PEDESTRIAN LEVEL WIND STUDY TERMS OF REFERENCE GUIDE

Prepared by:

City of Toronto
Urban Design, City Planning

In collaboration with:
RWDI

TABLE OF CONTENTS

1 DESCRIPTION

Pedestrian Level Wind Study (hereafter called ‘Wind Study’) is a technical report that provides a model and written description that is to provide consistent and comprehensive wind analysis as a result of a development. 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 in and around the development are adequate at various times of the year. This document is a guide to the Terms of Reference for wind studies required as part of the planning applications of development proposals in the City of Toronto.

To aspire to meet the Official Plan goals of promoting civic life, use of the public realm and comfortable pedestrian experience, it is important to consider the potential impacts of a proposed development on the local microclimate early in the planning and design process. This allows sufficient time to ensure comfortable wind conditions and air circulation on the public realm and adjacent open spaces are provided. It also ensures appropriate wind control and mitigation strategies to preserve the utility and intended use of these areas.

Wind Comfort

Wind is one of the crucial parameters 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 Terms of Reference deal with the mechanical and safety effects of wind on people and how conducive it is to pedestrian use of outdoor areas in the City. Thermal comfort is further addressed in the policy of the City of Toronto, and some aspects of the thermal comfort evaluation may be incorporated in a future edition of the City's Terms of Reference.

2 RATIONALE

To reduce the amount of undesirable wind activity, allow proper air circulation and to create comfortable spaces that align with outdoor pedestrian usage throughout the year.

To achieve the goals of Official Plan Policies:

3.1.3.1 “Development will be located and organized to fit with its existing and planned context. It will frame and support adjacent streets, lanes, parks and open spaces to promote civic life and the use of the public realm, and to improve the safety, pedestrian comfort, interest and experience, and casual views to these spaces from the development by: f) providing comfortable wind conditions and air circulation at the street and adjacent open spaces to preserve the utility and intended use of the public realm, including sitting and standing"

3.1.3.13 "Outdoor amenity spaces should: d) provide comfortable wind, shadow and noise conditions;"

3.1.4.10 "The tower portion of a tall building should be designed to: d) limit and mitigate pedestrian level wind impacts."

3.2.3.3 "The effects of development from adjacent properties, including additional shadows, noise, traffic and wind on parks and open spaces will be minimized as necessary to preserve their utility

3.1.1.18 "New parks and open spaces will be located and designed to: c) provide a comfortable setting with wind and sunlight conditions that promote use and enjoyment of the space for community events and by users of all ages and abilities;"

3 WHEN REQUIRED

Triggers

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 in and around the project are referred to as “triggers”. In this section The City of Toronto categorized triggers to: height related to geographical location, and additional (special) conditions such as context.

If the application meets the conditions specified under the list of triggers, then a wind assessment would be required for the project.

3.a. Height Triggers

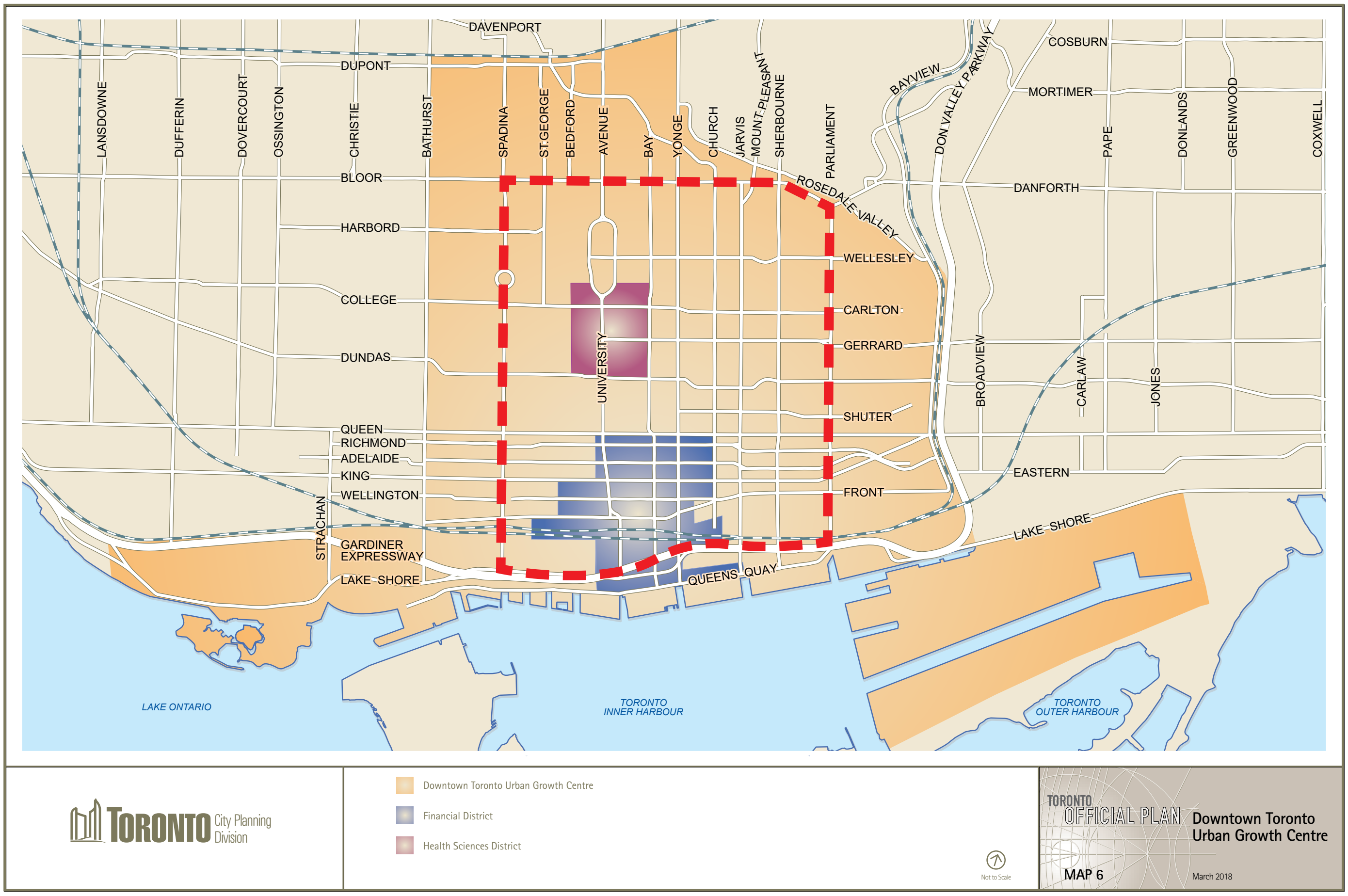
Project height triggers are classified into three levels – Low, Moderate and High – and are related to the location of the project.

