Appendix H

Wind Supporting Information

EIR Alternatives Analysis Memo

BMT Fluid Mechanics

India Basin Mixed-Use Project

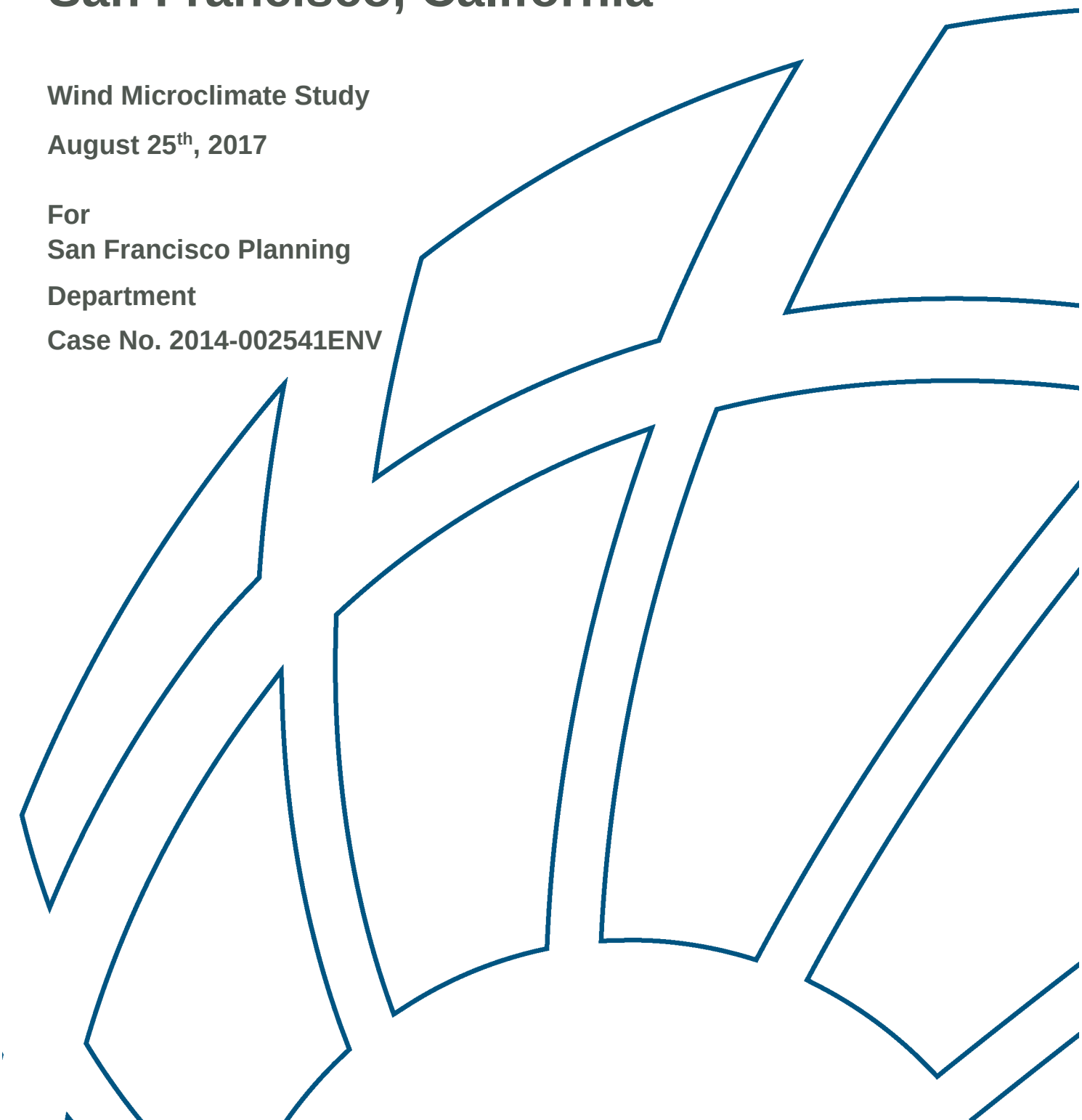
San Francisco, California

Wind Microclimate Study

August 25th, 2017

For
San Francisco Planning Department

Case No. 2014-002541ENV



Report Title	**India Basin Mixed-Use Project Wind Microclimate Study**		
For	**San Francisco Planning Department**		
Document No:	**432091rep2v6**	**Release: 6**	**Copy No:**
Status	**Final Report**		
Report Date:	**August 25th, 2017**		
Holds:			

	Name:	Signature:	Date:
Prepared by:	**Dr. R. Cummings**		**August 25th, 2017**
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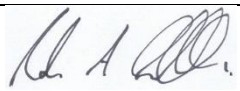
Approved by:	**Dr. R. Stanfield**		**August 25th, 2017**

Distribution:	**Copy no.**	**to**	**Client**
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Previous Release History:	Release No:	Status:	Date:
432091rep2v1	**1**	**Draft Report for Internal Review**	**October 5th, 2016**
432091rep2v2	**2**	**Draft Report for Client Review**	**October 6th, 2016**
432091rep2v3	**3**	**Second Draft Report for Client Review**	**October 7th, 2016**
432091rep2v4	**4**	**Third Draft Report for Client Review**	**November 11th, 2016**
432091rep2v5	**5**	**Fourth Draft Report for Client Review**	**February 9th , 2016**

India Basin Mixed-Use Project Wind Microclimate Study

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Executive Summary

Background

BMT Fluid Mechanics Ltd. (BMT) has conducted a pedestrian-level wind study for the proposed India Basin Mixed-Use Project (hereafter "India Basin Project" or "proposed Project Scenario (proposed project) and proposed Project Variant Scenario (variant)") along the India Basin shoreline of San Francisco Bay in San Francisco, California. The purpose of the wind study is to assess the probability of the proposed project or variant to cause local wind speeds to exceed "hazard" and "comfort" criteria at publicly accessible points in the project vicinity in order to determine whether wind effects would be suitable for the pedestrian environment in accordance with criteria specified in Section 148 of the San Francisco Planning Code.

Test Criteria

Planning Code Section 148 establishes a wind comfort criterion that requires, upon introduction of the proposed project, that equivalent wind speeds do not exceed 11 mph more than 10% of the time between 7:00am and 6:00pm throughout the year, in areas of substantial pedestrian use, and 7 mph in public seating areas.

Section 148 also establishes a wind hazard criterion that requires, upon introduction of new buildings or additions to existing buildings, that ground-level equivalent wind speeds do not exceed a one-minute average of 36 mph[1] for more than a single hour during the year.

The project site is not located in a C-3 District, a downtown commercial district; therefore Section 148 does not apply. However, the wind hazard criterion identified in Section 148 is used to determine the significance of a project's wind impacts on public spaces.

Test Scenarios

The evaluation of wind comfort and hazards was carried out by testing a 1:300 scale model of the proposed project in the boundary layer wind tunnel in accordance with standard City of San Francisco test protocols. A total of 219 City-approved publicly-accessible ground-level locations ("test points") have been selected on project-area sidewalks and crosswalks within a 1,500-foot radius of the project vicinity in order to measure and then compare wind conditions in the following test scenarios:

- **Existing Scenario**, assessing baseline wind conditions in the area;

[1] The 26 mph mean-hourly average is converted to a one-minute average of 36 mph, which is used to determine compliance with the 26 mph one-hour hazard criterion in the Planning Code.

- **Project Scenario**, measuring changes to baseline winds due to a residentially focused mixed-use development, also referred to as the "proposed project"; and
- **Project Variant Scenario,** evaluating the relative differences in wind speed outcomes for the maximum commercial project variant (with fewer dwelling units and more commercial development than the proposed project, also referred to as the "variant").

The relevant cumulative projects are too far from the project site and the study area (more than 1500 feet away) to interact with the proposed project or variant in a manner that would affect wind conditions on or near the project site. For this reason, the wind effect of the proposed project scenario or project variant scenario under the cumulative surrounding conditions is expected to be materially the same as for the proposed project scenario or variant scenario under the existing surrounding conditions. For this reason, a wind tunnel test that includes the other cumulative projects was not conducted. The changes to the wind environment under the cumulative conditions would be the same as the changes to the wind environment under the proposed project or variant.

Summary Results

Located on the eastern edge of the San Francisco peninsula, the India Basin Project site is principally exposed to winds blowing across the Bay from the north to east. Relatively speaking, however, these winds are comparatively infrequent and calmer in comparison with prevailing winds, which principally blow from a quadrant centred on the west. From this direction, the project site sits on the downwind edge of the San Francisco peninsula. While this is true, the upwind terrain, topography and building morphology do relatively little to impede strong prevailing winds originating from the Pacific. Low-rise, principally suburban neighborhoods occupy terrain with – in places – gentle hillsides. Thus, strong winds blow across the peninsula and, as might be expected, reach the project site, which, in its immediate vicinity, is substantially exposed to the west.

What results is an existing site whose current microclimate is expectedly windy, with the comfort and hazard criteria exceeded at a number of locations prior to the introduction of any new buildings. With an existing microclimate of this nature, the eradication of these exceedances would represent a significant challenge irrespective of the architecture.

In short, wind conditions would generally improve, in terms of wind comfort and hazard, in the proposed project scenario compared to the existing scenario.

The wind study concludes that implementing the proposed project, in terms of comfort, would reduce the average wind speed of all test points exceeded 10% of the time from 19.6 mph in the existing scenario to 17.2 mph. The proposed project would result in 206 test points exceeding the established 11 mph comfort criterion, a net decrease of 12 exceedances over the existing conditions. The total exceedances of

the wind hazard criterion would be reduced by 54 (from 137 to 83) and would reduce duration of hazardous winds by 119 hours in the proposed project scenario compared to the existing conditions (from 886 hours to 767 hours). The greatest increment in wind speeds and wind hazard exceedance hours of the test points would be located at the southwest corner of the 700 Innes "Hillside" parcel under the 14-storey building.

