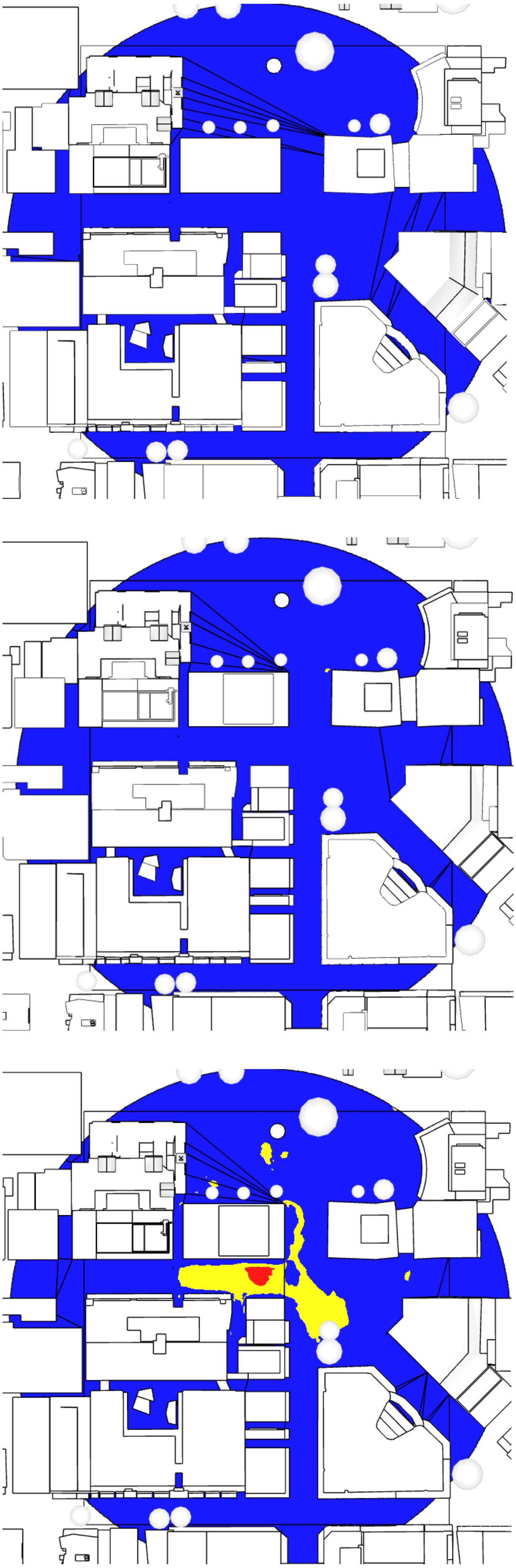
	A	2 m/s	< 5%	Outdoor Dining
	B	4 m/s	< 5%	Pedestrian Sitting
	C	6 m/s	< 5%	Pedestrian Standing
	D	8 m/s	< 5%	Pedestrian Walking
	E	10 m/s	< 5%	Business Walking
	U	10 m/s	> 5%	Uncomfortable

Lawson 2% exceedance standard for existing building scenario, added 30 m buildings, and added 90 m buildings (using maximum of mean and GEM wind speeds)



A	1.8 m/s	< 2%	Sitting Long
B	3.6 m/s	< 2%	Sitting Short
C	5.3 m/s	< 2%	Walking Leisurely
D	7.6 m/s	< 2%	Walking Fast
E	7.6 m/s	>= 2%	Uncomfortable

The NEN 8100 danger standard for existing building scenario, added 30 m buildings, and added 90 m buildings (using maximum of mean and GEM wind speeds)