Table 1 provides the height classification and **Map 1** provides the location classification.

TABLE 1: HEIGHT TRIGGERS

Trigger Level / Location	Low	Moderate	High
AREA 1 (Refer to Map 1)	>20 m and <60 m	>60 m and <100 m	>100 m
AREA 2 (All areas of Toronto except Area 1)	>20 m and <40 m	>40 m and <60 m	>60 m

Map 1: Boundary of Area 1



AREA 1 INCLUDES PROJECTS IN BLOCKS ALONG THE BOUNDARY OF AREA 1, AS DEFINED BY MAJOR STREETS AS SHOWN IN OFFICIAL PLAN MAP 3

3.b. Additional Triggers

Following the Height Trigger classification of the project, if one or more of the following apply to the project, the project will shift to the next higher Trigger Level.

- Projects with two or more buildings that are six storeys or 20 m in height or taller.
- Projects with a building(s) that is six storeys or 20m in height or taller, and located on the waterfront, adjacent to parks and ravines, other open spaces, cultural and natural heritage areas, schools, playgrounds and outdoor recreational spaces, and other areas deemed pedestrian sensitive at the discretion of the City of Toronto.

4 APPLICATION PROCESS

The City of Toronto accepts two types of wind studies:

- WTS (Wind Tunnel Study). A physical model tested in a wind tunnel.
- CFD (Computational Fluid Dynamics Study). A digital model tested with a software.

There are two types of CFD assessments:

- CFD Phase 1 (Preliminary Massing CFD): Intended to provide preliminary information. Required for the first application submission, and encouraged to be provided at the pre-application stage.
- CFD Phase 2 (Application Submission CFD): Intended to provide a more comprehensive wind analysis. Required for Zoning By-Law Amendment (ZBA) applications, and may be required for Official Plan Amendment (OPA) and/or Site Plan Control (SPA) applications.

If a CFD Phase 1 (Preliminary Massing CFD) was not provided at pre-application stage, it will be required as part of the application submission, in addition to the CFD Level 2.

Requirements for the application process and the type of study are described in Table 2

Communication with the City

- Prior to submission of a planning application, based on the triggers described in this document, the Applicant shall consult with City Planning, to agree upon the most appropriate approach for the wind study. This consultation may also take place at the pre-application consultation stage.
- Prior to submission of a planning application, wind-measurement locations or influence areas should be discussed and confirmed with City Planning. General guidelines for areas of interest are described in Section 5.2 Areas of Interest.
- To confirm the accuracy of the physical context being modelled for the wind study, the Applicant may be asked to submit documentation of the test scenarios for review by the City's Planner and Urban Designer prior to any wind testing/simulation.
- If the wind study shows that the proposed development is predicted to produce wind conditions that are considered unacceptable, the City's Planner and Urban Designer shall be consulted to discuss potential strategies going forward.