For the maximum commercial project variant scenario located within the existing setting, wind conditions would also improve, in terms of wind comfort and hazard, compare to the existing scenario. The average wind speed of all test points would be reduced from 19.6 mph to 17.3 mph. There would be 204 exceedances in total, representing a net decrease of 14 exceedances of the wind comfort criterion. The total exceedances of hazard criterion that would be exceeded would be reduced by 52 (from 137 to 85), and would reduce the total duration of hazardous winds by 190 hours (from 886 hours to 696 hours).

Wind conditions under the variant would be similar in terms of comfort, and would be a slight improvement in terms of hazard, compared to the proposed project. A marginal increment of 0.1 mph for average comfort wind speed of all test points exceeded 10% of the time would occur under the variant compared to the proposed project. The total number of hazard exceedances would increase by two but the total duration of hazardous winds would reduce by 71 hours per year.

On balance, the proposed project and variant would introduce an obstruction to wind blowing across the site compared to the current open existing condition that occurs at the site. Generally therefore, the proposed project and variant would have a broadly positive effect upon the wind microclimate, reducing both the average wind speed exceeded 10% of the time and the total number of locations that exceed the hazard criteria, relative to the existing conditions. Naturally with many regions where wind speeds would decrease, there are areas of localised acceleration, and as a result of the innate windiness of the site, these areas would continue to exceed hazard criteria. With this in mind it would be of notable benefit to incorporate a series of design measures that locally alleviate accelerated winds and enhance the microclimate. These might include, but not be limited to, wind canopies, solid/porous screens and building fins.

India Basin Mixed-Use Project San Francisco, California Wind Microclimate Study

1. Introduction

BMT Fluid Mechanics Ltd. (BMT) has worked with AECOM and the San Francisco Planning Department to conduct a pedestrian wind microclimate study for the proposed India Basin Mixed-Use Project (hereafter "proposed project") along the India Basin shoreline of San Francisco Bay in San Francisco, California.

The purpose of the wind study is to assess the probability of the project to cause local wind speeds to exceed "hazard" and "comfort" thresholds specified in San Francisco Planning Code Section 148 at publicly accessible points in the project vicinity in order to determine whether wind effects are suitable for the pedestrian environment.

1.1. Study Area

1.1.1. Project Site

The project site is in the Bayview Hunters Point neighborhood, in the southeast quadrant of San Francisco. The site is generally bounded by the San Francisco Bay to the north, the Candlestick Point–Hunters Point Phase I and Phase II Shipyard Development Plan areas to the east, Innes Avenue 2 to the south, and Hunters Point Boulevard and Hawes Street to the west. Portions of Innes Avenue adjacent to the site are included in the project boundary. The project site is generally flat between Hudson Street and Earl Street to the India Basin Open Space boundary, with slope toward the Bay. The elevation of the site is highest along Innes Avenue at approximately 50 feet above mean sea level, and lowest along the shoreline at approximately 5 feet above mean sea level.

The site location is presented within the context of the wider surrounding area in **Figure 1.1**. The buildings immediately surrounding the project site have also been included in modelling under the existing, proposed project and project variant scenarios.

1.1.2. Proposal

The proposed project consists of private-owned 700 Innes and publicly-owned 900 Innes, India Basin Shoreline Park and India Basin Open Space. The 700 Innes property

consists of multiple parcels ranging from one to 14 stories (20 to 150 feet tall) (see **Figures 1.2 and 1.3 for the proposed project and variant, respectively)**. The 900 Innes property would only contain 3 structures ranging in height from 1-2 stories (10 to 25 feet tall). Shoreline Park would contain 3 structures also including a restroom, concessions and covered pavilion on the Bay that will be 1 story tall, (see **Figure 1.4)** which contain the 6 structures. The India Basin Open Space also plans to include some 1 story uses, potentially a café, maintenance facility, rentals, and concessions.

1.2. Test Scenarios

The study considers the following scenarios:

- **Existing Scenario**, assessing baseline wind conditions in the area;
- **Project Scenario**, measuring changes to baseline winds due to the residential project; and
- **Project Variant Scenario,** evaluating the relative differences in wind speed outcomes for the maximum commercial project variant.

The existing, or baseline scenario, is tested in order to characterize the wind environment of the project site vicinity as it exists today. The project scenario entails testing a 1:300 scale model of the proposed project wind within the existing setting, in order to investigate changes to ground-level winds that the proposed project could affect.

Figures 1.1, 1.5 and **1.6** show the Existing Scenario, Project Scenario and Project Variant Scenario, respectively.

As the relevant cumulative projects are relatively far away from the proposed project and variant site and the study area (more than 1500 feet away), the wind effect of the proposed project scenario or variant scenario under the cumulative surrounding conditions is expected to be materially the same as for the same configurations within existing surrounding conditions. For this reason, a wind tunnel test that includes the other cumulative projects was not conducted. The changes to the wind environment under the cumulative conditions would be the same as the changes to the wind environment under the proposed project or variant.

Figure 1.1: Existing Scenario

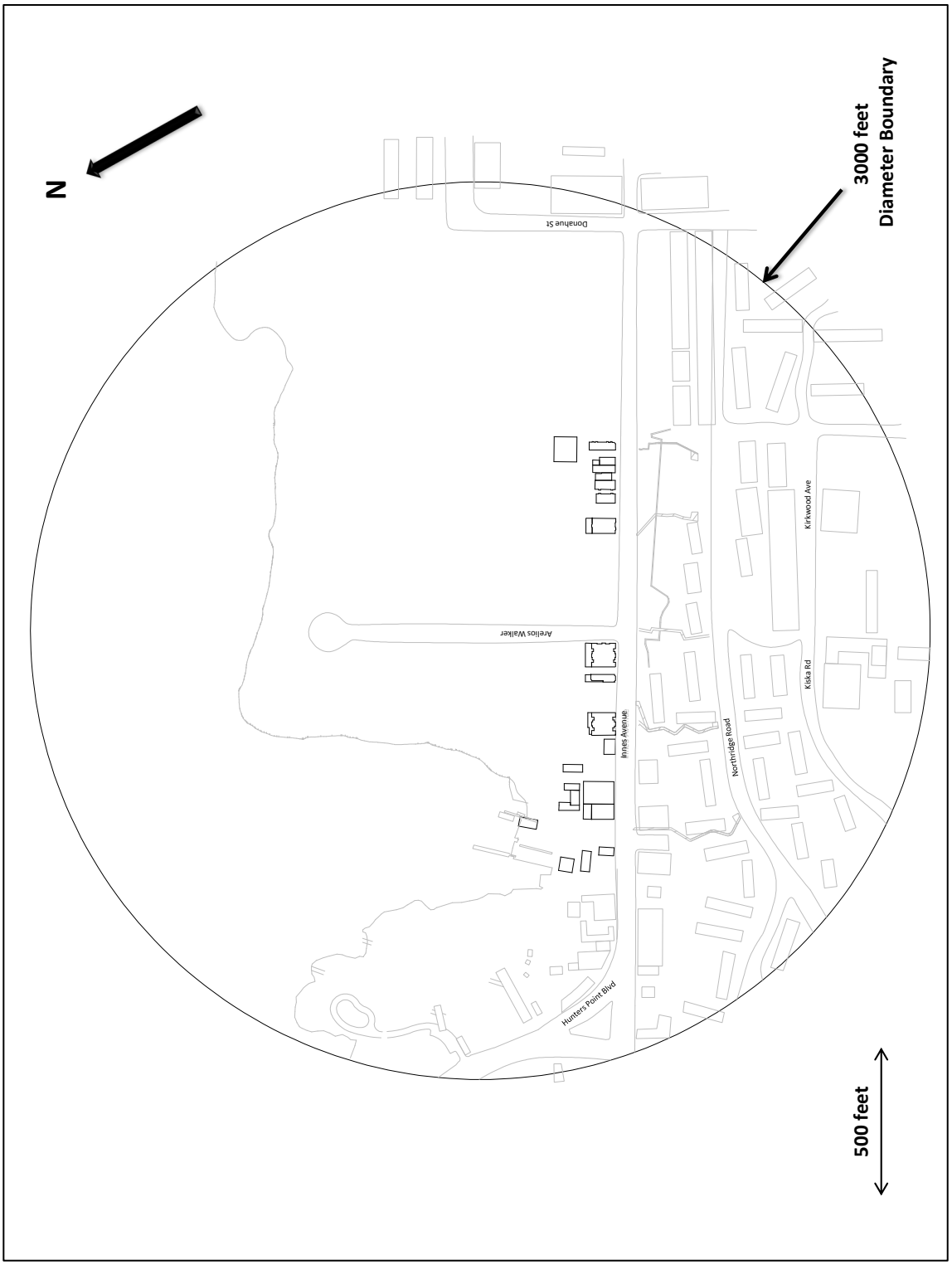


Figure 1.2: Proposed Project Building Heights (India Basin Open Space and 700 Innes)

Figure 1.3: Proposed Variant Building Heights (India Basin Open Space and 700 Innes)

Figure 1.4: Proposed Variant Building Heights (India Basin Shoreline Park and 900 Innes)

