PEDESTRIAN LEVEL WIND STUDY TERMS OF REFERENCE GUIDE

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IN COLLABORATION WITH:

RWDI

TABLE OF CONTENTS

LIST OF APPENDICES

1 DESCRIPTION

Pedestrian Level Wind Study (hereafter called 'Wind Study') is a technical report that provides a model and written description that is to deliver consistent and fulsome wind analysis as a result of a development proposal. The Wind Study will determine the wind impact of a development, inform and direct the development design to be wind responsive, and ensure that wind conditions on and around the development are adequate at various times of the year. This document provides Terms of Reference for Wind Studies where required as part of the planning applications.

Wind is a crucial parameter that defines human comfort. The mechanical force of wind on people can impact daily common activities in varying levels. Typically, the higher the wind speed, the greater the wind force on a person; the more active a person is in an instance, the greater the wind speed one can tolerate. The Pedestrian Level Wind Study - Terms of Reference deals with the wind effects on people and how conducive it is to pedestrian use of outdoor areas.

2 RATIONALE

These standards are intended to reduce undesirable wind activity, and to create comfortable spaces that align with outdoor pedestrian usage throughout the year.

Properties or circumstances of a project, such as the scale, shape, height, location, density of surroundings, proximity to important areas, etc. that, through precedents, are known to be causative factors for noticeable wind impacts around the project are referred to as "triggers". If the project meets the specifications under the following triggers, then a wind assessment would be required for the project.

Note, wind assessments are required for habitable buildings, and do not apply to structures such as farm buildings, communication towers, etc.

2.1 Height Triggers

Low Trigger: A Qualitative Wind Assessment may be required for a development comprised of two or more buildings in close proximity that is at least 16 m or 5 storeys in height . Nevertheless, a Qualitative Wind Assessment will be required for all development that is 35 m or 10 storeys in height or greater, where development does not fall under a High Trigger.

High Trigger: A Quantitative Wind Assessment may be required for a development that is 40 m or 12 storeys in height or greater.

Note, a Quantitative study may be required for lower building heights where a Qualitative Wind Assessment indicates uncomfortable or potentially unsafe wind conditions at a pedestrian level.

3 REQUIREMENTS

3.1 Who Can Conduct a Wind Study?

A Wind Study must be prepared by a qualified microclimate professional. The studies are to be signed and sealed by a Professional Engineer. If a Wind Study is prepared by an individual or company that does not have extensive experience in pedestrian level wind evaluation, an independent peer review may be required at the expense of the applicant.

3.2 Types of Pedestrian Level Wind Studies

Depending on the Trigger Level, the Region of Niagara accepts two types of wind studies:

1. **Qualitative Wind Study:** A desktop assessment using computational fluid dynamics (CFD).
2. **Quantitative Wind Study:** A scale model study using a boundary-layer wind tunnel.

Requirements for the application process for the two Trigger Levels and the types of study required are described in Table 1.

TABLE 1: APPLICATION PROCESS AND WIND STUDY TYPE

The methodology and specifications for each study type is described in the Appendix.

Trigger Level	Low	High
OPA/ZBA Application	Qualitative Assessment (i.e., Desktop assessment using computational fluid dynamics, CFD)	Quantitative Assessment (i.e., Wind tunnel study)
SPA Application	• A quantitative assessment may be required if a qualitative assessment concluded there would be uncomfortable or unsafe conditions, and no quantitative assessment has been done. • If the project did not go through an OPA/ZBA process or it went through an OPA/ZBA process, but there have been significant changes (i.e., revisions to built form height and massing), wind impacts of the new design should be confirmed using the same type of wind study conducted for the final OPA/ZBA submission. • If the project went through an OPA/ZBA process, and there have been no significant changes, an additional wind study is not required upon the confirmation of wind consultant. • The type of wind study required is at the discretion of the City.	

3.3 Technical Requirements

The following is a summary of the technical requirements for a Wind Study. Detailed information is provided in the Appendix.