Pre-Application Consultation

A CFD Phase 1 (Preliminary Massing CFD) study report is encouraged for developments that meet the criteria for Moderate and High Trigger. Objectives of this study are to explore the following at early stages of the development design:

- The possibility of improving the existing wind conditions
- Potential impact of wind speed increases created by the development on the surroundings
- Design changes strictly relating to the massing, orientation and positioning of the development that can minimize its wind impact

The planning application submitted to the City should include a Computational Fluid Dynamics (CFD Phase 1: Preliminary Massing CFD) wind study report that demonstrates the wind impact of the proposed massing and a description of design changes that will be adopted to achieve acceptable wind conditions in and around the project as the project moves forward. This information is encouraged to be provided at the Pre-Application Consultation Stage. See the Appendix for further information.

Strategies adopted for wind control should relate to the location, orientation and form of the building(s). Landscaping is not to be included at this stage. General factors to be addressed in order to reduce the wind impact of the project in the preliminary massing study include the following:

- Height of the proposed development in relation to the height of surrounding built form
- The orientation of the building(s) in the development with respect to the primary wind directions
- Location of building(s) on the project site relative to open spaces and public realm
- Location and shape of specific design features and form articulation that impact wind activity

The City, at their discretion, may ask for additional massing studies.

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

The submission to the City should include a wind study report that shows satisfactory wind conditions in and around the project. If needed, wind control measures should be implemented, and their effectiveness demonstrated through additional studies submitted as part of the complete application, following the information provided in the Appendix.

At least two Wind Studies will be requested for a ZBA/OPA application. If a CFD Phase 1 (Preliminary Massing CFD) was not provided at pre-application consultation, it will be required as part of a complete application, in addition to the CFD Phase 2/ WTS. Applicants should consult with City Planning on the timing of the CFD Phase 2 (Application Submission CFD) to support a ZBA/OPA application."

Site Plan Control Application (SPA)

A wind study is required if significant design changes have been made since the previous accepted Wind Study 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, at their discretion, may ask for additional studies.

Examples of significant design changes and mitigation guidelines are described in the Appendix. The design submitted should incorporate all recommendations from previous submissions.

TABLE 2: APPLICATION PROCESS AND WIND STUDY TYPE			
Study Types and the required content in the wind study report for each are described in the Appendix.			
Trigger Level / **Process**	**Low**	**Moderate**	**High**
OPA/ZBA/SPA Pre-Application (encouraged)	N/A	CFD Phase 1	CFD Phase 1
OPA/ZBA Application ***	CFD Phase 1 (Preliminary Massing CFD)* CFD Phase 2 (Application Submission CFD)**	CFD Phase 1 (Preliminary Massing CFD)* CFD Phase 2 (Application Submission CFD) **	CFD Phase 1 (Preliminary Massing CFD) * WTS
SPA Application	• If the project went through an OPA and/or ZBA process, and there have been significant changes, 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 and or / ZBA process, and there have been no significant changes (as described in the Appendix), additional wind study is not required. • If the project did not go through a recent OPA and/or ZBA process, the two wind studies may be required.		

* If not provided at Pre-Application Consultation Stage
** At OPA and/or ZBA stages, a WTS may be required depending on consultant's recommendation
*** The CFD and/or WTS may need to be resubmitted as part of the development application review and circulation process if there are significant changes to built form and massing

5 REQUIRED CONTENTS

5.1 Project Context Scenarios / Massing Scenarios

Wind Study Reports for all stages should present the following scenarios:

- **Existing Scenario:** Existing site and all existing context including surrounding buildings, significant topographic features, developments under construction and projects that were approved in the last 5 years. Additional information for modeling can be found in the Appendix.

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

- **Mitigation Scenario(s), if required:** Undesirable wind conditions should be mitigated primarily with changes to the building siting and massing. Where mitigation is required to achieve acceptable pedestrian wind comfort levels, mitigation measures should be implemented to the Proposed Scenario in order to demonstrate the benefits of the mitigation strategies.

The acceptable mitigation methods are described in the Appendix, in the Wind Control Strategies section.

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

Large Projects and Design Configuration

Projects with two or more buildings which includes a piece of the public realm, park, street, or POPS.

At their discretion, City Planning may request different design and configuration options when reviewing applications related to Large Projects.

5.2 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) within the development and adjacent to it
- Major entrances on the proposed development and adjacent buildings on all sides
- Public and private open space surrounding building on the site and adjacent to the site, such as laneways
- Privately-Owned Publicly Accessible Spaces (POPS) on site and on adjacent sites
- Public parks, recreational areas, school yards, ravines, and other recreational areas and open spaces on or adjacent to the site
- Publicly accessible above-grade locations, including outdoor shared amenity space, roof terraces, for the building and adjacent to the site

The City may ask for additional areas of interest for the wind assessment.

5.3 DESIGN CRITERIA

Comfort and Safety Criteria must be met for all development applications and should comply with Table 3 in the Appendix.

- Pedestrian wind comfort and safety assessment shall be done for four seasonal periods: spring (March to May), summer (June to August), fall (September to November) and winter (December to February).
- The criteria must be used as a guide for massing design for a CFD Phase 1 (Preliminary Massing CFD) study, and the criteria for comfort and safety must be met for a CFD Phase 2 (Application Submission CFD) study and WTS.
- Note that outdoor usage of pedestrian areas may vary with seasons. For additional information see the Wind Criteria for Pedestrian Comfort and Safety in the Appendix.