Figure 1.5: Project Scenario

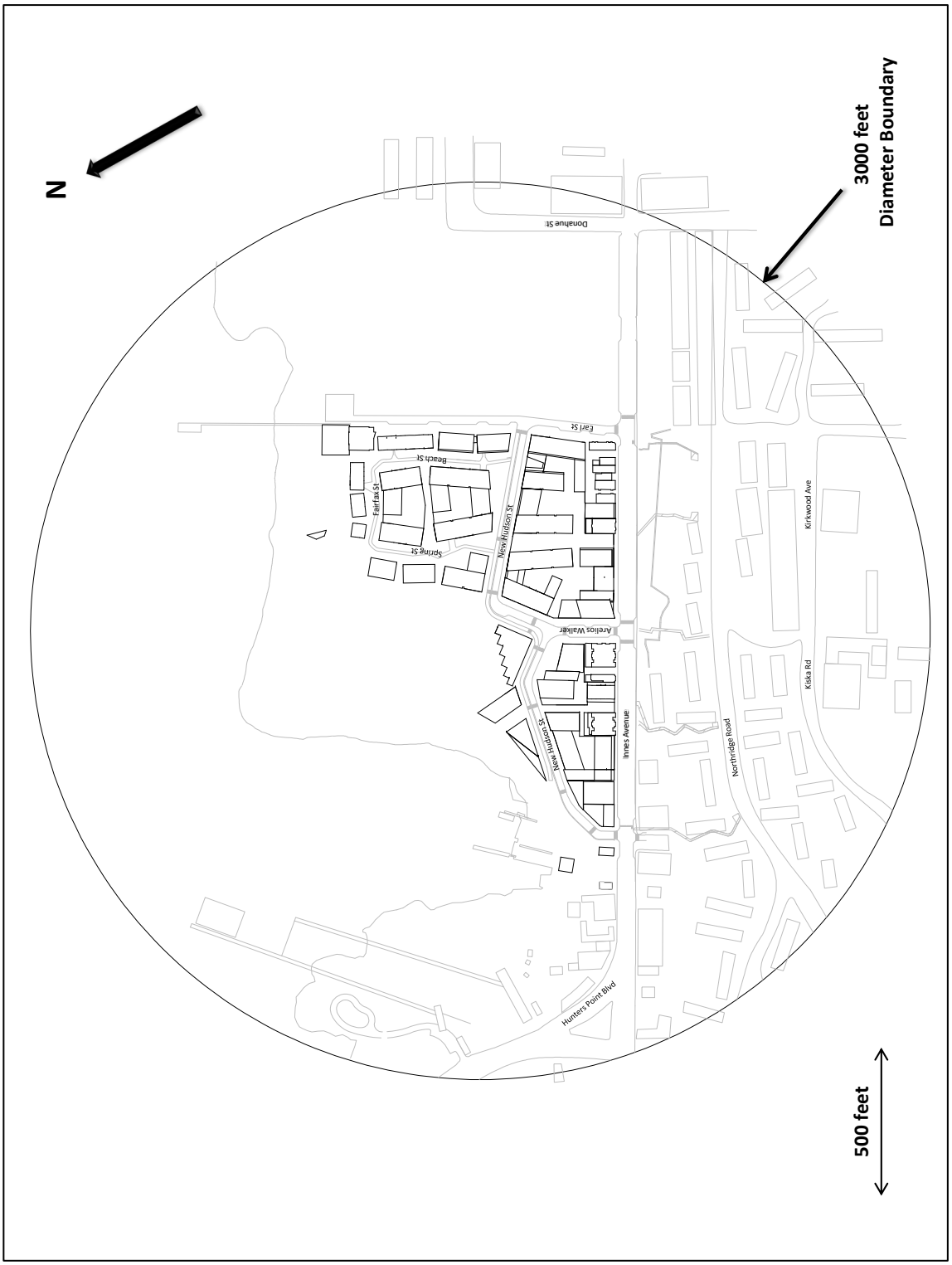
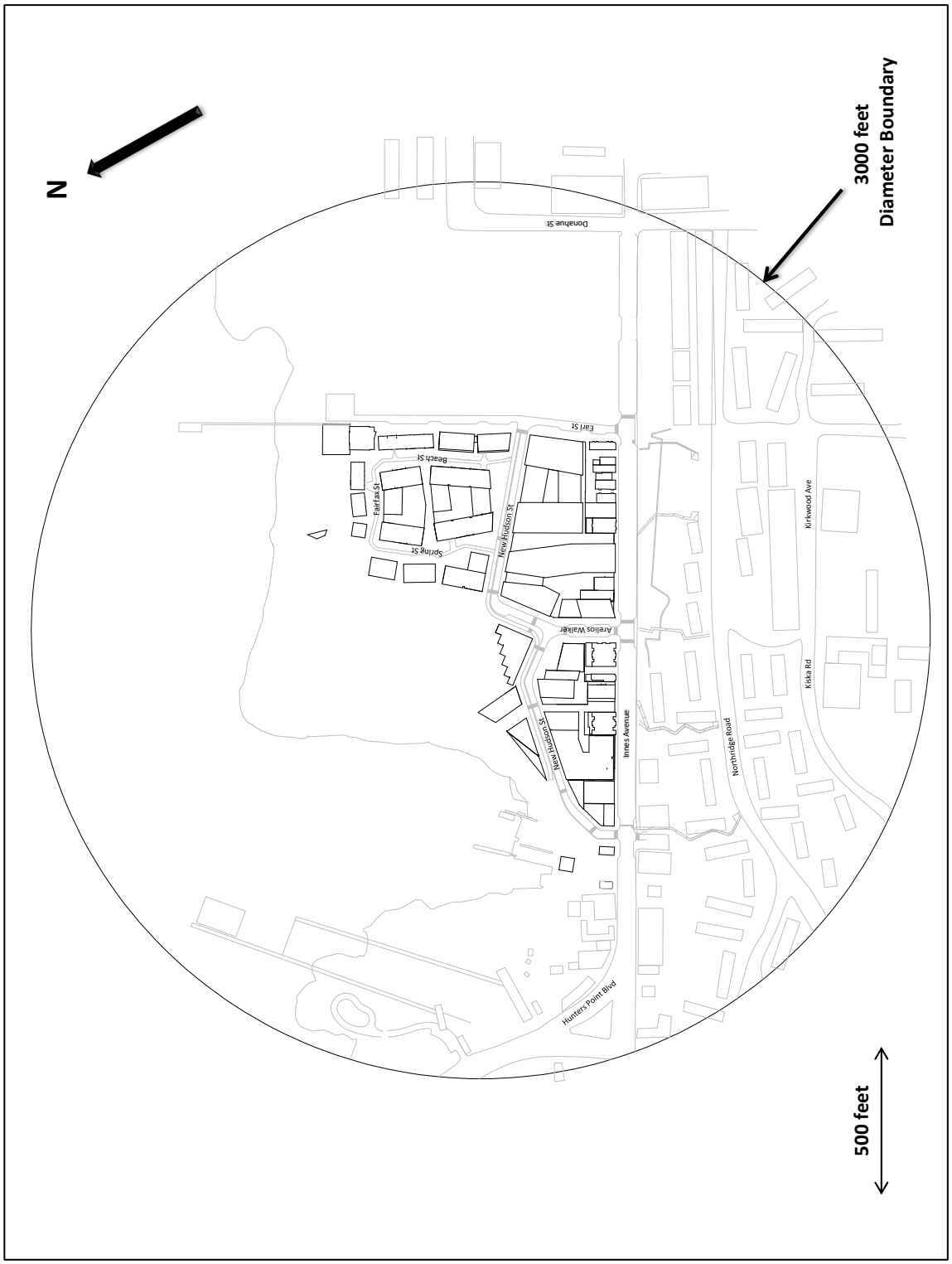


Figure 1.6: Project Variant Scenario



2. The Assessment of Wind Microclimate

A microclimate can be defined as the distinctive climate of a small-scale area. The weather variables in a microclimate, such as wind, may be different to the conditions prevailing over the area as a whole.

Wind microclimate assessments consider the wind conditions that would result upon the introduction of a new development into an established setting. Wind speed data generated by tunnel testing assists decision-makers to determine whether a project's wind conditions would be suitable or unsuitable, and whether or not design adjustments or mitigation measures would be required to address potentially hazardous wind effects and the pedestrian comfort issues. It is for these purposes that wind microclimate assessments are undertaken.

2.1. Buildings, the Built Environment and Wind Speed

The direction and speed of wind currents can be altered by natural features of the land or by buildings and structures. A number of basic features can influence the wind flows around buildings. These include the general building envelope, the cross-sectional shape, the building orientation (particularly in relation to the prevailing wind direction), the overall height and proximity to other buildings and the general exposure of the site. Groups of buildings clustered together tend to act as obstacles that reduce wind speeds; the heights, massing, and orientations or profiles of the buildings are some of the factors that can affect wind speeds. When a building is much taller than those around it, rather than a similar height, it can intercept and redirect winds downward that might otherwise flow overhead. The winds can be directed down the vertical face of the building to ground level, and these redirected winds can be relatively strong and relatively turbulent. The massing of a building can affect wind speeds. In general, slab-shaped buildings have the greatest potential to accelerate ground-level winds, while buildings that have unusual shapes or are more geometrically complex tend to deflect the wind away from reaching to the pedestrian level.

The building height relative to the adjacent buildings is particularly important since higher level winds can be deflected by the building towards ground level. In general terms, for a given cross-sectional shape the higher the building, the windier it would be at pedestrian level. Because of this downward deflection of high-level winds, significant localized acceleration can occur around the base of a building, particularly near the corners of the building. This is demonstrated by the common experience of windy conditions near tall buildings even on a relatively calm day.

The corner geometry in particular is important because sharp edged corners cause separated flows with strong wind speed gradients (rapid changes over a short

distance). Softer, or more rounded corners improve this, although some acceleration still occurs.