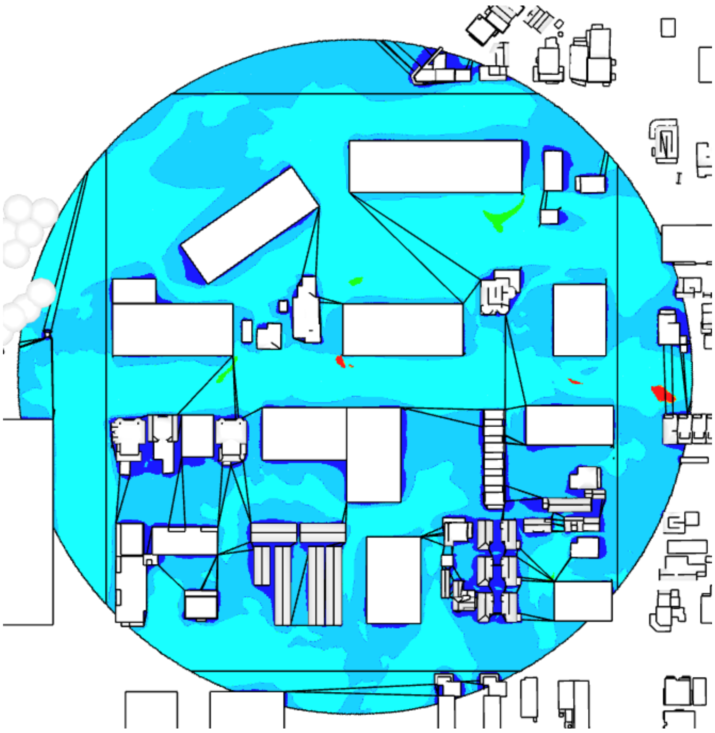


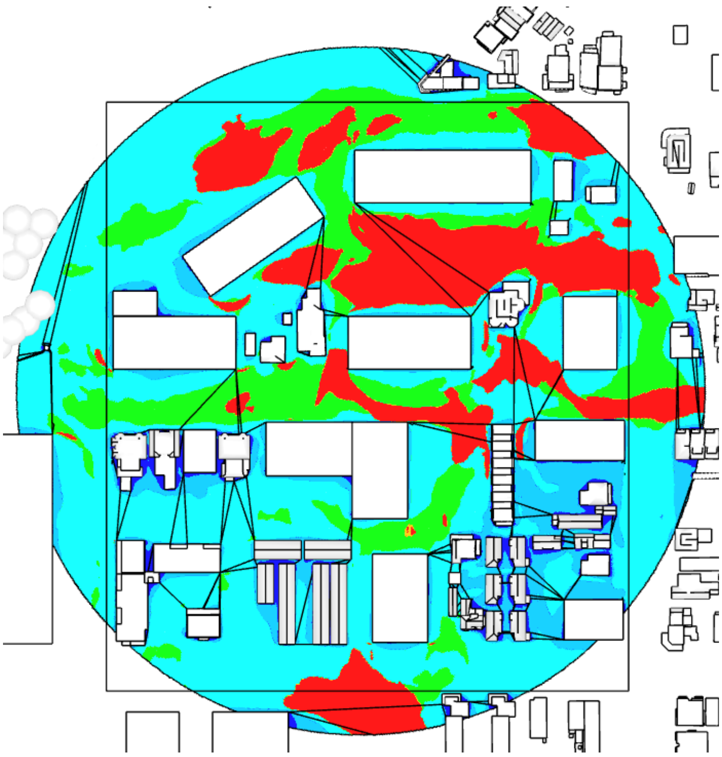
	A	15 m/s	< 0.05%	No Risk
	B	15 m/s	< 0.30%	Limited Risk
	C	15 m/s	>= 0.30%	Dangerous

9. Urban residential wind modelling results

Below are results for the three proposed wind impact standards for an urban residential area including for included 6-story buildings scenario and for included mixed 6 and 10-story buildings (as shown in Appendix 2). For comparison the Lawson 2% exceedance standard has been included in the results to compare with the 5% exceedance standards.

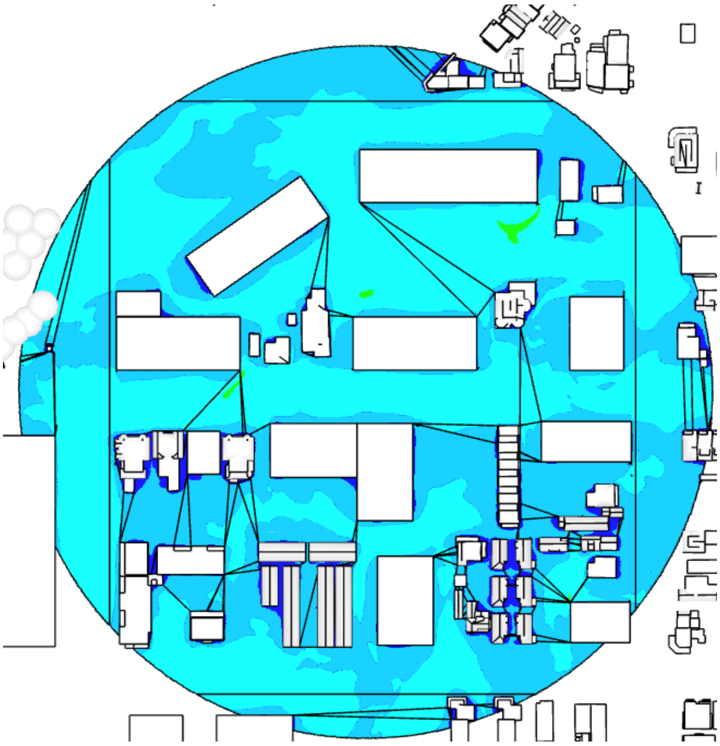
The London LDDC standard for 6-story buildings, and mixed 6 and 10-story building scenario (using maximum of mean and GEM wind speeds)