5.4 DOCUMENTATION

Upon request from City Planning, the applicant will provide the relevant information for the application:

- Long-term meteorological data that was used for calculation
- Documentation of all relevant scenarios and the physical context being modelled:
    - o For CFD, the applicant will provide the 3D model for each scenario that was used. The 3D model should comply with the technical specifications described in the City of Toronto Application Support Material: Terms of Reference, Computer Generated Building Mass Model.
    - o For WTS, the applicant will provide a clear plan with dimensions, step-backs, massing and heights.

5.5 REPORT

A written report documenting the wind study and conclusions, including the following, should be provided for every stage of the process:

- Template A, located at the front of the Wind Study Report
- Objectives of the study
- Brief description of the project (height and location, including a location map)
- Description and images of the study and proximity models
- Description of the source and period of meteorological data used, including a graphical representation of the data
- For CFD, the name of the software used, and credentials of the consultant are required
- Wind Criteria for Pedestrian Comfort and Safety
- Results
    - o Wind speeds must be presented in km/h
    - o Results should correspond to pedestrian level (i.e. approximately 1.5 m above the concerned level). Vertical slices or axonometric views depicting flow patterns may be included as needed to understand flow mechanisms in critical areas.
    - o **CFD**: Graphical presentation of simulation results representing comfort categories for four seasons in accordance with the colour coding provided in Appendix, and an indication of any areas where the safety criterion is estimated to be exceeded.
    - o **WTS**: Results shall be presented in both tabular and graphic forms for all the test scenarios, with seasonal comfort data and annual safety data. Graphics should present results in accordance with the colour coding provided in Appendix.
- Discussion of Results
    - o The text shall include interpretation of the results for each scenario as it relates to the Design Criteria, discussions about causative flow mechanisms and recommendations for mitigation of adverse or undesirable wind conditions.
    - o Where conditions are predicted to be unacceptable for the intended pedestrian usage, design alternatives and wind control strategies should be recommended to improve the wind comfort to acceptable levels, as described in the Appendix, or appropriate adjustments to pedestrian usage should be suggested in consultation with City staff.

- The technical specifications for the studies are described in the Appendix.

5.6 PEER REVIEW

If the City is not satisfied with the level of experience demonstrated by the consultant or wishes to verify the results of a study, a peer review of the wind study may be required by the City at any stage of the application. The cost of the peer review is to be borne by the applicant.

6 APPENDIX

6.1 Importance of Wind Studies

Wind assessments can be done through physical scale modelling in wind tunnels, and computational modelling. Each method has its benefits and drawbacks, and it is essential that the right approach be chosen for the type of application, context, and approval stage of the project. See the Technical Specifications in Section 6.3 for details and technical specifications for the different approaches.

6.2 Significant Design Changes

The significance of a design change with respect to its impact on wind conditions must be evaluated by the Consultant and through discussions with the City between the OPA/ZBA and SPA submissions, as the criteria will vary for each project. Some criteria are considered significant include, but are not limited to:

- Change in the number of buildings on the site or in the surroundings
- Change in the orientation/location of a building on the site
- Change in the setback of a (part of a) building from a public sidewalk and open spaces
- Reshaping of the building massing
- Change in the height of a building
- Change in the offset distance of a tower from podium edges
- Change in canopies and small-scale architectural features

These criteria will be evaluated by the Consultant and City staff as wind impacts depend on a combination of on-site massing, off-site massing, geographic and meteorological factors.

6.3 Wind Consultants

In addition to the submitted material, the Consultant will sign Template A. Pedestrian Level Wind Studies are to be conducted by professionals who specialize in and can demonstrate extensive experience in dealing with wind and microclimate issues in the built environment. The City of Toronto is considering future regulation for Consultants' qualifications.

6.4 Technical Specifications

6.4.1 Project and Proximity Model

- The model should be constructed to include all massing and architectural features on the project that would influence wind flow around it. Typically dimensions less than 1 m do not have a notable impact on wind related to pedestrian comfort.
- The surrounding context (proximity model) within a minimum radius of approximately 350 m from the proposed development site should be modelled. This radius is to be measured from the outer bounds of the proposed development for masterplan projects. Tall buildings outside of this zone that could have an influence on wind conditions within the project site should be included.
- Structures and natural features beyond the modelled surroundings shall be represented physically and/or numerically, as appropriate for the study type.
- Landscaping features should not be considered for wind studies, unless, through discussions with the City, such features are to be included for wind mitigation.
- For Wind Tunnel Studies, model scale should be selected to allow representation of sufficient architectural detail on the proposed development and surrounding context. Typically scales of 1:500 to 1:300 have proven to be effective. A scale outside the range may be used provided the reason for the choice and why the recommended scales would not be appropriate for the wind study is included in the Wind Study Report. Note that the model scale chosen for optimal data quality could vary, depending on the test equipment and instrumentation use. Models for CFD studies are typically at 1:1 scale.