  - The use of long-term wind data can be obtained from ***Niagara International Airport, Niagara Falls, New York***

- The Wind Study should use the pedestrian wind criteria to evaluate wind comfort and safety as outlined in this document (Table 2 in Appendix).

- To determine the wind impact associated with a new development, the predicted wind conditions should be related back to the Existing Scenario. Note that the Existing Scenario should include both existing buildings as well as approved planning applications for new buildings surrounding the property. Additional Scenarios may be evaluated as required.
- Based on the Trigger Level, a Qualitative Assessment using computational fluid dynamics or a Quantitative Assessment using a boundary-layer wind tunnel should be pursued. The specific requirements for each study type are outlined in the Appendix.
- Potential wind mitigation solutions and/or recommendations for revised building massing should be detailed in the Wind Study.

4 APPLICATION PROCESS

4.1 Communication with the City

- Prior to applying, the Applicant shall consult with the City and attend a pre-consultation meeting where the requirements will be determined based upon the triggers described in this document.
- Prior to applying, wind measurement locations or influence areas should be discussed and confirmed with the authority requesting the study. General guidelines for areas of interest are described in the Appendix.
- To confirm the accuracy of the scale model for the wind tunnel study, the Applicant may be asked to submit test scenarios for review by the City, prior to any wind testing or simulation.
- If the wind study indicates that the proposed development is predicted to produce wind conditions that are considered unsafe or unacceptable, the City shall be consulted to discuss potential wind mitigation strategies going forward.

4.2 Official Plan and Zoning By-Law Amendment (OPA/ZBA)

The submission to the City should include a wind study report that shows satisfactory wind conditions on and around the project. If needed, wind control measures should be implemented, and their effectiveness demonstrated through additional studies.

4.3 Site Plan Control Application (SPA)

A wind study is required if significant design changes have been made since the previous submission to evaluate the project’s performance and ensure it continues to satisfy the recommended wind criteria. The consultant’s professional opinion regarding the changes is to be presented in writing to inform this decision. The City may ask for additional studies.

Examples of significant design changes are described in the Appendix (Section A.6.2). The design submitted should incorporate all recommendations from previous submissions.

4.4 Tourist Area Developments in Proximity to the Falls

In addition to the above, a wind study is required for any building with a height of 35 metres or 10 storeys in height or greater and in proximity the Falls or Queen Victoria Park, as determined in consultation with the Niagara Parks Commission. Such analysis is to provide at minimum a qualitative analysis to determine microclimate impacts, if any, on misting and wind conditions adjacent to Niagara Falls or in Queen Victoria Park. This requirement may be scoped or waived in consultation with the Niagara Parks Commission.

APPENDIX

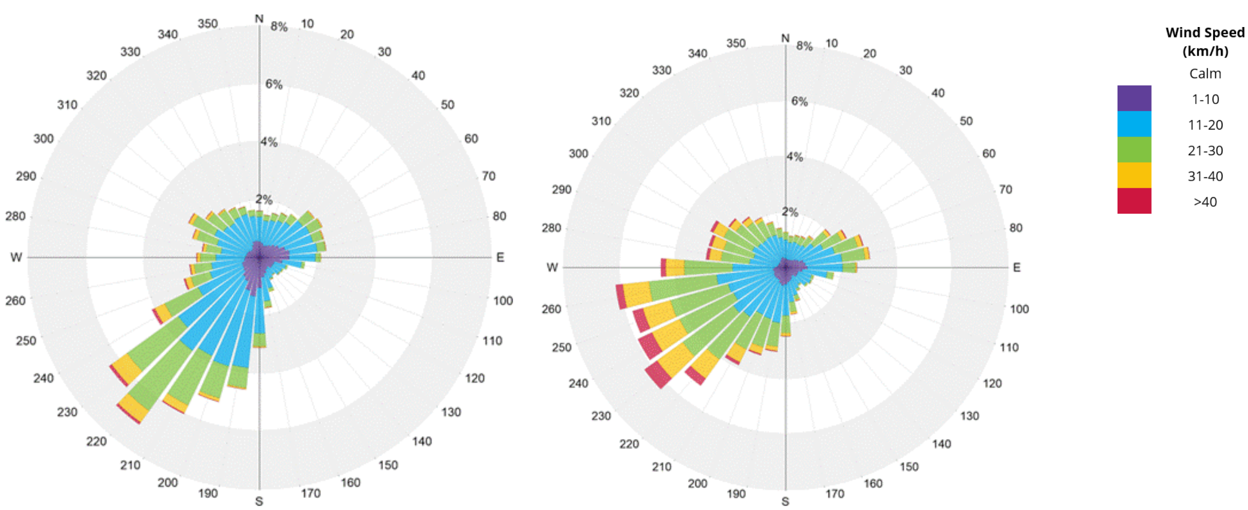
APPENDIX: METHODOLOGY AND SPECIFICATIONS