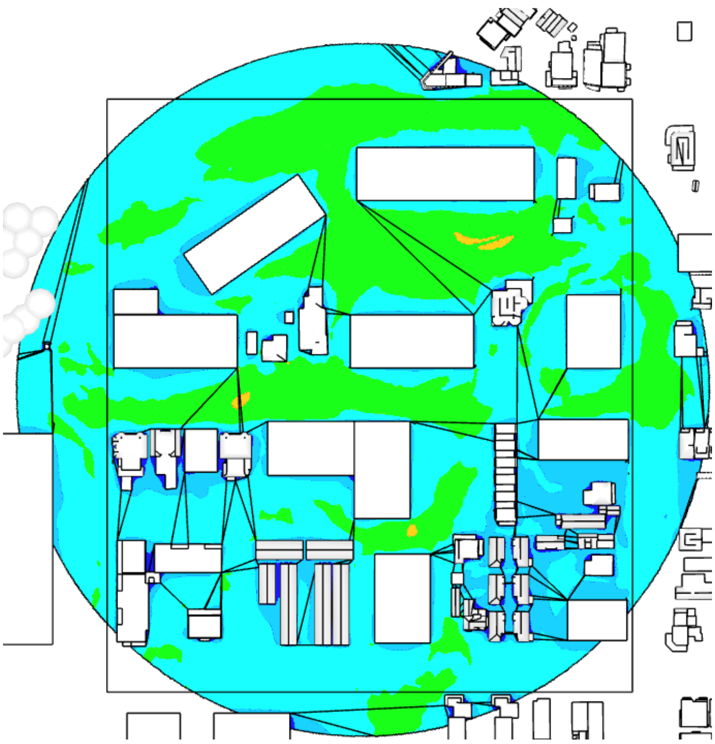




A	2.5 m/s	< 5%	Frequent Sitting
B	4 m/s	< 5%	Occasional Sitting
C	6 m/s	< 5%	Standing
D	8 m/s	< 5%	Walking
E	8 m/s	> 5%	Uncomfortable
S	15 m/s	> 0.022%	Unsafe

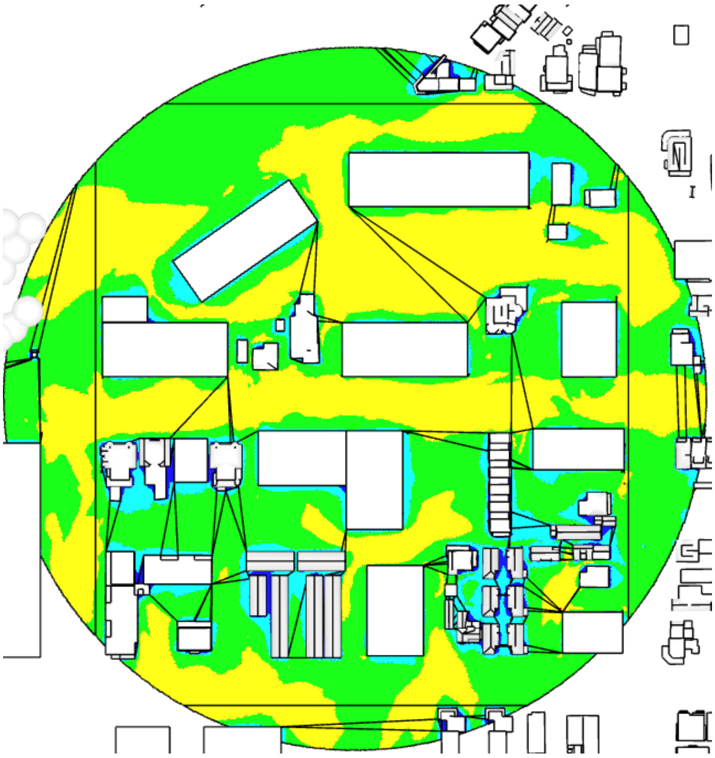
The Lawson LDDC standard for 6-story buildings, and mixed 6 and 10-story building scenario (using maximum of mean and GEM wind speeds)





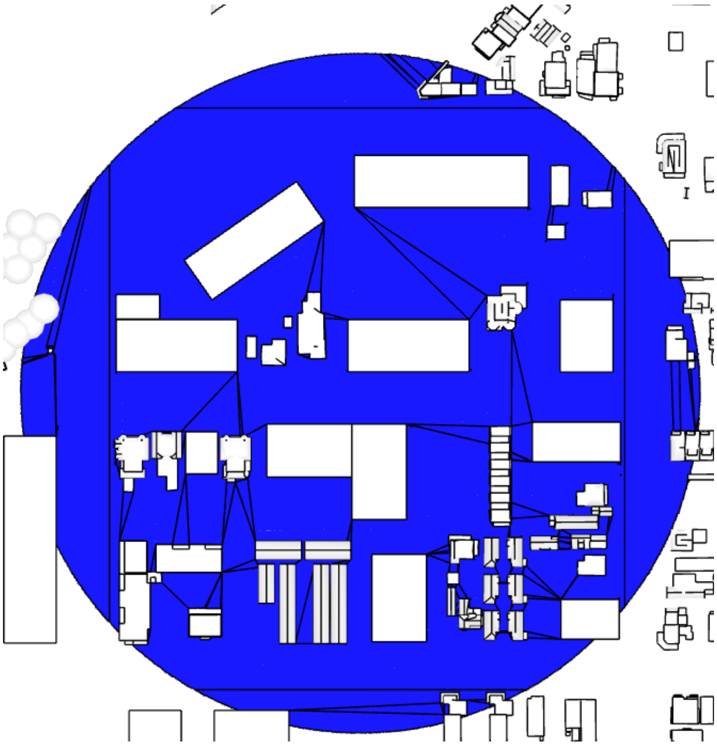
	A	2 m/s	< 5%	Outdoor Dining
	B	4 m/s	< 5%	Pedestrian Sitting
	C	6 m/s	< 5%	Pedestrian Standing
	D	8 m/s	< 5%	Pedestrian Walking
	E	10 m/s	< 5%	Business Walking
	U	10 m/s	> 5%	Uncomfortable