6.4.2 Computational Fluid Dynamics (CFD) Study

CFD is a numerical modelling technique for simulating wind flow in complex environments. For urban wind modelling, computational fluid dynamics (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 urban 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) within the urban environment. It is these types of flow behaviour that can cause pedestrian discomfort and safety concerns.

The CFD Phase 1 (Preliminary Massing CFD) and the CFD Phase 2 (Application Submission CFD) are conducted in a similar technical process. However, since they are submitted in different stages of the process, the information that they provide is analyzed differently to provide the appropriate information for the relevant stage.

Requirements for a CFD Study

- A CFD study (based on Table 2) is:
    - o Encouraged at the Pre-Application stage for projects that meet the criteria for Moderate or High triggers.
    - o Required for projects at the OPA and/or ZBA stage that meet the criteria for Low or Moderate triggers and may be required at the SPA stage. With consultation with City staff, the consultant may recommend a Wind Tunnel Study to replace the CFD.
- The assessment should be done for four seasons in accordance with the Design Criteria and the technical specifications that follow.
- Software
    - o The CFD software used should follow the COST 732 Best Practice Guideline for CFD Simulations in an urban environment.
    - o The CFD simulation should appropriately represent the atmospheric boundary layer for winds approaching the project.
    - o The CFD software used should use a 2-equation turbulence model if a RANS model is used. The turbulence components (k. e or w) should be modeled by transport equations. Large Eddy Simulation (LES) is also accepted given the appropriate inlet conditions are used.
    - o 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.

N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
0°/360°	22.5°	45°	67.5°	90°	112.5°	135°	157.5°	180°	202.5°	225°	247.5°	270°	292.5°	315°	337.5°

- Analysis and Results
    - o Wind speeds shall be presented in km/h.
    - o Assessment should be done for all areas of interest.
    - o The processing of results should consider the probability of all wind directions simulated using meteorological data as described in the Appendix.
    - o 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.
    - o The results for seasonal comfort should be based on the Design Criteria and presented using the colour-coding as described in the Appendix.
    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.

6.4.3 Wind Tunnel Study (WTS)

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. In general, such modelling provides a good, 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.

Requirements for a WTS

- A WTS study is required (based on Table 2):
    - o For projects at the OPA/ZBA stage that meet the criteria for High triggers and may be required at the SPA stage.
    - o For projects at the OPA/ZBA stage that meet the criteria for Low or Moderate triggers depending on the consultant's recommendations.
- The assessment should be done for four seasons in accordance with the Design Criteria in Section 5.3 of this Guide and the technical specifications that follow.
- 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
    - o 36 wind directions at equal intervals shall be tested
    - o Sensors shall be omni-directional and shall measure the magnitude of horizontal wind speeds.
    - o The measurements should represent the wind speed at a full-scale height of approximately 1.5 m above local grade.
    - o 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.
    - o 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
    - o 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.
    - o Sensor locations should capture all areas of interest as described in Section 5.2 Areas of Interest. 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.
    - o 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
    - o Wind speeds shall be presented in km/h.
    - o Assessment should be done for all areas of interest.
    - o The analysis should consider the probability of all wind directions tested using meteorological data obtained in accordance with the description in the Appendix.
    - o The results shall be presented in both tabular and graphic forms for all the test scenarios, with seasonal comfort data and annual safety data based on the Design Criteria.
        - The table of results must include wind speed and associated wind speed category at each measurement location.
        - The graphical presentation of results should use the colour-coding as described in the Appendix.

6.4.4 Meteorological Data

Data Source

Long-term wind data recorded in major airports are often used in the prediction of pedestrian wind conditions. In the Greater Toronto Area, wind data are available from Pearson International Airport and Billy Bishop Toronto City Airport. When these data are corrected for the surrounding terrain and scaled up to a gradient height, above which wind is not influenced features on the planetary surface (e.g., 600 m), the difference in speeds is not significant between the two airports. However, the data from Billy Bishop Toronto City Airport shows more easterly components, which may be more representative for the areas along Lake Ontario and east of Toronto downtown. Therefore, the zone map proposed for the wind data source is as shown in Map 2.

Data Download

Data for the airports can be downloaded from the links provided below. It may be necessary to download from multiple links to obtain a complete data set depending on the time period of interest. Exposure corrections will have to be applied due to the inhomogeneous terrain surrounding the airports. Data should be scaled to be appropriate for the project site based on established mathematical models.

Toronto Pearson International Airport: Link 1 Link 2 Link 3

Billy Bishop Toronto City Airport: Link 4 Link 5 Link 6

Specifications

- A minimum of 30 years of hourly wind data should be used
- The Data is to be presented and used on a four-season basis as described in Section 5.3 Design Criteria:
  - o Spring: Hourly winds occurring during the period of March to May
  - o Summer: Hourly winds occurring during the period of June to August
  - o Fall: Hourly winds occurring during the period of September to November
  - o Winter: Hourly winds occurring during the period of December to February
- Appropriate hours of pedestrian usage for a typical project (e.g., between 6:00 and 23:00) should be considered for wind comfort, while data for 24 hours should be used to assess wind safety.