A1 Meteorological Data

Long-term wind data recorded in major airports are often used in the prediction of pedestrian wind conditions. In the Niagara Region, wind climate is affected by the adjacent Lake Ontario and Lake Erie and wind data obtained from Niagara International Airport, Niagara Falls, New York can be used to conduct pedestrian wind studies:

Wind data should be presented on a two-season basis: Summer (defined as May through October), and Winter (defined as November through April). Appropriate hours of pedestrian usage for a typical project (i.e., between 06:00 and 23:00) should be used for wind comfort, while data for 24-hours should be used to assess pedestrian wind safety. The wind roses obtained from each meteorological station is provided in Images 2 and 3 for both seasons.

Image 2: Directional Distribution of Winds Approaching Niagara Falls International Airport (1991 to 2020)



Summer (May to October)

Winter (November to April)

A.2 Wind Criteria for Pedestrian Comfort and Safety

The public realm, streetscapes and public/private outdoor open spaces related to the existing and proposed buildings are to be comfortable for their intended use. Table 2 describes the minimum criteria for specific locations. The criteria deal with comfort and safety of pedestrians:

Comfort: Commonly experienced wind speeds have been categorized into ranges based on the activity level of a person that the winds would be conducive to. Lower wind speeds are desirable for passive activities and active pedestrians would be tolerant of higher wind speeds.

Safety: It is important to assess wind conditions in the pedestrian realm from a safety perspective as strong wind gusts can deter safe pedestrian use of outdoor spaces. Wind speeds associated with wind gusts are infrequent but deserve special attention due to their potential impact on pedestrian safety.

TABLE 2: WIND CRITERIA FOR PEDESTRIAN COMFORT AND SAFETY

Comfort Category	GEM Speed (km/h)	Minimum Occurrence (% of Time)	Description	Area of Application
Sitting	≤ 10	80	Light breezes desired for outdoor seating areas where one can read a paper without having it blown away.	Park benches, restaurant and café seating, balconies, amenity terraces, children's areas, etc. intended for relaxed, and usually seated activities.
Standing	≤ 15	80	Gentle breezes suitable for passive pedestrian activities where a breeze may be tolerated	Main entrances, bus-stops, dog areas, and other outdoor areas where seated activities are not expected.
Walking	≤ 20	80	Relatively high speeds that can be tolerated during intentional walking, running and other active movements.	Sidewalks, parking lots, alleyways, and areas where pedestrian activity is primarily for walking.
Uncomfortable	> 20	20	Strong winds, considered a nuisance for most activities.	Not acceptable in areas with pedestrian access

NOTES:

1) Gust Equivalent Mean (GEM) speed = maximum of either mean speed or gust speed/1.85. The gust speed can be measured directly from wind tunnel or estimated as mean speed + (3 x RMS speed).
2) Comfort calculations are to be based on wind events recorded between 6:00 and 23:00 daily.