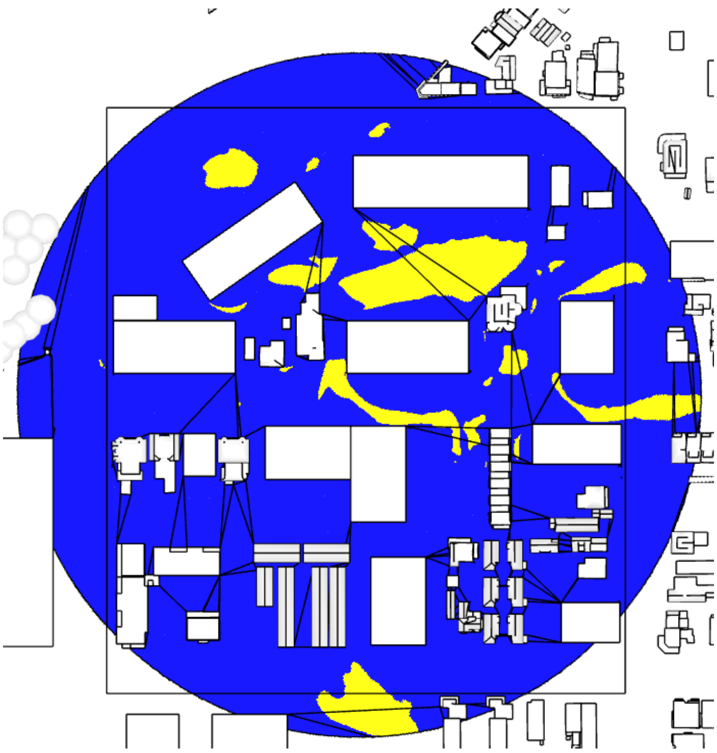
A Lawson 2% exceedance criteria standard for 6-story buildings, and mixed 6 and 10-story building scenario (using maximum of mean and GEM wind speeds)



A	1.8 m/s	< 2%	Sitting Long
B	3.6 m/s	< 2%	Sitting Short
C	5.3 m/s	< 2%	Walking Leisurely
D	7.6 m/s	< 2%	Walking Fast
E	7.6 m/s	>= 2%	Uncomfortable

The NEN 8100 Danger standard for 6-story buildings, and mixed 6 and 10-story building scenario (using maximum of mean and GEM wind speeds)





A	15 m/s	< 0.05%	No Risk
B	15 m/s	< 0.30%	Limited Risk
C	15 m/s	>= 0.30%	Dangerous

10. Results discussion

The modelling results for the CBD show that wind impacts at ground level increase with building height from around 30 m. Wind impacts are shown to increase for building heights above 30 m in the vicinity of the taller buildings and in open spaces. There was no significant increase in wind impacts for the 30 m building added compared to the existing scenario, except for a few locations of low frequency strong wind gusts. These results are what is expected with taller buildings expected to intercept stronger winds above the sheltered zone created by the city environment.

For the residential modelling, there is a reasonable increase in wind impacts when increasing building heights from 6-storeys (modelled as 18 m height) to 10-storey buildings (modelled as 30 m height). Increased wind impacts are expected for lower building heights outside of the CBD due to the more exposed environment.

Following discussion in the workshop on 6 May 2022 and subsequent emails, and considering the modelling results, the proposed building heights of 28 m for the CBD, and 20 m for residential and mixed-use areas are appropriate levels to initiate a wind impact assessment.

Note that the larger buildings had smooth facades, which could enhance downwash effects in the results.

11. Wind Mitigation

The following mitigation measures can be considered to reduce wind impacts:

- Use of vegetation and other porous/mesh barriers strategically aligned to reduce wind speeds at street level.
- Use of vegetation next to or under building overhangs.
- Avoiding larger towers/slab structures facing into stronger wind regimes, such as for northeast, southwest and northwest winds in Christchurch.
- Use of wind canopies at street level for larger towers/slab structures, especially those facing into stronger wind regimes.
- Balconies and other ‘rough’ features on the building facades will reduce downwash, especially buildings facing into stronger wind regimes (such as northeast, southwest and northwest). Note that such features were not included in the models for this exercise. Small features such as balconies can be challenging to model due to the scale of such features; however, there are methods that they can be represented.
- Use of wind lobbies and revolving doors for laneways exposed to the stronger wind regimes.