The proximity of adjacent buildings is an important consideration with regard to wind shielding and funnelling (channelling). The potential for local wind accelerations and decelerations due to interaction with local structures must be taken into account when assessing the local wind environment. Therefore the adjacent relevant existing buildings have been incorporated into the wind model.

Wind speeds are statistical in nature and throughout this report are discussed based on the frequency of occurrence; namely 10% of the time. Higher wind speeds would occur, but on a less frequent basis. Lower wind speeds would occur 90% of the time.

3. Assessment Criteria

3.1. Pedestrian Comfort and Hazard Wind Speeds

At each area investigated, the suitability of pedestrian level wind conditions in terms of "comfort" and the presence of "hazards" can be assessed based upon local hourly-mean wind speed as defined by the San Francisco Planning Code Section 148.

3.2. San Francisco Planning Department's Environmental Review Guidelines and Criteria

In order to provide a safe and comfortable wind environment for people in San Francisco, the City has established comfort and hazard criteria for use in evaluating the wind effects of proposed buildings. Planning Code Section 148, "Reduction of Ground-level Wind Currents in C-3 Districts," specifically outlines these criteria for the Downtown Commercial (C-3) Districts. Additional Planning Code sections apply the same criteria to the Rincon Hill, Van Ness Avenue, and South of Market areas. As explained below, under Section 148, new buildings and additions within specific areas of San Francisco may not cause wind speeds that meet or exceed this hazard criterion.

Section 148 establishes 11 mph as the comfort level for wind speed in areas of substantial pedestrian use and 7 mph as the comfort level for wind speed in public seating areas. New development shall not exceed these comfort levels more than 10 percent of the time year round between 7:00 a.m. and 6:00 p.m. Section 148 also establishes a wind hazard criterion: ground-level winds cannot meet or exceed an equivalent wind speed of 26 mph for more than a single hour during the year.

The Section 148 comfort criteria are based on wind speeds measured and averaged over one minute, the same averaging time as the weather bureau wind data. In contrast, the hazard criterion is defined by a wind speed that is measured and averaged over one hour; when stated on the same time-basis as the comfort criteria wind speeds, the hazard criterion wind speed (26 mph for a full hour) is a one-minute average wind speed of 36 mph. The test results presented in this wind tunnel report use the one-minute average of 36 mph for the hazard criterion.

The following significance criteria are from Appendix B of the San Francisco Planning Department's Environmental Review Guidelines and are used to determine the level of impacts related to wind. The proposed project or variant would result in a significant impact if it would:

- alter wind in a manner that substantially affects public areas

To assess whether a project would result in a significant impact under this criterion, the City uses the Planning Code's hazard criterion; that is, it determines whether a project would cause equivalent wind speeds to reach or exceed the wind hazard criterion of 26 mph for a single hour of the year. If a project would cause a wind hazard or add to an existing wind hazard in a public area, it may result in a significant impact under CEQA, because the project would result in hazardous wind conditions for pedestrians. The City requires mitigation measures to avoid new wind hazards or an increase in existing wind hazards.

The Section 148 comfort criteria are not CEQA significance criteria.

4. Assessment Methodology

4.1. Boundary Layer Wind Tunnel Testing

Wind tunnel testing is a well-established and robust means of assessing the pedestrian wind microclimate. It enables the wind conditions at the site to be quantified and classified in accordance with the San Francisco Planning Code Section 148 Wind Speed Criteria.

Wind is unsteady or gusty, and this 'gustiness' or turbulence depends on the site. Modelling these effects is achieved by a series of grid, barrier and floor roughness elements to create an atmospheric boundary layer that is representative of urban or open country conditions, as is appropriate.

A 1:300 scale model of the existing buildings at and surrounding the project site within a 1,500-foot radius of the center of the site was constructed along with a scale model of the project site. Wind speed measurements at assessment locations were made using probes capable of measuring fluctuating pressure differences that are calibrated against wind speed. A system of probes running simultaneously was used to obtain results from 219 locations for the existing scenario, project scenario, and project variant scenario at a height corresponding to 5ft at full scale (i.e. pedestrian height).

Measurements were taken for a full rotation of 16 wind directions in increments of 22.5º (0° represents the compass north). The methodology for quantifying the pedestrian level wind microclimate of the site is outlined below:

1. Measure the building-induced wind speeds at pedestrian level in the wind tunnel;

2. Combine these with wind frequency statistics derived from the San Francisco International Airport weather station to obtain the expected frequency and magnitude of wind speeds at pedestrian level; and

3. Compare the results with the Section 148 Wind Speed Criteria to the conditions around the site.

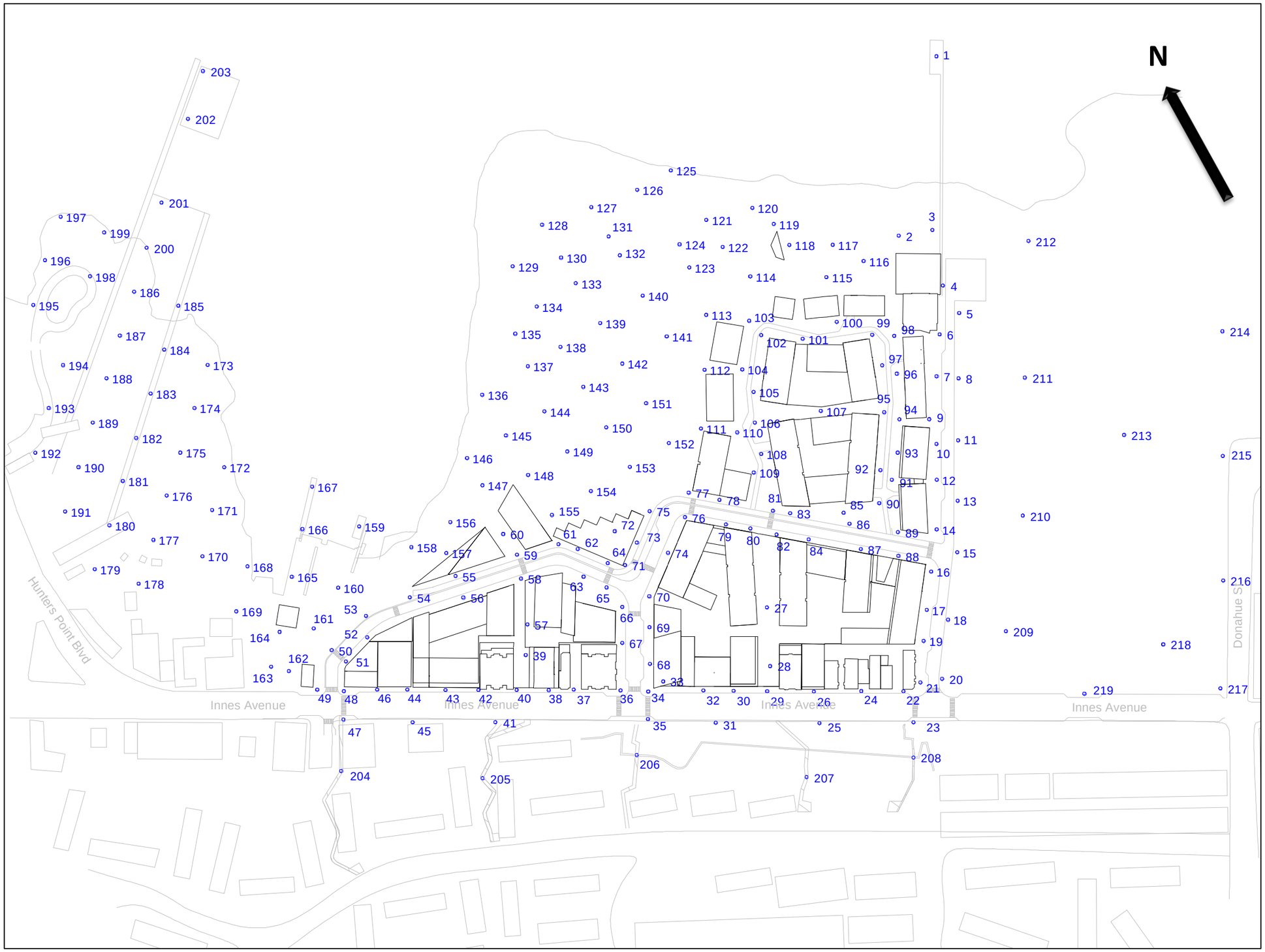
The technical details relating to the instrumentation, measurements and analysis for the wind study are described in Appendix D.

4.2. Test Points

A total of 219 test points are included in this wind tunnel test for proposed project and variant scenarios tested. The 219 test points are selected within a 1,500 foot radius of the project site. The test points are positioned in key locations within the study area, which are the areas of substantial pedestrian use, including the locations on the sidewalks, street intersections as well as the open spaces. Test points are also located in the future Northside Park to the east of the proposed project site. These test points have potential changes in wind speeds and turbulence levels within the development areas of the proposed project and variant.

The locations of the test points are distributed amongst study area streets as illustrated **Figure 4.1**. The test point locations are the same for the existing, proposed project and variant scenarios.

Figure 4.1: Test Point Map for Proposed Project and Variant



5. Wind Microclimate Results

Table 5.1 shows the wind comfort analysis results for:
- Existing Scenario
- Project Scenario
- Project Variant Scenario

Table 5.2 shows the wind hazard analysis results for:
- Existing Scenario
- Project Scenario
- Project Variant Scenario

The tabular wind comfort results are expressed as the probability of having the comfort one-minute mean wind speed of 11 mph exceeded followed by the one-minute mean wind speed that is exceeded 10% of the time. All of the points tested were on sidewalks, pedestrian crossings or within the publicly accessible areas on the project site and within the relevant study area.