Safety Criterion	Gust Speed (km/h)	Minimum Occurrence Annual	Description	Area of Application
Exceeded	> 90	0.1% (9 hours in a year)	Excessive gust speeds that can adversely affect a pedestrian's balance and footing. Wind mitigation is typically required.	Not acceptable in any area of interest

NOTES:

3) Safety calculations are to be based on wind events recorded for 24 hours a day

A.3 Configurations

A Wind Study report should present the following scenarios:

- **Existing Scenario:** Existing site and all existing surrounding buildings, significant topographic features, developments under construction and projects that were approved for construction in the last 5 years.

- **Proposed Scenario**: Proposed project in place of existing site.

- **Mitigation Scenario(s), if warranted:** Undesirable wind conditions can be mitigated through various measures ranging from building massing changes to landscaping elements. Where mitigation is required to achieve acceptable pedestrian wind comfort levels, mitigation measures should be implemented in the Proposed configuration scenario to demonstrate the benefits of the mitigation strategies.

- **Phasing Scenario(s), if applicable:** Where the site construction is phased, there is a need to assess interim scenarios, as well as scenarios that may create adverse conditions before subsequent buildings are added to the site. The City may ask for the study of different site scenarios.

A.4 Areas of Interest

Wind studies will focus on the public realm and shared open space(s) on the site and adjacent to the site including:

- Sidewalks (public and private) adjacent to the development, building entrances and building perimeters on the site and adjacent to the site,
- Privately Owned Public Spaces (POPS) on site and on adjacent sites,
- Public parks, recreational areas, school yards, ravines, and other recreational areas on or adjacent to the site,
- Above-grade pedestrian locations, including outdoor shared amenity space, roof terraces, for the building and adjacent to the site, and
- City staff may ask for additional areas of interest for the wind assessment.

A.5 Specifications for Wind Studies

A.5.1 Qualitative Assessment

As outlined in Table 1, a Qualitative Assessment may be conducted as a Desktop Assessment using computational fluid dynamics (CFD).

A Desktop Assessment is based on CFD simulations the existing and proposed configurations, together with the wind consultant’s experience and professional judgement. Example computational fluid dynamics simulation results is shown in Image 4.