12. District plan rule and assessment criteria recommentations

Potential rule option for Christchurch city wind impact

To be able to quantify changes of the pedestrian level wind environment resulting from a proposed new building (above 30 m height in the CDB, and above 20 m height for urban residential and mixed zones) by comparing with existing wind conditions. Where wind conditions deteriorate as a result of a proposed building, the assessment must address the following:

1. Show that wind conditions (comfort and safety) do not exceed that for pedestrian use as indicated by the London LDDC and/or Lawson LDDC standards.
2. If wind conditions exceed the criteria for intended pedestrian use, show that mitigation options reduce wind conditions to an acceptable level (such as given in Table 1 or Table 2).
3. If a reduction to 'required wind levels' is not possible at all locations, the wind assessment must show the steps taken to minimise wind impacts (through mitigation options and/or design changes).
4. If reduction to 'required wind levels' is not possible at all locations, the wind assessment can show if/where wind conditions have improved in some areas as a result of the new building.

The wind assessment must address both comfort and safety considerations. It is recommended that the London LDDC and/or Lawson LDDC standards are used to assess wind comfort, and the NEN 8100 Danger standard is used to assess safety. These standards should use 5% exceedance wind speed criteria, the maximum of the mean and GEM (gust equivalent mean) wind speeds, and with background wind data covering a 24-hour period.

In our opinion the 2% exceedance level criteria (as for the Lawson 2% exceedance standard results (as provided above), would be less forgiving for the higher building scenarios, and could make achieving suitable wind levels difficult for more locations, especially for a relatively windy city such as Christchurch.

Other considerations for Christchurch city wind assessments:

- The wind assessment covers pedestrian areas/parks, laneways etc. such as within 100 m (for example) from the edge of the new building/development.
- Surrounding buildings, other significant structures, and later vegetation features within at least one additional block from the edge of the assessment area should also be included in the model domain.
- The wind assessment should aim to include all features greater than 1 m in dimension.
- The wind assessment can use CFD software and/or a wind tunnel.
- A wind study using the wind comfort and safety standard approach should include at least eight wind direction sectors.
- The wind assessment must use the wind climate file provided.
- The wind assessment should use a standard geometry file (that can be provided).
- Show that the existing wind modelling results reflects reality

13. Cyclist considerations

There has been discussion on how practical it could be to require mitigation for cycle lanes. One challenge of this is that wind speeds tend to be higher on streets due to channelling effects down streets and between buildings, and wind acceleration around exposed corners of buildings. For example, a new building on a corner could potentially increase wind speeds much more than a new buildings in the centre of a block.

For a new development, a wind assessment could be required to cover an adjacent cycle way to show that wind conditions do not exceed a certain level, such as one of the criteria from the NEN 8100 wind standard.