The tabular wind hazard results are presented as the probability of having an equivalent wind speed exceed the 26 mph mean-hourly wind speed hazard criterion for a full hour within any one year period, followed by the wind speed that is exceeded once per year and the number of hours that the hazard criterion of 26 mph is exceeded. As explained above in footnote 2 in subsection 3.2, the 26 mph hourly average is converted to a one-minute mean of 36 mph, which is used to determine compliance with the 26 mph one-hour hazard criterion in the Planning Code.

The results for the aforementioned configurations are also presented graphically as follows:

- **Figure 5.1a**: Wind comfort results for the Existing Scenario
- **Figure 5.1b**: Wind hazard results for the Existing Scenario
- **Figure 5.2a**: Wind comfort results for the Project Scenario
- **Figure 5.2b**: Wind hazard results for the Project Scenario
- **Figure 5.3a**: Wind comfort results for the Project Variant Scenario
- **Figure 5.3b**: Wind hazard results for the Project Variant Scenario

Table 5.1: Wind comfort analysis results

Location Number	Comfort Criterion (mph)	Existing Scenario			Project Scenario				Project Variant Scenario				
		Wind Speed exceeded 10% of time (mph)	Percentage of Time Wind Speed Exceeds 11 mph	Exceeds	Wind Speed exceeded 10% of time (mph)	Percentage of Time Wind Speed Exceeds 11 mph	Speed Change Relative to Existing (mph)	Exceeds	Wind Speed exceeded 10% of time (mph)	Percentage of Time Wind Speed Exceeds 11 mph	Speed Change Relative to Existing (mph)	Speed Change Relative to Project (mph)	Exceeds
1	11	15	33%	e	14	26%	-1	e	14	27%	-1	0	e
2	11	25	60%	e	21	45%	-4	e	21	45%	-4	0	e
3	11	22	54%	e	20	43%	-2	e	20	43%	-2	0	e
4	11	19	48%	e	10	8%	-9	-	10	8%	-9	0	-
5	11	21	53%	e	12	13%	-9	e	12	13%	-9	0	e
6	11	20	48%	e	11	8%	-9	-	11	8%	-9	0	-
7	11	15	27%	e	9	5%	-6	-	9	5%	-6	0	-
8	11	19	48%	e	12	15%	-7	e	12	16%	-7	0	e
9	11	24	53%	e	10	8%	-14	-	10	8%	-14	0	-
10	11	25	58%	e	11	9%	-15	-	11	10%	-15	0	-
11	11	19	46%	e	13	20%	-6	e	14	22%	-5	0	e
12	11	23	55%	e	15	31%	-8	e	16	35%	-7	1	e
13	11	22	54%	e	13	20%	-9	e	14	22%	-9	0	e
14	11	22	54%	e	16	31%	-6	e	18	39%	-4	2	e
15	11	20	49%	e	15	33%	-5	e	17	38%	-3	1	e
16	11	18	41%	e	10	7%	-8	-	10	8%	-7	0	-
17	11	8	3%		9	4%	0		9	4%	1	0	
18	11	12	14%	e	10	5%	-2	-	11	9%	-1	1	-
19	11	15	33%	e	10	7%	-5	-	11	9%	-5	1	-
20	11	14	26%	e	13	19%	-1	e	13	21%	-1	0	e
21	11	13	21%	e	12	16%	-1	e	13	18%	-1	0	e
22	11	14	26%	e	13	22%	-1	e	13	22%	-1	0	e
23	11	17	39%	e	17	40%	0	e	17	39%	0	0	e
24	11	14	24%	e	14	24%	0	e	15	28%	1	1	e
25	11	18	40%	e	19	44%	1	e	19	45%	1	0	e
26	11	18	43%	e	13	21%	-5	e	14	24%	-4	1	e
27	11	21	50%	e	14	26%	-7	e	10	7%	-10	-4	-
28	11	16	33%	e	16	31%	0	e	12	13%	-4	-4	e
29	11	16	34%	e	16	33%	0	e	16	33%	0	0	e
30	11	14	27%	e	19	43%	5	e	20	44%	6	1	e
31	11	17	36%	e	19	46%	3	e	19	46%	2	0	e
32	11	15	32%	e	20	43%	5	e	20	44%	5	0	e
33	11	13	20%	e	32	55%	19	e	32	56%	19	0	e
34	11	16	32%	e	18	43%	3	e	19	44%	3	0	e
35	11	14	25%	e	16	36%	2	e	16	38%	2	0	e
36	11	16	35%	e	17	36%	1	e	18	38%	1	1	e
37	11	17	39%	e	13	21%	-4	e	13	19%	-4	0	e
38	11	17	39%	e	13	20%	-4	e	12	14%	-5	-1	e
39	11	15	28%	e	9	3%	-6	-	8	2%	-7	-1	-
40	11	17	38%	e	12	15%	-5	e	13	18%	-4	1	e
41	11	19	44%	e	17	37%	-2	e	18	39%	-1	1	e
42	11	19	41%	e	12	12%	-7	e	13	16%	-6	1	e
43	11	12	17%	e	11	10%	-1	e	12	12%	-1	0	e
44	11	15	32%	e	13	20%	-2	e	14	26%	-1	1	e
45	11	13	18%	e	13	19%	0	e	13	22%	1	1	e
46	11	13	21%	e	14	23%	0	e	14	26%	1	1	e
47	11	18	42%	e	14	25%	-4	e	14	25%	-4	0	e
48	11	14	27%	e	18	39%	4	e	19	42%	5	1	e
49	11	14	28%	e	14	25%	0	e	14	24%	-1	0	e
50	11	12	17%	e	13	20%	1	e	13	21%	1	0	e
51	11	13	19%	e	10	5%	-3	-	10	4%	-3	0	-
52	11	16	33%	e	16	32%	0	e	16	31%	0	0	e
53	11	14	23%	e	18	39%	4	e	17	37%	3	-1	e
54	11	15	31%	e	15	28%	-1	e	15	28%	0	0	e
55	11	16	37%	e	18	38%	2	e	19	39%	2	0	e
56	11	16	38%	e	16	26%	-1	e	15	21%	-1	0	e
57	11	18	41%	e	18	44%	0	e	18	43%	0	0	e
58	11	19	43%	e	28	52%	9	e	24	48%	5	-4	e
59	11	21	49%	e	20	47%	-1	e	20	46%	-1	0	e
60	11	17	40%	e	21	45%	4	e	21	44%	3	-1	e
61	11	24	55%	e	18	45%	-5	e	19	46%	-5	1	e
62	11	23	53%	e	16	32%	-7	e	17	37%	-6	1	e
63	11	21	49%	e	17	40%	-4	e	18	43%	-3	1	e
64	11	22	53%	e	14	25%	-8	e	15	28%	-8	1	e
65	11	19	44%	e	19	43%	0	e	20	45%	1	1	e
66	11	17	39%	e	25	54%	7	e	25	55%	7	0	e
67	11	15	31%	e	21	47%	6	e	21	48%	6	0	e
68	11	13	17%	e	13	21%	1	e	14	23%	1	0	e
69	11	16	34%	e	21	47%	5	e	21	48%	5	0	e
70	11	17	37%	e	24	51%	7	e	23	51%	6	-1	e
71	11	21	51%	e	18	40%	-4	e	18	41%	-3	0	e
72	11	21	49%	e	6	0%	-15	-	6	0%	-15	0	-
73	11	21	51%	e	14	24%	-7	e	14	24%	-7	0	e
74	11	17	42%	e	18	39%	1	e	16	35%	-1	-2	e
75	11	23	54%	e	14	26%	-9	e	14	27%	-9	0	e

Table 5.1: Wind comfort analysis results (continued)