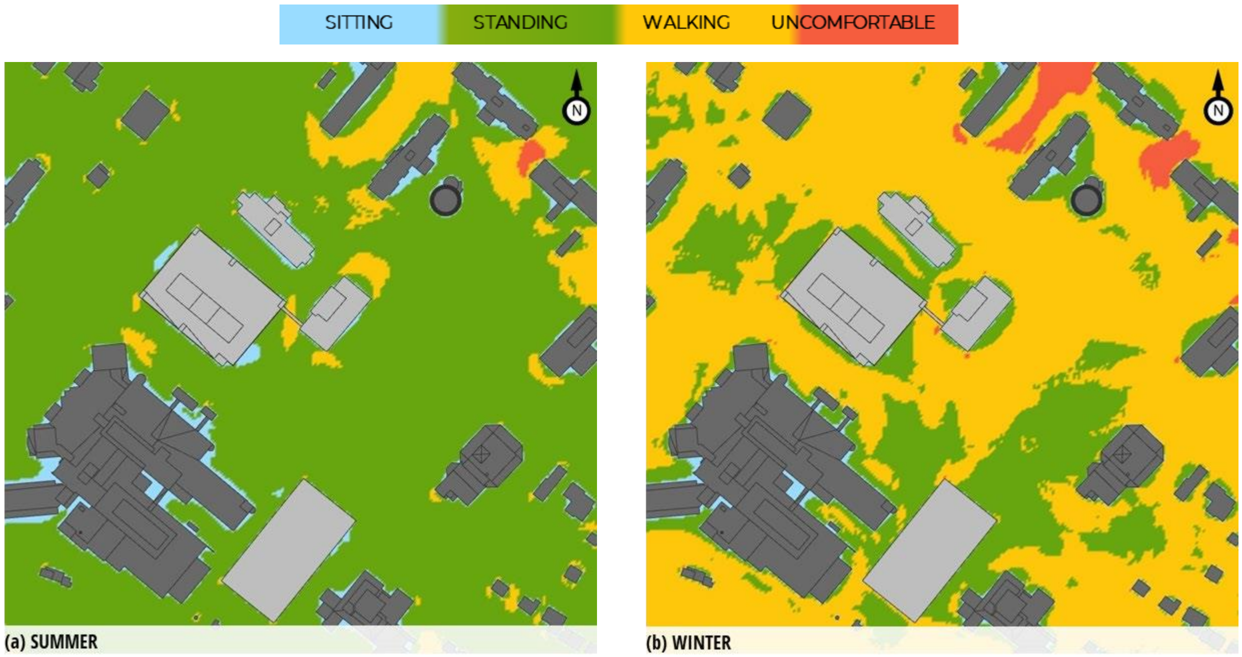


Image 4: Example Computational Fluid Dynamics Simulation Results

Requirements for a Desktop Assessment:

- A prediction of wind speeds at critical locations around a proposed development, while acknowledging the primary wind directions and frequencies of strong wind events.
- The use of the standard wind comfort and safety criteria and the meteorological data outlined in this document.
- Where wind conditions are considered unacceptable for the intended pedestrian usage, mitigation concepts and recommendations should be presented to improve wind conditions.

CFD is a numerical modelling technique for simulating wind flow in complex environments. For wind modelling, CFD techniques are used to generate a virtual wind tunnel where flows around the site, surroundings and the study building are simulated at full scale. The computational domain that covers the site and surroundings is divided into millions of small cells where calculations are performed, allowing for results to be presented in high spatial resolution. There are no limitations to the number of points of measurement and results can be obtained from any data point in the computational domain even after the simulation is over. CFD allows for the “mapping” of wind conditions across the entire study-domain.

CFD excels as a tool for wind modelling for providing early design advice, resolving complex flow physics, and helping diagnose problematic wind conditions. It is useful for the qualitative assessment of complex buildings and contexts and provides a visual representation of the potential wind conditions which makes it easy to judge or compare designs and site scenarios. CFD is not suited to predicting wind patterns for safety-based design issues on buildings. It struggles to accurately predict flow separation, turbulent eddies (circular movement of air) and gusts (brief but strong rush of wind). It is these types of flow behaviour that can cause pedestrian discomfort and safety concerns.

Requirements for a CFD Study:

- Software
  - The CFD software used should follow the COST 732 Best Practice Guideline for CFD Simulations.
  - The CFD simulation should appropriately represent the atmospheric boundary layer for winds approaching the project.
  - The user or the Consultant should be confident with the results produced and ensure that it is technically correct.
- A minimum of sixteen (16) wind directions at equal intervals, as follows, shall be simulated.
- Analysis and Results
  - Wind speeds shall be presented in km/h.
  - Assessment should be done for all areas of interest.
  - The processing of results should consider the probability of all wind directions simulated using meteorological data as described in the Appendix.
  - The results shall be presented for all areas of interest in the form of wind speed contours at a horizontal plane approximately 1.5 m above grade or the concerned level.
  - The results for seasonal comfort should be based on the wind comfort and safety criteria. Compliance with the annual safety criterion may be assessed numerically or using experience-based methods and areas where the criterion is assessed to be exceeded should be indicated graphically.

A.5.2 Quantitative Assessment

Wind tunnel testing is the established tool used for modelling wind flow around buildings and structures in order to quantify and assess wind conditions, among other types of assessments. A scale model of the study area and surroundings are placed in a wind tunnel, instrumented appropriately for wind speed measurements, and subjected to wind flows physically simulated to represent winds approaching the actual site (Image 5). In general, such modelling provides a quantified representation of both mean and gust effects and the transient behavior of wind. It is a complex tool and requires experience and expertise to produce useful information and to interpret data, and therefore are accessible only through consultants and universities that specialize in wind engineering.