Appendix A – CFD models for CBD area

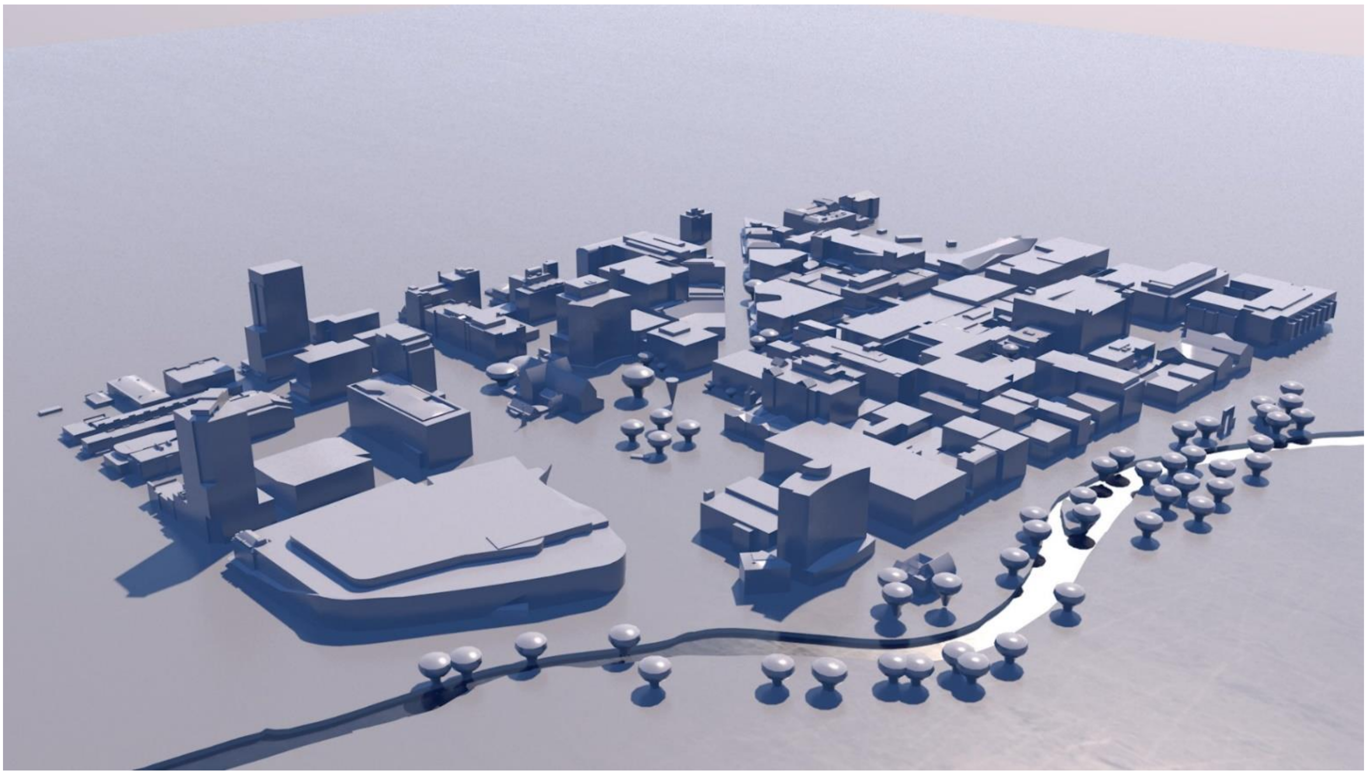


Figure 2: Existing Christchurch CDB model

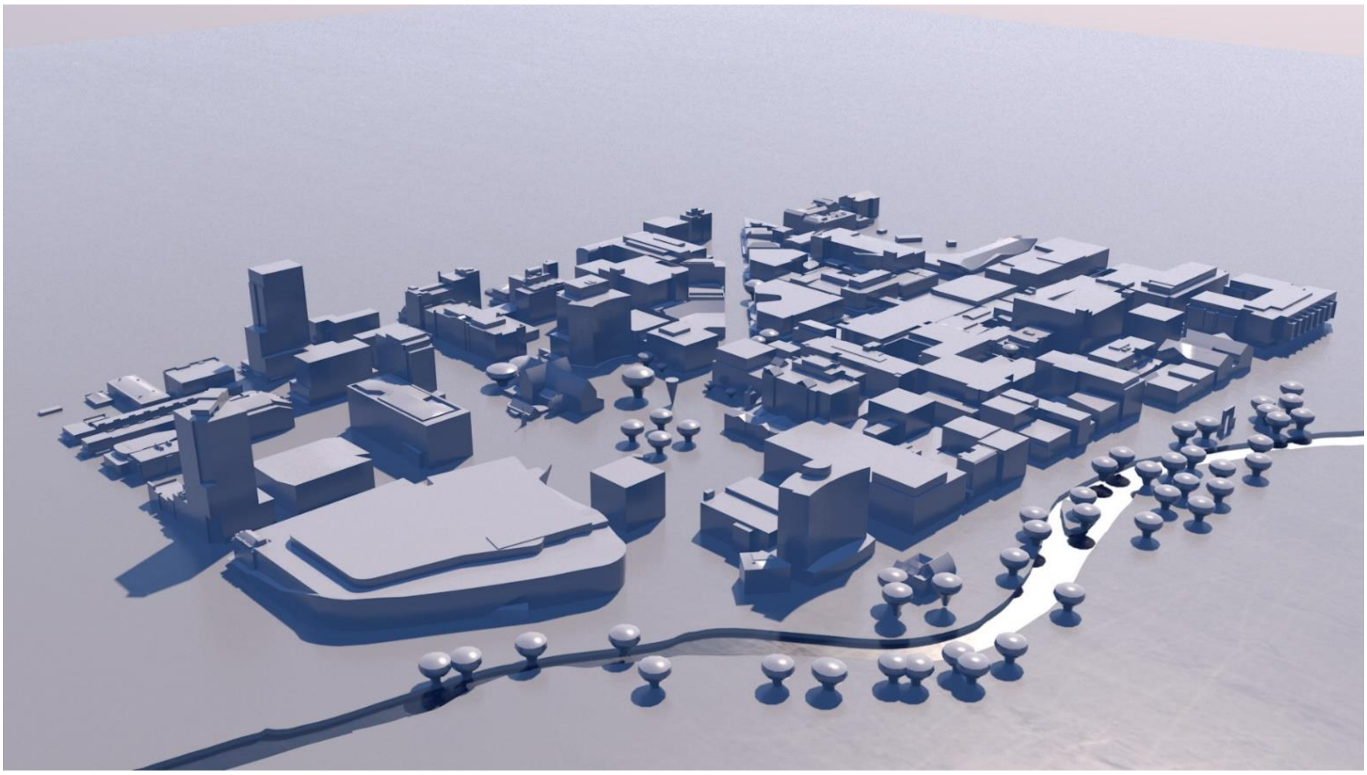


Figure 3: Christchurch CDB model with added 30 m high buildings