TOR Map 2: Recommended Zones for Meteorological Data Source Selection

DATA FROM BILLY BISHOP TORONTO CITY AIRPORT SHOULD BE USED FOR PROJECTS IN BLOCKS LOCATED ALONG THE METEOROLOGICAL BOUNDARY, AS DEFINED BY MAJOR STREETS AS SHOWN IN OFFICIAL PLAN MAP 3

6.5 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. The following table describes the minimum criteria for specific location. 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 relaxed 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 3: 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	Areas where seated activities are not expected but would be used for passive activities such as bust stops, dog areas and main entrances.
Walking	≤ 20	80	Relatively high speeds that can be tolerated during intentional walking, running and other active movements.	Sidewalks, parking lots, laneways 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.
3) Wind speeds lower than 5 km/h for majority of the time (e.g., 80%) have the potential to create low air circulation. Potential problems related to low air flow are buildup of vehicle and/or building exhaust, and in full exposure to sun, low air flow can lead to issues related to thermal comfort.

SAFETY CRITERION	**GUST SPEED (km/h)**	**MINIMUM OCCURRENCE (% OF TIME) Annual**	**DESCRIPTION**	**AREA OF APPLICATION**
Exceeded	> 90	0.1 (9 hours in a year)	Excessive gust speeds that can adversely affect safety and a pedestrian's balance and footing. Wind mitigation is typically required.	Not acceptable in any area of interest

NOTES:

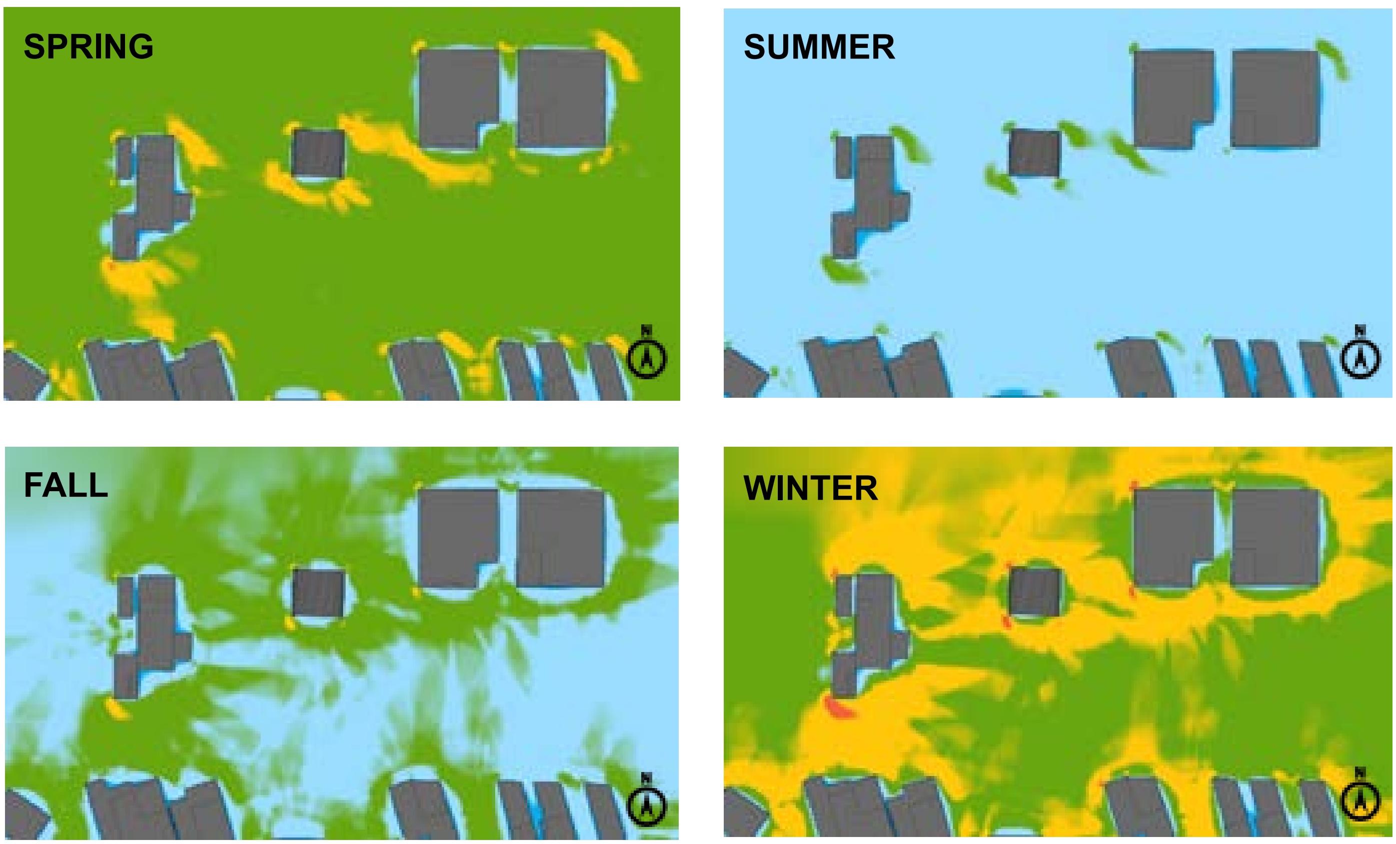
4) Safety calculations are to be based on wind events recorded for 24 hours a day
5) Unsafe conditions should be clearly highlighted both in the graphic presentation and in the written report