Image 5: Example Study Model in a Boundary-Layer Wind Tunnel

- The wind simulation facility must be capable of simulating the earth's atmospheric boundary layer and appropriate wind speed and turbulence profiles for each of the wind directions tested.
- Wind Speed Measurement
  - 36 wind directions at equal intervals shall be tested
  - Sensors shall be omni-directional and shall measure the magnitude of horizontal wind speeds.
  - The measurements should represent the wind speed at a full-scale height of approximately 1.5 m above local grade.
  - Sensors and instrumentation should be capable of measuring mean wind speed and wind speed fluctuations with time, including peak gusts of three to ten second duration. Peak gusts can be directly measured from wind tunnel testing or estimated by "Mean + 3*RMS" wind speeds.
  - Sampling time in the wind tunnel shall represent a minimum of one hour of full-scale time and sampling frequency a minimum 1 Hz in full scale.
- Sensor Placement
  - Sensors shall be placed at a full-scale interval of approximately 10 m along street frontages of the project buildings and at all locations where pedestrians will gather. The interval may be increased farther away from the project site.

    - Locations to capture all areas of interest as described in Section A.4. Generally, it should include entrances to the project building(s) and major entrances to buildings across the street from the project in all directions, sidewalks, seating areas, bus stops, plazas, etc.
    - A typical development project would require a minimum of 50 sensor locations on and around the proposed development to provide adequate coverage.

- Analysis and Results
    - Wind speeds shall be presented in km/h.
    - The analysis should consider the probability of all wind directions tested using meteorological data.
    - The results shall be presented in both tabular and graphic forms for all the test scenarios, with seasonal comfort data and annual safety data.
    - The table of results must include wind speed and associated wind speed category at each measurement location.

A.6 Wind Responsive Design Guidelines

A.6.1 Basic Flow Patterns

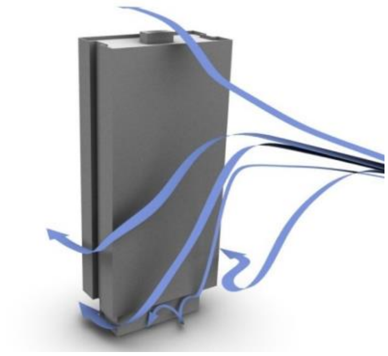
Wind speed increases with elevation; wind typically flows unobstructed and at high speeds over areas of uniform height (built structures or natural terrain). Short buildings typically do not deflect winds to a level that would result in adverse wind impacts. Wind, when obstructed by a structure such as a building, will find the path of least resistance to continue its motion, in the process, creating zones of high-wind activity around the building. The following is an overview of some of the common wind flow mechanisms seen in the built environment. One or a combination of such mechanisms could result in undesirable wind activity in the pedestrian realm, depending on the local climate, building form and its exposure to winds and the surrounding terrain.

Consider a tall building with the broad façade facing a strong wind stream. When the stream is intercepted by the building, some of the flow moves upward and over the building, but much of the stream is redirected downward (**Downwashing**) and around the lower portion of the building.

The flow attaches to the building, and then separates at the edges creating high wind activity at the corners (**Corner Acceleration**). This effect could be intensified if a short building is located upwind, because of the air pressure differential between the top and bottom of the building. The area between the buildings could be very windy as a result. However, strategic master planning uses this arrangement to an advantage as locating shorter buildings upwind of taller ones reduces the exposure of the taller and more impactful buildings to wind, thereby reducing the potential for adverse wind impacts.