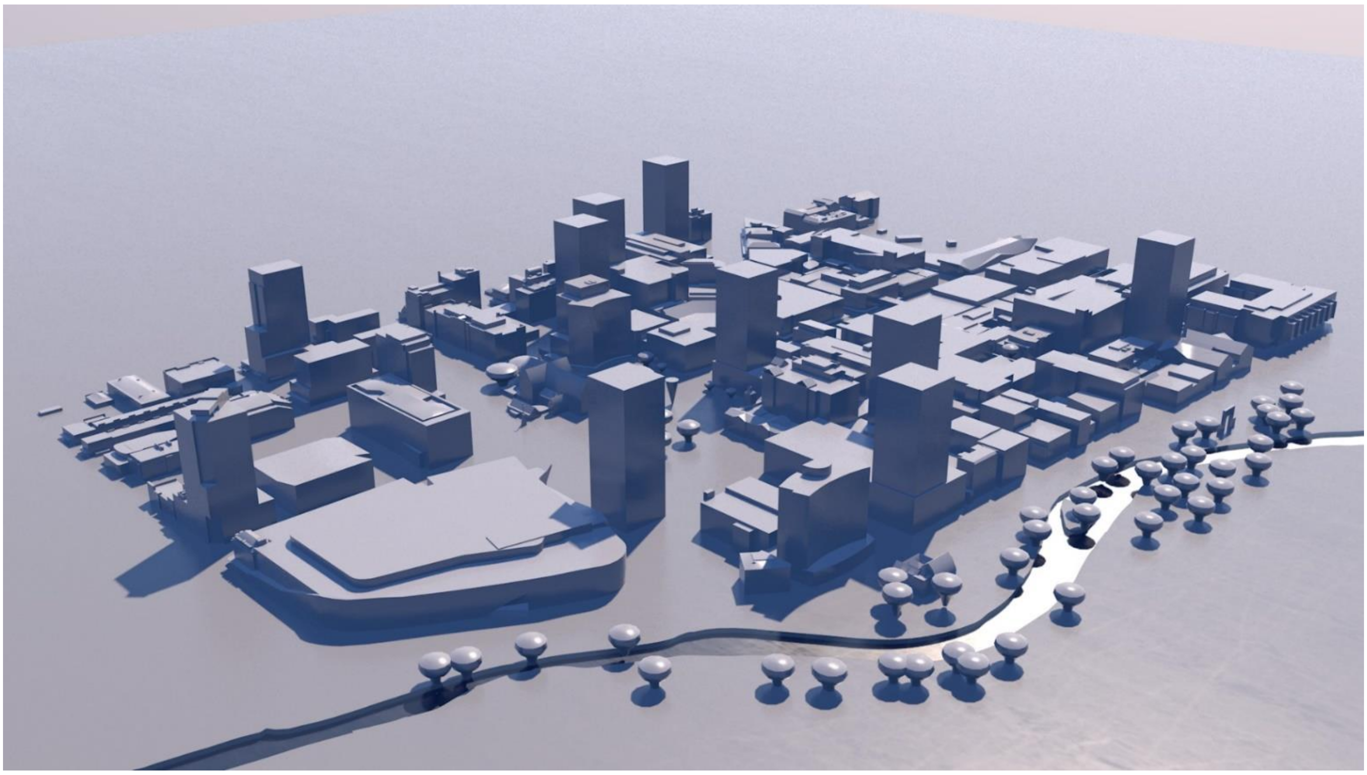


Figure 4: Christchurch CDB model with added 90 m high buildings

Appendix B – CFD models for high density residential area

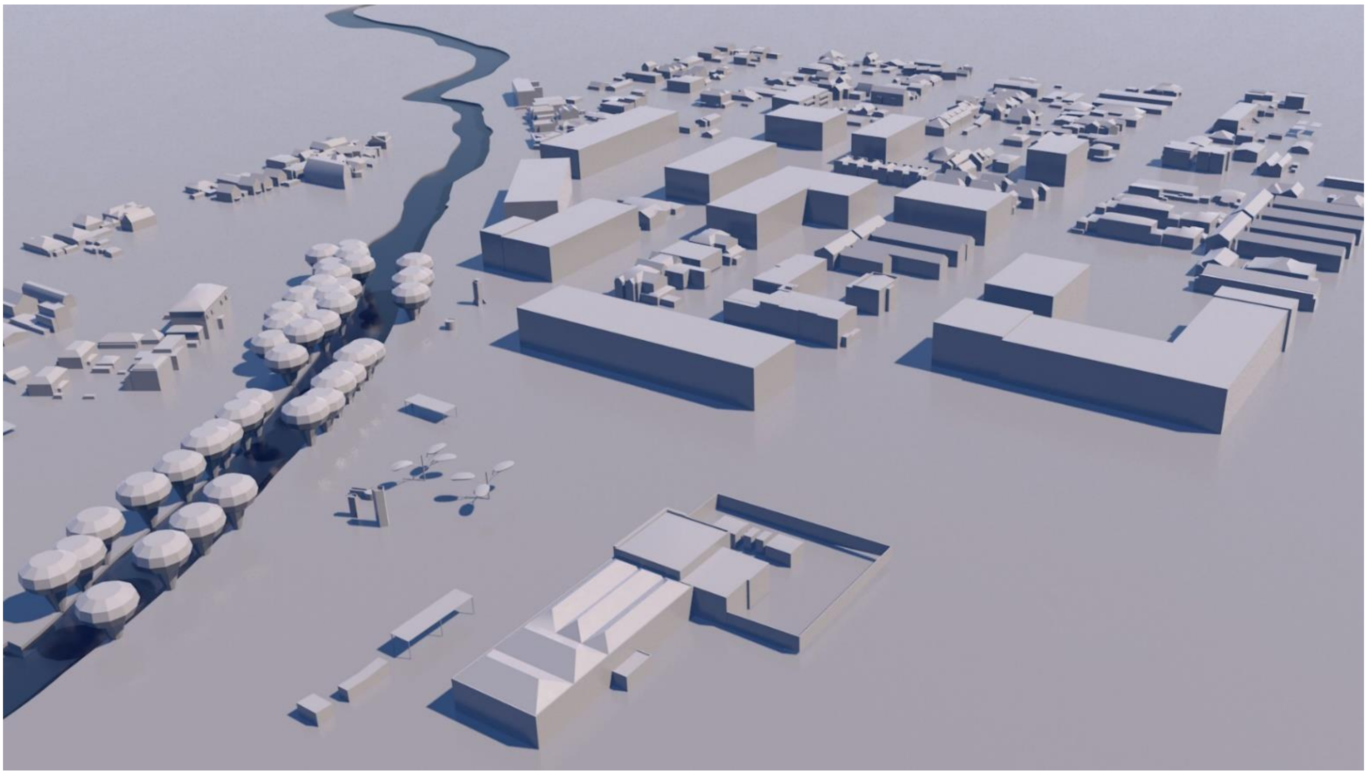