Location Number	Comfort Criterion (mph)	Existing Scenario			Project Scenario				Project Variant Scenario				
		Wind Speed exceeded 10% of time (mph)	Percentage of Time Wind Speed Exceeds 11 mph	Exceeds	Wind Speed exceeded 10% of time (mph)	Percentage of Time Wind Speed Exceeds 11 mph	Speed Change Relative to Existing (mph)	Exceeds	Wind Speed exceeded 10% of time (mph)	Percentage of Time Wind Speed Exceeds 11 mph	Speed Change Relative to Existing (mph)	Speed Change Relative to Project (mph)	Exceeds
76	11	22	53%	e	17	37%	-5	e	18	38%	-5	0	e
77	11	20	48%	e	20	44%	0	e	20	44%	0	0	e
78	11	21	49%	e	16	34%	-5	e	18	40%	-3	2	e
79	11	20	45%	e	17	29%	-3	e	16	28%	-3	0	e
80	11	22	53%	e	14	25%	-8	e	14	24%	-8	0	e
81	11	17	39%	e	19	42%	2	e	19	43%	3	1	e
82	11	17	39%	e	14	25%	-3	e	14	25%	-3	0	e
83	11	17	38%	e	14	25%	-3	e	13	23%	-3	0	e
84	11	21	50%	e	12	15%	-9	e	12	15%	-9	0	e
85	11	19	44%	e	11	10%	-8	e	11	10%	-8	0	e
86	11	21	51%	e	14	25%	-7	e	14	27%	-7	0	e
87	11	20	47%	e	11	11%	-9	e	11	9%	-10	-1	-
88	11	22	49%	e	15	31%	-7	e	13	21%	-8	-2	e
89	11	24	54%	e	18	41%	-6	e	19	44%	-5	1	e
90	11	24	52%	e	16	34%	-7	e	18	39%	-6	1	e
91	11	21	46%	e	18	39%	-3	e	19	42%	-2	1	e
92	11	19	43%	e	14	24%	-5	e	14	26%	-5	1	e
93	11	22	47%	e	16	32%	-6	e	17	35%	-5	1	e
94	11	23	52%	e	16	35%	-7	e	18	40%	-5	2	e
95	11	22	50%	e	13	19%	-10	e	14	23%	-9	1	e
96	11	21	46%	e	14	24%	-7	e	15	27%	-6	1	e
97	11	24	52%	e	12	16%	-11	e	14	22%	-10	1	e
98	11	23	54%	e	13	21%	-10	e	14	23%	-10	0	e
99	11	23	55%	e	10	7%	-13	-	11	9%	-12	0	-
100	11	21	50%	e	14	24%	-7	e	14	27%	-7	0	e
101	11	21	53%	e	14	24%	-7	e	14	24%	-7	0	e
102	11	23	56%	e	16	35%	-7	e	16	34%	-7	0	e
103	11	24	57%	e	18	41%	-6	e	18	41%	-6	0	e
104	11	24	56%	e	18	42%	-6	e	19	43%	-5	1	e
105	11	14	25%	e	17	36%	2	e	17	37%	3	0	e
106	11	16	33%	e	19	43%	3	e	19	43%	3	0	e
107	11	22	54%	e	11	11%	-11	e	11	11%	-11	0	e
108	11	20	48%	e	18	41%	-1	e	19	41%	-1	0	e
109	11	24	56%	e	18	41%	-6	e	18	41%	-6	0	e
110	11	14	23%	e	15	31%	1	e	16	33%	2	0	e
111	11	21	47%	e	19	40%	-2	e	18	40%	-3	0	e
112	11	25	59%	e	20	47%	-5	e	21	47%	-4	0	e
113	11	24	58%	e	23	49%	-2	e	23	50%	-1	0	e
114	11	24	59%	e	22	46%	-3	e	22	46%	-3	0	e
115	11	24	59%	e	15	26%	-9	e	15	25%	-9	0	e
116	11	27	64%	e	18	38%	-9	e	18	37%	-9	0	e
117	11	25	62%	e	18	39%	-7	e	18	39%	-7	0	e
118	11	23	58%	e	13	22%	-10	e	13	22%	-10	0	e
119	11	22	54%	e	21	46%	-1	e	21	46%	-1	0	e
120	11	23	54%	e	22	49%	0	e	22	49%	0	0	e
121	11	24	57%	e	23	53%	0	e	23	53%	0	0	e
122	11	24	60%	e	24	54%	-1	e	24	54%	-1	0	e
123	11	24	58%	e	23	53%	-1	e	23	53%	-1	0	e
124	11	25	59%	e	24	55%	-1	e	24	56%	-1	0	e
125	11	21	49%	e	20	46%	0	e	21	47%	0	0	e
126	11	21	52%	e	21	49%	0	e	21	50%	0	0	e
127	11	22	54%	e	20	48%	-2	e	21	49%	-1	1	e
128	11	20	51%	e	19	43%	-2	e	19	44%	-1	0	e
129	11	17	42%	e	17	38%	-1	e	17	39%	0	0	e
130	11	24	58%	e	23	54%	-1	e	23	54%	-1	0	e
131	11	22	55%	e	21	52%	-1	e	21	52%	-1	0	e
132	11	23	57%	e	22	54%	-1	e	22	54%	-1	0	e
133	11	23	57%	e	22	53%	-1	e	22	53%	-1	0	e
134	11	22	55%	e	22	52%	0	e	22	52%	0	0	e
135	11	24	58%	e	23	55%	0	e	23	55%	0	0	e
136	11	14	26%	e	14	26%	0	e	14	25%	0	0	e
137	11	24	58%	e	23	54%	-1	e	23	54%	-1	0	e
138	11	24	58%	e	22	53%	-1	e	22	52%	-1	0	e
139	11	22	54%	e	21	49%	-1	e	21	49%	-1	0	e
140	11	22	55%	e	21	49%	-1	e	21	49%	-1	0	e
141	11	23	57%	e	19	43%	-5	e	19	43%	-5	0	e
142	11	22	55%	e	19	45%	-3	e	19	45%	-3	0	e
143	11	24	58%	e	22	50%	-2	e	22	50%	-2	0	e
144	11	24	56%	e	23	51%	0	e	23	50%	-1	0	e
145	11	21	52%	e	21	49%	0	e	21	48%	0	0	e
146	11	16	32%	e	18	41%	2	e	18	41%	2	0	e
147	11	18	40%	e	18	39%	0	e	17	39%	0	0	e
148	11	22	51%	e	27	50%	6	e	27	49%	5	0	e
149	11	21	52%	e	19	40%	-2	e	18	38%	-3	-1	e
150	11	24	57%	e	18	39%	-6	e	18	40%	-6	0	e

Table 5.1: Wind comfort analysis results (continued)

Location Number	Comfort Criterion (mph)	Existing Scenario			Project Scenario				Project Variant Scenario				
		Wind Speed exceeded 10% of time (mph)	Percentage of Time Wind Speed Exceeds 11 mph	Exceeds	Wind Speed exceeded 10% of time (mph)	Percentage of Time Wind Speed Exceeds 11 mph	Speed Change Relative to Existing (mph)	Exceeds	Wind Speed exceeded 10% of time (mph)	Percentage of Time Wind Speed Exceeds 11 mph	Speed Change Relative to Existing (mph)	Speed Change Relative to Project (mph)	Exceeds
151	11	22	55%	e	16	33%	-6	e	16	34%	-6	0	e
152	11	23	56%	e	15	28%	-9	e	15	30%	-8	0	e
153	11	24	56%	e	15	28%	-9	e	14	27%	-9	0	e
154	11	24	58%	e	14	25%	-10	e	14	23%	-11	0	e
155	11	22	53%	e	12	14%	-10	e	12	14%	-10	0	e
156	11	20	46%	e	16	34%	-4	e	16	35%	-3	0	e
157	11	18	41%	e	15	28%	-3	e	15	27%	-3	0	e
158	11	17	41%	e	15	31%	-2	e	16	33%	-2	0	e
159	11	22	48%	e	19	42%	-3	e	19	42%	-3	0	e
160	11	19	43%	e	18	40%	-2	e	17	38%	-2	-1	e
161	11	12	16%	e	14	22%	2	e	13	20%	1	0	e
162	11	12	15%	e	13	18%	0	e	12	18%	0	0	e
163	11	12	14%	e	12	15%	0	e	12	14%	0	0	e
164	11	14	25%	e	13	20%	-1	e	13	19%	-1	0	e
165	11	17	39%	e	16	35%	-1	e	16	33%	-2	0	e
166	11	21	48%	e	20	45%	-1	e	20	44%	-1	0	e
167	11	20	43%	e	19	43%	0	e	20	43%	0	0	e
168	11	17	40%	e	16	37%	-1	e	16	36%	-1	0	e
169	11	17	37%	e	16	32%	-1	e	15	30%	-2	0	e
170	11	19	47%	e	18	45%	-1	e	18	45%	-1	0	e
171	11	19	49%	e	18	46%	-1	e	18	45%	-1	0	e
172	11	20	50%	e	19	47%	-1	e	19	47%	-1	0	e
173	11	16	36%	e	16	35%	0	e	16	34%	0	0	e
174	11	20	50%	e	19	49%	0	e	19	49%	0	0	e
175	11	21	53%	e	21	51%	-1	e	21	51%	-1	0	e
176	11	24	59%	e	23	58%	-1	e	23	58%	-1	0	e
177	11	26	61%	e	25	59%	-1	e	25	59%	-1	0	e
178	11	21	48%	e	20	46%	-1	e	20	46%	-1	0	e
179	11	23	54%	e	22	53%	-1	e	22	53%	-1	0	e
180	11	25	60%	e	24	59%	0	e	25	59%	0	0	e
181	11	28	65%	e	28	64%	-1	e	28	64%	-1	0	e
182	11	26	62%	e	26	61%	-1	e	26	61%	-1	0	e
183	11	25	61%	e	25	60%	0	e	25	59%	-1	0	e
184	11	21	54%	e	21	53%	0	e	21	53%	0	0	e
185	11	16	36%	e	17	41%	1	e	20	46%	4	2	e
186	11	19	47%	e	19	47%	0	e	20	48%	1	1	e
187	11	19	47%	e	19	46%	0	e	19	46%	0	0	e
188	11	21	55%	e	21	54%	0	e	21	54%	0	0	e
189	11	26	62%	e	25	61%	0	e	25	61%	0	0	e
190	11	23	55%	e	23	55%	0	e	23	55%	0	0	e
191	11	15	33%	e	16	34%	0	e	16	34%	0	0	e
192	11	21	55%	e	21	54%	0	e	21	54%	0	0	e
193	11	22	55%	e	22	54%	-1	e	22	54%	0	0	e
194	11	23	57%	e	22	57%	0	e	23	57%	0	0	e
195	11	21	53%	e	21	52%	0	e	21	52%	0	0	e
196	11	21	52%	e	20	51%	0	e	20	51%	0	0	e
197	11	22	52%	e	22	51%	0	e	22	51%	0	0	e
198	11	21	52%	e	21	52%	0	e	21	52%	0	0	e
199	11	20	49%	e	20	49%	0	e	20	48%	0	0	e
200	11	20	48%	e	20	47%	0	e	20	48%	0	0	e
201	11	16	30%	e	16	30%	0	e	16	31%	0	0	e
202	11	17	37%	e	17	37%	0	e	17	37%	0	0	e
203	11	16	35%	e	16	35%	0	e	16	34%	0	0	e
204	11	16	33%	e	16	33%	0	e	16	33%	0	0	e
205	11	20	45%	e	19	40%	-1	e	19	40%	-1	0	e
206	11	15	30%	e	15	31%	0	e	15	32%	0	0	e
207	11	17	39%	e	17	39%	0	e	17	40%	0	0	e
208	11	23	54%	e	23	53%	0	e	23	53%	0	0	e
209	11	17	39%	e	14	26%	-3	e	14	26%	-3	0	e
210	11	21	51%	e	13	21%	-8	e	14	23%	-8	0	e
211	11	22	54%	e	15	30%	-7	e	15	32%	-7	0	e
212	11	23	57%	e	19	46%	-4	e	19	45%	-4	0	e
213	11	21	52%	e	16	37%	-5	e	16	39%	-4	0	e
214	11	14	28%	e	20	50%	6	e	21	52%	7	1	e
215	11	26	60%	e	22	55%	-4	e	22	56%	-4	0	e
216	11	17	40%	e	16	34%	-2	e	16	35%	-1	0	e
217	11	14	23%	e	13	19%	-1	e	13	20%	-1	0	e
218	11	18	39%	e	15	30%	-3	e	15	32%	-3	0	e
219	11	18	41%	e	16	36%	-2	e	16	36%	-1	0	e
		Average	**Average**	**Sum**	**Average**	**Average**	**Average**	**Sum**	**Average**	**Average**	**Average**	**Average**	**Sum**
		19.6	44.8%	218	17.2	35.6%	-2.4	206	17.3	35.9%	-2.3	+0.1	204
			Existing, e	218			Existing, e	206				Existing, e	204
							New, due to proposed project, p	0				New, due to proposed project variant, p	0
							New, at new location, n	0				New, at new location, n	0
							Eliminated by Proposed Project, -	12				Eliminated by proposed project variant, -	14