6.6 Presentation of Results

CFD STUDY

LEGEND

Sample Results
One Set Of Figures Per Scenario. Each Set Should Comprise Four Seasonal Result Images



WIND TUNNEL STUDY

LEGEND

COMFORT

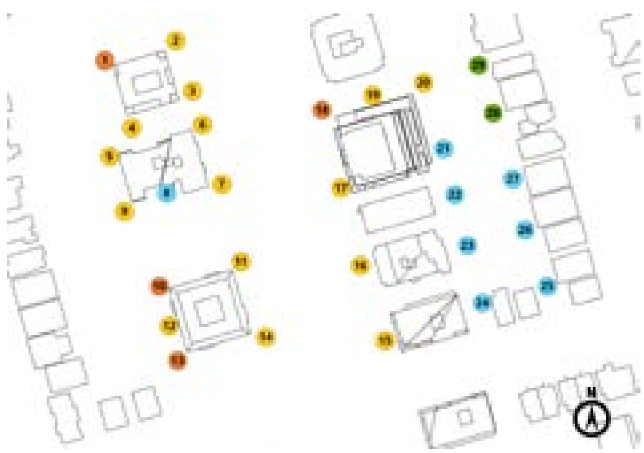
- SITTING
- STANDING
- WALKING
- UNCOMFORTABLE

SAFETY

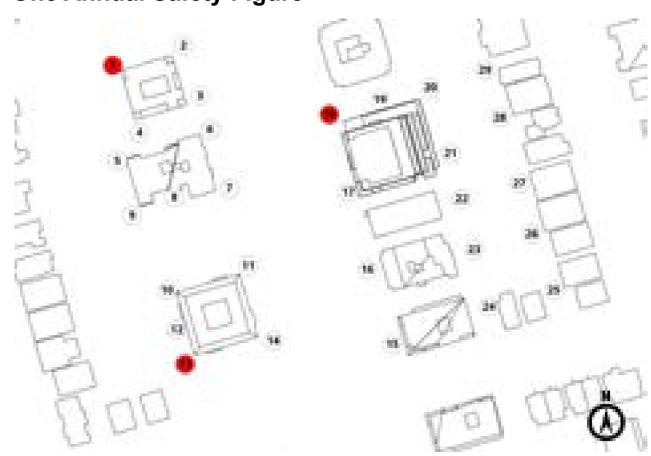
- ACCEPTABLE
- EXCEEDING

Sample Results
One Set Of Figures Per Scenario. Each Set Should Comprise The Following

Four Seasonal Comfort Result Images



One Annual Safety Figure



6.7 Wind Responsive Design Guidelines

6.7.1 Wind Flow in the Built Environment

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.

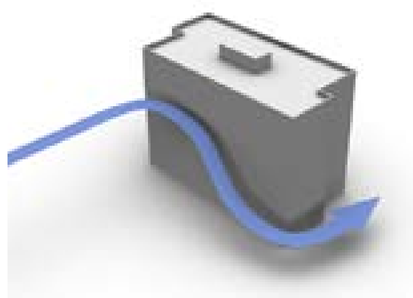
Consider a tall building with the broad façade facing a strong wind stream. When the stream is intercepted by the building, some of the flow moves upward and over the building, but much of the stream would be redirected downward **(Downwashing)** and around the lower portion of the building.

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.

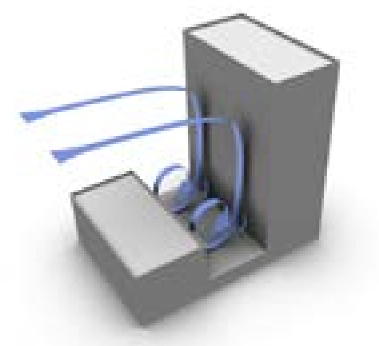
When gaps between buildings, that are narrow relative to the building heights, are aligned with the prevailing winds, wind accelerates in the gaps because of what's commonly called **Venturi effect**. A similar acceleration is also common under bridges and in underpasses as the air is forced to go through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

In a typical urban setting, 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.