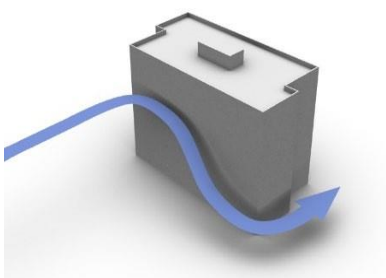
When gaps between buildings, that are narrow relative to the building heights, are aligned with the prevailing winds, wind accelerates in the gaps because of what's commonly called **Venturi effect**. A similar acceleration is also common under bridges and in underpasses as the air is forced to go through a narrow passage.

Typically, wind interacts with multiple buildings and the resulting flow is much more complex. Depending on the wind-rearrangement caused by building groups (or a single building on its own), the causative flow mechanisms involved and design flexibility, the choice between "spot-treatments" and measures that have a large-scale impact becomes critical.



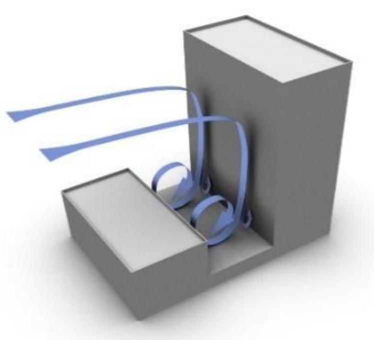
Downwashing Flows

Tall buildings tend to intercept the stronger winds at higher elevations and redirect them to the ground level. This is often the main cause for wind accelerations around large buildings at the pedestrian level.



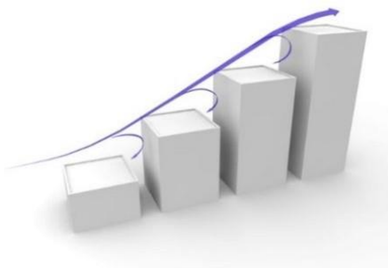
Corner Acceleration

When winds approach at an oblique angle to a tall façade and are deflected down, a localized increase in the wind activity or corner acceleration can be expected around the exposed building corners at pedestrian level.



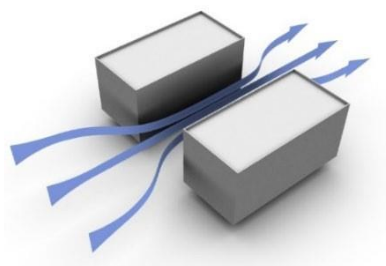
Short Building Upwind of Tall Building

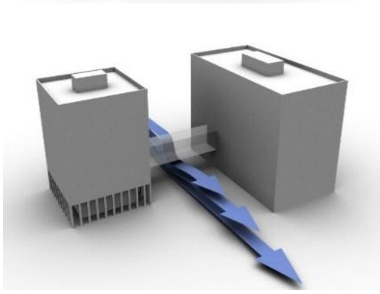
Shorter adjacent buildings have the potential to capture and accelerate downwashed winds.



Short Buildings Upwind Reduce Wind-Exposure of Downwind Buildings

Potential wind impacts would be moderated by stepped massing of the building as its location adjacent to shorter buildings or lower roofs of the neighbouring buildings disrupting downwash.





Venturi/Channelling Effect

When two buildings are situated side by side, wind flow tends to accelerate through the space between the buildings due to channelling effect caused by the narrow gap.

Image 6: Examples of Common Wind Flows

A.6.2 Wind Control Strategies

The most effective wind control measures involve adjustments to the building early in the design process and relate to the location, orientation, height, massing, and form of buildings. Such adjustments are more responsive to the local wind climate. These large-scale modifications can be assisted by features like tower setbacks, large podiums, tower shapes, corner articulations, colonnades/arcades, etc.

A description of three levels of wind control strategies, moving from large-scale to small-scale features, is provided following this section.