Table 5.2: Wind hazard analysis results

Location Number	Hazard Criterion (mph)	Existing Scenario			Project Scenario				Project Variant Scenario				
		Wind Speed Exceeded 1 Hour per Year (mph)	Hours per Year Wind Speed Exceeds Hazard Criteria	Exceeds	Wind Speed Exceeded 1 Hour per Year (mph)	Hours per Year Wind Speed Exceeds Hazard Criteria	Hours Change Relative to Existing	Exceeds	Wind Speed Exceeded 1 Hour per Year (mph)	Hours per Year Wind Speed Exceeds Hazard Criteria	Hours Change Relative to Existing	Hours Change Relative to Project	Exceeds
1	36	30	0		26	0	0		26	0	0	0	
2	36	45	13	e	39	4	-9	e	40	4	-9	0	e
3	36	42	4	e	41	5	1	e	41	5	1	0	e
4	36	40	2	e	41	3	1	e	42	3	1	0	e
5	36	41	3	e	41	2	-1	e	40	2	-1	0	e
6	36	40	2	e	30	0	-2	-	30	0	-2	0	-
7	36	38	1	e	34	0	-1	-	35	0	-1	0	-
8	36	40	2	e	36	1	-1	e	36	1	-1	0	e
9	36	42	9	e	42	4	-5	e	42	4	-5	0	e
10	36	43	15	e	36	0	-15	-	36	0	-15	0	-
11	36	37	1	e	35	0	-1	-	34	0	-1	0	-
12	36	44	10	e	38	1	-9	e	39	1	-9	0	e
13	36	42	4	e	34	0	-4	-	33	0	-4	0	-
14	36	44	6	e	37	1	-5	e	37	1	-5	0	e
15	36	39	2	e	34	0	-2	-	34	0	-2	0	-
16	36	39	2	e	37	1	-1	e	38	1	-1	0	e
17	36	26	0		27	0	0		28	0	0	0	
18	36	28	0		25	0	0		25	0	0	0	
19	36	33	0		31	0	0		33	0	0	0	
20	36	35	0		29	0	0		29	0	0	0	
21	36	37	1	e	36	1	0	e	35	0	-1	-1	-
22	36	41	3	e	32	0	-3	-	31	0	-3	0	-
23	36	33	0		36	1	1	p	36	0	0	-1	
24	36	25	0		25	0	0		27	0	0	0	
25	36	31	0		33	0	0		34	0	0	0	
26	36	33	0		25	0	0		26	0	0	0	
27	36	34	0		34	0	0		28	0	0	0	
28	36	29	0		31	0	0		27	0	0	0	
29	36	30	0		33	0	0		32	0	0	0	
30	36	28	0		34	0	0		34	0	0	0	
31	36	34	0		35	0	0		35	0	0	0	
32	36	27	0		34	0	0		34	0	0	0	
33	36	27	0		52	252	252	p	52	261	261	9	p
34	36	30	0		39	2	2	p	39	1	1	-1	p
35	36	29	0		38	1	1	p	39	1	1	0	p
36	36	33	0		29	0	0		30	0	0	0	
37	36	33	0		30	0	0		30	0	0	0	
38	36	34	0		28	0	0		28	0	0	0	
39	36	35	0		22	0	0		22	0	0	0	
40	36	34	0		28	0	0		28	0	0	0	
41	36	35	0		38	1	1	p	38	1	1	0	p
42	36	32	0		24	0	0		26	0	0	0	
43	36	27	0		23	0	0		25	0	0	0	
44	36	30	0		29	0	0		30	0	0	0	
45	36	27	0		27	0	0		27	0	0	0	
46	36	29	0		32	0	0		33	0	0	0	
47	36	35	0		35	0	0		35	0	0	0	
48	36	29	0		38	1	1	p	37	1	1	0	p
49	36	27	0		27	0	0		27	0	0	0	
50	36	25	0		26	0	0		26	0	0	0	
51	36	25	0		23	0	0		23	0	0	0	
52	36	30	0		28	0	0		27	0	0	0	
53	36	24	0		30	0	0		30	0	0	0	
54	36	33	0		24	0	0		25	0	0	0	
55	36	32	0		36	0	0		38	2	2	2	p
56	36	31	0		41	3	3	p	39	2	2	-1	p
57	36	37	1	e	59	23	22	e	57	20	19	-3	e
58	36	33	0		46	79	79	p	42	13	13	-66	p
59	36	37	1	e	42	3	2	e	40	2	1	-1	e
60	36	32	0		41	8	8	p	41	8	8	0	p
61	36	40	6	e	47	6	0	e	44	4	-2	-2	e
62	36	37	1	e	32	0	-1	-	33	0	-1	0	-
63	36	38	1	e	39	1	0	e	39	2	1	1	e
64	36	38	2	e	28	0	-2	-	29	0	-2	0	-
65	36	35	0		32	0	0		35	0	0	0	
66	36	34	0		43	16	16	p	44	19	19	3	p
67	36	39	2	e	55	17	15	e	54	15	13	-2	e
68	36	31	0		46	7	7	p	48	10	10	3	p
69	36	32	0		36	1	1	p	37	1	1	0	p
70	36	30	0		40	5	5	p	41	4	4	-1	p
71	36	40	2	e	34	0	-2	-	34	0	-2	0	-
72	36	37	1	e	14	0	-1	-	14	0	-1	0	-
73	36	43	5	e	27	0	-5	-	26	0	-5	0	-
74	36	36	1	e	33	0	-1	-	31	0	-1	0	-
75	36	44	8	e	27	0	-8	-	26	0	-8	0	-

Table 5.2: Wind hazard analysis results (continued)