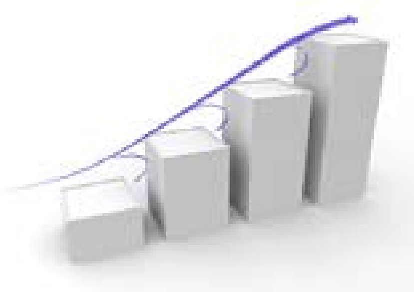
Downwashing Flows



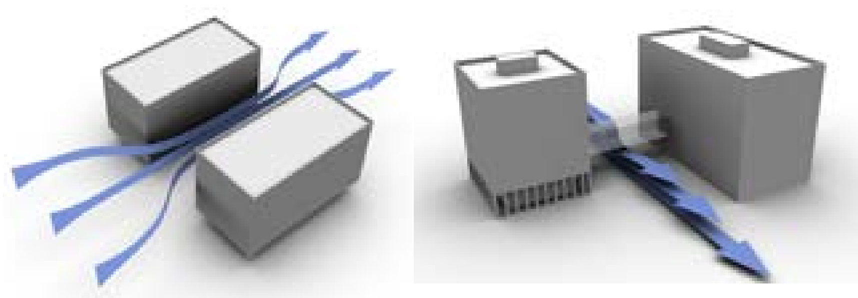
Corner Acceleration



Short Building Upwind of Tall Building



Short Building Upwind Reduce Wind-Exposure of Downwind Buildings



Venturi Effect

6.7.2 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 types of wind control strategies, moving from large-scale to small-scale features, is provided following this section. The City of Toronto instructs applicants that the strategies be prioritized and applied as follows:

Orientation, Siting, & Building Massing (CFD Phase 1: Preliminary Massing CFD)

At the earliest stage, the applicant should consider large-scale measures, i.e., orientation, siting and sculpting the -building massing to minimize the wind-impact of the proposed development.

Smaller Scale Architectural Features (CFD Phase 2: Application Submission CFD)

Once the orientation, siting and building massing have been addressed to minimize wind-impacts of the proposed development, high-wind conditions may be further reduced using smaller-scale architectural features such as canopies, façade details, etc.

Localized Features:

Once all large-scale and architectural design options have been explored to address adverse wind-impacts of the proposed development, the impact of localized features such as wind screens and landscaping may be explored. The Applicant will require written approval from the City to use such features in the final design as a means of wind control.

Building Form

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). 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.

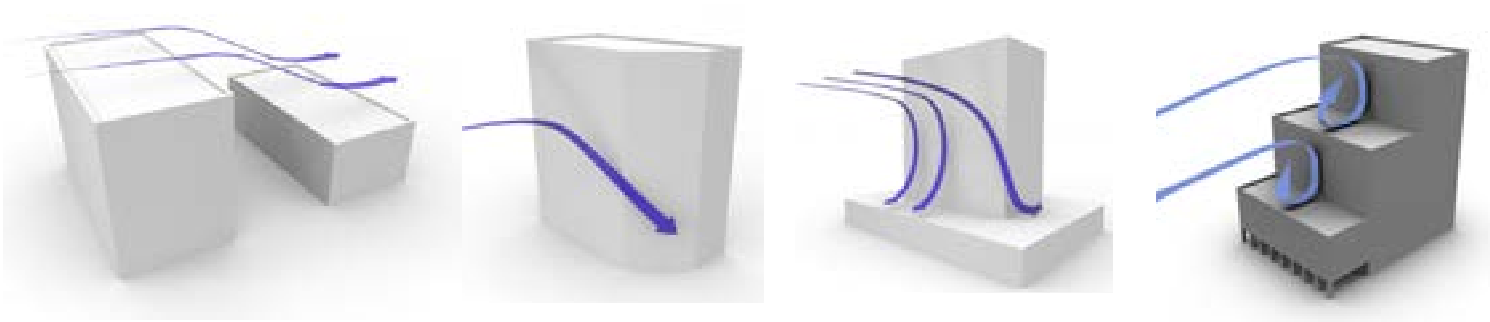
Architectural Details

Features such as façade articulations, canopies, covered walkways and recessed entrances are effective solutions for localized wind mitigation. 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

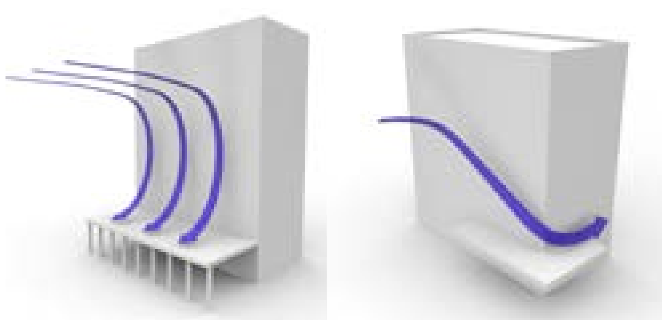
Localized Accessory Elements

Smaller-scale measures such as wind screens, 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.

The use of landscaping and wind screens as part of a mitigation strategy 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.



Examples of Building Form Details for Wind Control



Examples of Architectural Details for Wind Control