Figure 5: Christchurch residential model with added 6-story high buildings

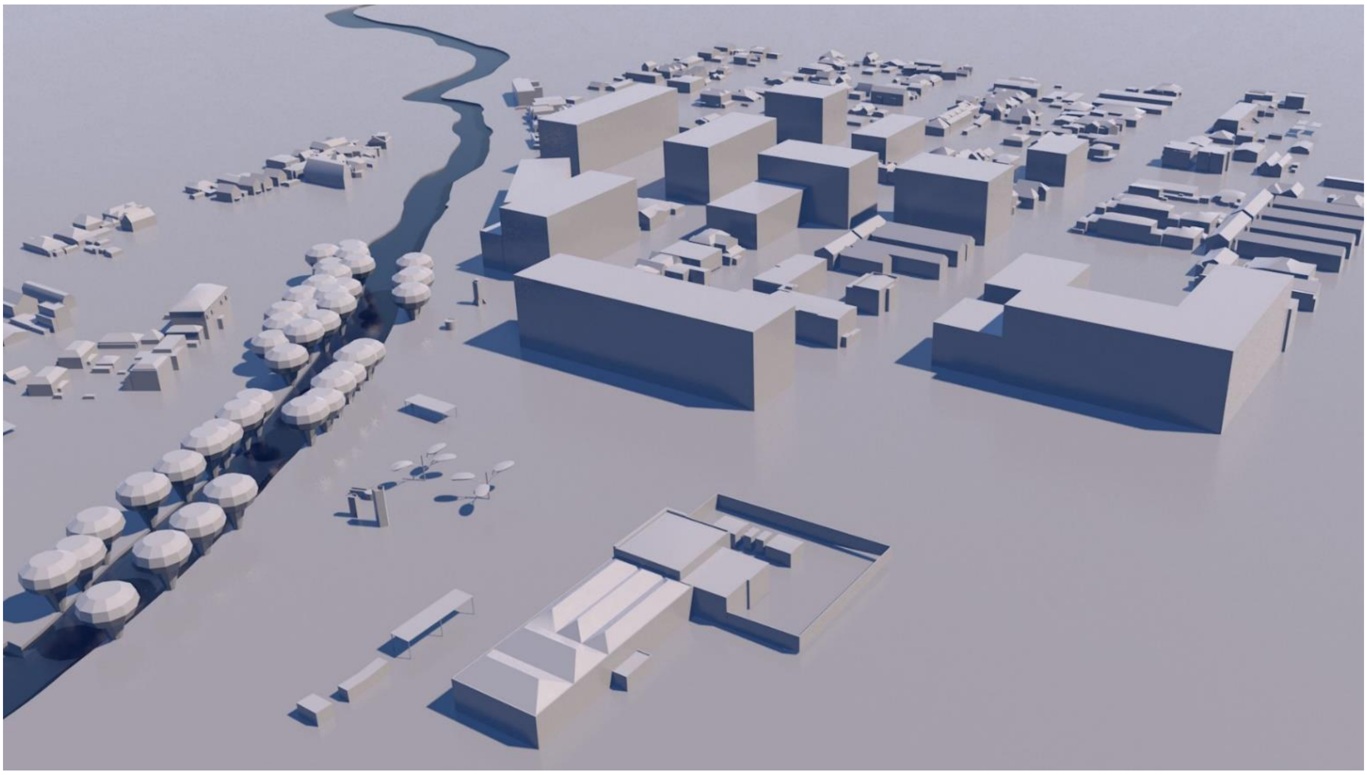


Figure 6: Christchurch residential model with added mixed 6 and 10-story high buildings