Building Form

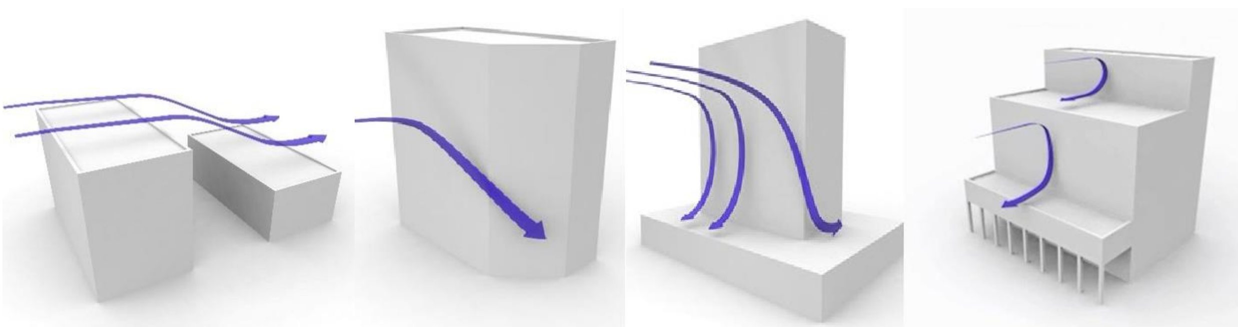


Image 7: Examples of Building Form Details for Wind Control

Strategic reshaping of the building can allow wind flow around it to be either more streamlined (chamfered or rounded corners) or diffused at the corners (stepped or re-entrant corners) (Image 7). Low buildings may also be designed with a stepped form to achieve a similar wind speed reduction. This approach is considered a large-scale solution that would lower the potential for severe wind impact at grade and has a large area of influence.

Architectural Details

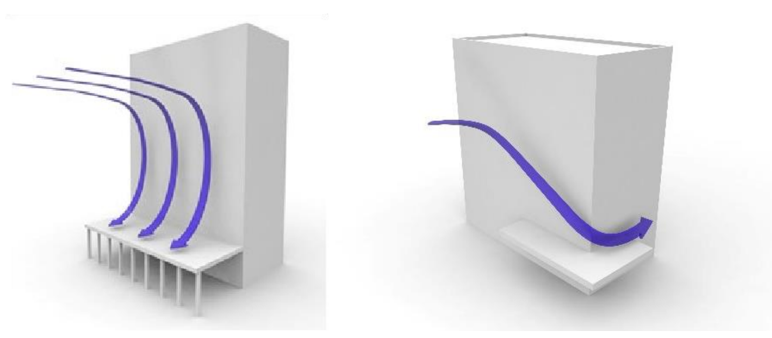


Image 8: Examples of Architectural Details for Wind Control

Features such as façade articulations, canopies, covered walkways and recessed entrances are effective solutions for localized wind mitigation (Image 8). Recessed walls create areas that will be protected from ambient wind activity. If entrances are in such recessed areas, it also creates a waiting area for patrons using the entrance, as well as a transition zone for patrons exiting to get acclimatized to the ambient conditions. Covered walkways, similarly, provide a protected area for pedestrians at the base of tall towers that are prone to downwashing impacts.

Localized Accessory Elements

Smaller-scale measures such as wind screens, trellises, street art, landscaping and other localized features can be considered at an advanced design stage, after all possible large-scale measures have been considered and implemented, for area-specific wind speed reductions and refinements. The impact of these features is typically limited to a small area around them.

Wind screens may be placed on both sides of entrances, on private sidewalks and other amenity spaces on private lands to create localized low wind areas. It is recommended that wind screens be at least 2 m tall and approximately 30% open/porous for good wind control efficacy. Landscaping elements, especially coniferous and marcescent species, are commonly used to improve wind conditions to appropriate levels, all year round. Deciduous landscaping is most effective during the summer months. The use of landscaping as part of a mitigation strategy is acceptable but should be selected and sized to be effective at the time of installation. Landscaping can only be recommended as a mitigation measure, where the wind conditions are suitable for it to thrive and for its maintenance. See photos in Image 9 for examples.

Note, localized accessory elements must be located on private lands of the development parcel and not placed within the public realm or road allowance.

Image 9: Examples of Effective Localized Accessory Elements