Location Number	Hazard Criterion (mph)	Existing Scenario			Project Scenario				Project Variant Scenario				
		Wind Speed Exceeded 1 Hour per Year (mph)	Hours per Year Wind Speed Exceeds Hazard Criteria	Exceeds	Wind Speed Exceeded 1 Hour per Year (mph)	Hours per Year Wind Speed Exceeds Hazard Criteria	Hours Change Relative to Existing	Exceeds	Wind Speed Exceeded 1 Hour per Year (mph)	Hours per Year Wind Speed Exceeds Hazard Criteria	Hours Change Relative to Existing	Hours Change Relative to Project	Exceeds
76	36	40	3	e	31	0	-3	-	31	0	-3	0	-
77	36	42	4	e	39	2	-2	e	39	2	-2	0	e
78	36	39	2	e	34	0	-2	-	34	0	-2	0	-
79	36	39	2	e	38	1	-1	e	40	2	0	1	e
80	36	42	4	e	36	0	-4	-	36	0	-4	0	-
81	36	36	0		34	0	0		35	0	0	0	
82	36	36	0		31	0	0		30	0	0	0	
83	36	32	0		33	0	0		33	0	0	0	
84	36	41	3	e	26	0	-3	-	28	0	-3	0	-
85	36	33	0		27	0	0		29	0	0	0	
86	36	40	2	e	36	0	-2	-	37	1	-1	1	e
87	36	38	2	e	31	0	-2	-	31	0	-2	0	-
88	36	40	3	e	39	2	-1	e	39	2	-1	0	e
89	36	48	18	e	51	15	-3	e	50	13	-5	-2	e
90	36	42	7	e	31	0	-7	-	31	0	-7	0	-
91	36	35	0		29	0	0		31	0	0	0	
92	36	32	0		23	0	0		25	0	0	0	
93	36	35	0		26	0	0		28	0	0	0	
94	36	40	3	e	29	0	-3	-	31	0	-3	0	-
95	36	37	1	e	30	0	-1	-	30	0	-1	0	-
96	36	35	0		27	0	0		29	0	0	0	
97	36	40	6	e	30	0	-6	-	31	0	-6	0	-
98	36	40	5	e	28	0	-5	-	28	0	-5	0	-
99	36	39	4	e	26	0	-4	-	27	0	-4	0	-
100	36	36	1	e	35	0	-1	-	37	1	0	1	e
101	36	38	1	e	30	0	-1	-	30	0	-1	0	-
102	36	49	14	e	30	0	-14	-	30	0	-14	0	-
103	36	45	10	e	31	0	-10	-	32	0	-10	0	-
104	36	50	29	e	31	0	-29	-	32	0	-29	0	-
105	36	33	0		36	0	0		36	1	1	1	p
106	36	37	1	e	33	0	-1	-	37	1	0	1	e
107	36	41	4	e	22	0	-4	-	22	0	-4	0	-
108	36	44	5	e	31	0	-5	-	31	0	-5	0	-
109	36	51	20	e	36	1	-19	e	35	0	-20	-1	-
110	36	34	0		34	0	0		40	2	2	2	p
111	36	34	0		31	0	0		31	0	0	0	
112	36	41	11	e	33	0	-11	-	34	0	-11	0	-
113	36	42	7	e	36	1	-6	e	37	1	-6	0	e
114	36	46	13	e	36	1	-12	e	36	1	-12	0	e
115	36	46	11	e	31	0	-11	-	31	0	-11	0	-
116	36	50	39	e	35	0	-39	-	35	0	-39	0	-
117	36	48	23	e	37	1	-22	e	37	1	-22	0	e
118	36	44	9	e	24	0	-9	-	24	0	-9	0	-
119	36	40	3	e	35	0	-3	-	35	0	-3	0	-
120	36	39	3	e	36	1	-2	e	37	1	-2	0	e
121	36	41	6	e	38	3	-3	e	39	3	-3	0	e
122	36	47	15	e	39	4	-11	e	39	4	-11	0	e
123	36	42	7	e	38	3	-4	e	38	3	-4	0	e
124	36	45	15	e	41	9	-6	e	41	8	-7	-1	e
125	36	38	1	e	34	0	-1	-	35	0	-1	0	-
126	36	40	3	e	35	0	-3	-	35	0	-3	0	-
127	36	42	4	e	35	0	-4	-	35	0	-4	0	-
128	36	36	1	e	32	0	-1	-	32	0	-1	0	-
129	36	38	1	e	32	0	-1	-	33	0	-1	0	-
130	36	43	8	e	39	3	-5	e	39	3	-5	0	e
131	36	44	7	e	37	1	-6	e	37	1	-6	0	e
132	36	43	7	e	38	2	-5	e	38	2	-5	0	e
133	36	44	8	e	36	1	-7	e	36	1	-7	0	e
134	36	43	5	e	36	1	-4	e	36	1	-4	0	e
135	36	43	9	e	40	6	-3	e	40	5	-4	-1	e
136	36	33	0		28	0	0		28	0	0	0	
137	36	41	7	e	39	3	-4	e	39	3	-4	0	e
138	36	47	11	e	37	1	-10	e	37	1	-10	0	e
139	36	41	3	e	35	0	-3	-	35	0	-3	0	-
140	36	40	3	e	35	0	-3	-	35	0	-3	0	-
141	36	42	6	e	32	0	-6	-	32	0	-6	0	-
142	36	41	3	e	32	0	-3	-	32	0	-3	0	-
143	36	43	9	e	37	1	-8	e	37	1	-8	0	e
144	36	40	4	e	38	3	-1	e	38	2	-2	-1	e
145	36	44	5	e	36	0	-5	-	35	0	-5	0	-
146	36	33	0		32	0	0		32	0	0	0	
147	36	32	0		30	0	0		31	0	0	0	
148	36	39	2	e	46	63	61	e	46	55	53	-8	e
149	36	43	4	e	36	0	-4	-	35	0	-4	0	-
150	36	43	7	e	32	0	-7	-	32	0	-7	0	-

Table 5.2: Wind hazard analysis results (continued)

Location Number	Hazard Criterion (mph)	Existing Scenario			Project Scenario				Project Variant Scenario				
		Wind Speed Exceeded 1 Hour per Year (mph)	Hours per Year Wind Speed Exceeds Hazard Criteria	Exceeds	Wind Speed Exceeded 1 Hour per Year (mph)	Hours per Year Wind Speed Exceeds Hazard Criteria	Hours Change Relative to Existing	Exceeds	Wind Speed Exceeded 1 Hour per Year (mph)	Hours per Year Wind Speed Exceeds Hazard Criteria	Hours Change Relative to Existing	Hours Change Relative to Project	Exceeds
151	36	42	4	e	29	0	-4	-	29	0	-4	0	-
152	36	41	4	e	26	0	-4	-	27	0	-4	0	-
153	36	40	5	e	28	0	-5	-	28	0	-5	0	-
154	36	47	14	e	30	0	-14	-	29	0	-14	0	-
155	36	42	5	e	27	0	-5	-	27	0	-5	0	-
156	36	33	0		29	0	0		28	0	0	0	
157	36	31	0		26	0	0		26	0	0	0	
158	36	32	0		27	0	0		27	0	0	0	
159	36	37	1	e	31	0	-1	-	30	0	-1	0	-
160	36	33	0		30	0	0		29	0	0	0	
161	36	24	0		26	0	0		26	0	0	0	
162	36	28	0		33	0	0		34	0	0	0	
163	36	25	0		28	0	0		29	0	0	0	
164	36	25	0		24	0	0		24	0	0	0	
165	36	30	0		27	0	0		27	0	0	0	
166	36	33	0		32	0	0		32	0	0	0	
167	36	32	0		31	0	0		31	0	0	0	
168	36	31	0		29	0	0		28	0	0	0	
169	36	35	0		31	0	0		30	0	0	0	
170	36	36	0		32	0	0		32	0	0	0	
171	36	36	1	e	33	0	-1	-	32	0	-1	0	-
172	36	39	2	e	35	0	-2	-	35	0	-2	0	-
173	36	33	0		32	0	0		31	0	0	0	
174	36	40	2	e	36	1	-1	e	36	1	-1	0	e
175	36	38	1	e	35	0	-1	-	35	0	-1	0	-
176	36	44	9	e	40	3	-6	e	40	3	-6	0	e
177	36	44	25	e	41	12	-13	e	41	14	-11	2	e
178	36	44	8	e	40	2	-6	e	40	2	-6	0	e
179	36	39	3	e	37	1	-2	e	38	1	-2	0	e
180	36	48	20	e	43	10	-10	e	43	11	-9	1	e
181	36	51	81	e	47	56	-25	e	47	56	-25	0	e
182	36	45	24	e	43	16	-8	e	42	15	-9	-1	e
183	36	45	15	e	42	10	-5	e	41	8	-7	-2	e
184	36	43	5	e	39	2	-3	e	38	1	-4	-1	e
185	36	34	0		33	0	0		33	0	0	0	
186	36	37	1	e	35	0	-1	-	35	0	-1	0	-
187	36	41	3	e	38	1	-2	e	37	1	-2	0	e
188	36	40	3	e	38	1	-2	e	37	1	-2	0	e
189	36	44	20	e	44	20	0	e	43	18	-2	-2	e
190	36	41	7	e	41	8	1	e	41	8	1	0	e
191	36	30	0		29	0	0		29	0	0	0	
192	36	49	17	e	47	12	-5	e	47	12	-5	0	e
193	36	38	2	e	37	1	-1	e	37	1	-1	0	e
194	36	41	4	e	39	3	-1	e	40	3	-1	0	e
195	36	37	1	e	36	0	-1	-	36	0	-1	0	-
196	36	39	2	e	37	1	-1	e	37	1	-1	0	e
197	36	38	2	e	38	2	0	e	37	2	0	0	e
198	36	38	1	e	36	1	0	e	36	0	-1	-1	-
199	36	38	1	e	36	1	0	e	36	0	-1	-1	-
200	36	37	1	e	36	1	0	e	36	0	-1	-1	-
201	36	39	2	e	37	1	-1	e	38	1	-1	0	e
202	36	30	0		30	0	0		30	0	0	0	
203	36	35	0		35	0	0		35	0	0	0	
204	36	31	0		31	0	0		32	0	0	0	
205	36	37	1	e	32	0	-1	-	33	0	-1	0	-
206	36	31	0		36	0	0		36	1	1	1	p
207	36	39	2	e	37	1	-1	e	37	1	-1	0	e
208	36	43	5	e	38	3	-2	e	39	3	-2	0	e
209	36	38	1	e	31	0	-1	-	31	0	-1	0	-
210	36	38	1	e	34	0	-1	-	34	0	-1	0	-
211	36	40	2	e	40	2	0	e	39	2	0	0	e
212	36	43	7	e	43	5	-2	e	44	6	-1	1	e
213	36	39	1	e	38	1	0	e	38	1	0	0	e
214	36	36	0		36	0	0		37	1	1	1	p
215	36	45	20	e	43	6	-14	e	43	6	-14	0	e
216	36	40	2	e	40	2	0	e	40	2	0	0	e
217	36	42	3	e	40	2	-1	e	40	2	-1	0	e
218	36	38	1	e	35	0	-1	-	35	0	-1	0	-
219	36	38	1	e	35	0	-1	-	36	0	-1	0	-
		Average	**Sum**	**Sum**	**Average**	**Sum**	**Sum**	**Sum**	**Average**	**Sum**	**Sum**	**Sum**	**Sum**
		37.5	888	137	34.2	767	-121	83	34.3	696	-192	-71	85
			Existing, e	137			Existing, e	70				Existing, e	68
							New, due to proposed project, p	13				New, due to proposed project variant, p	17
							New, at new location, n	0				New, at new location, n	0
							Eliminated by Proposed Project, -	67				Eliminated by proposed project variant, -	69

Figure 5.1a: Wind comfort results - Existing Scenario

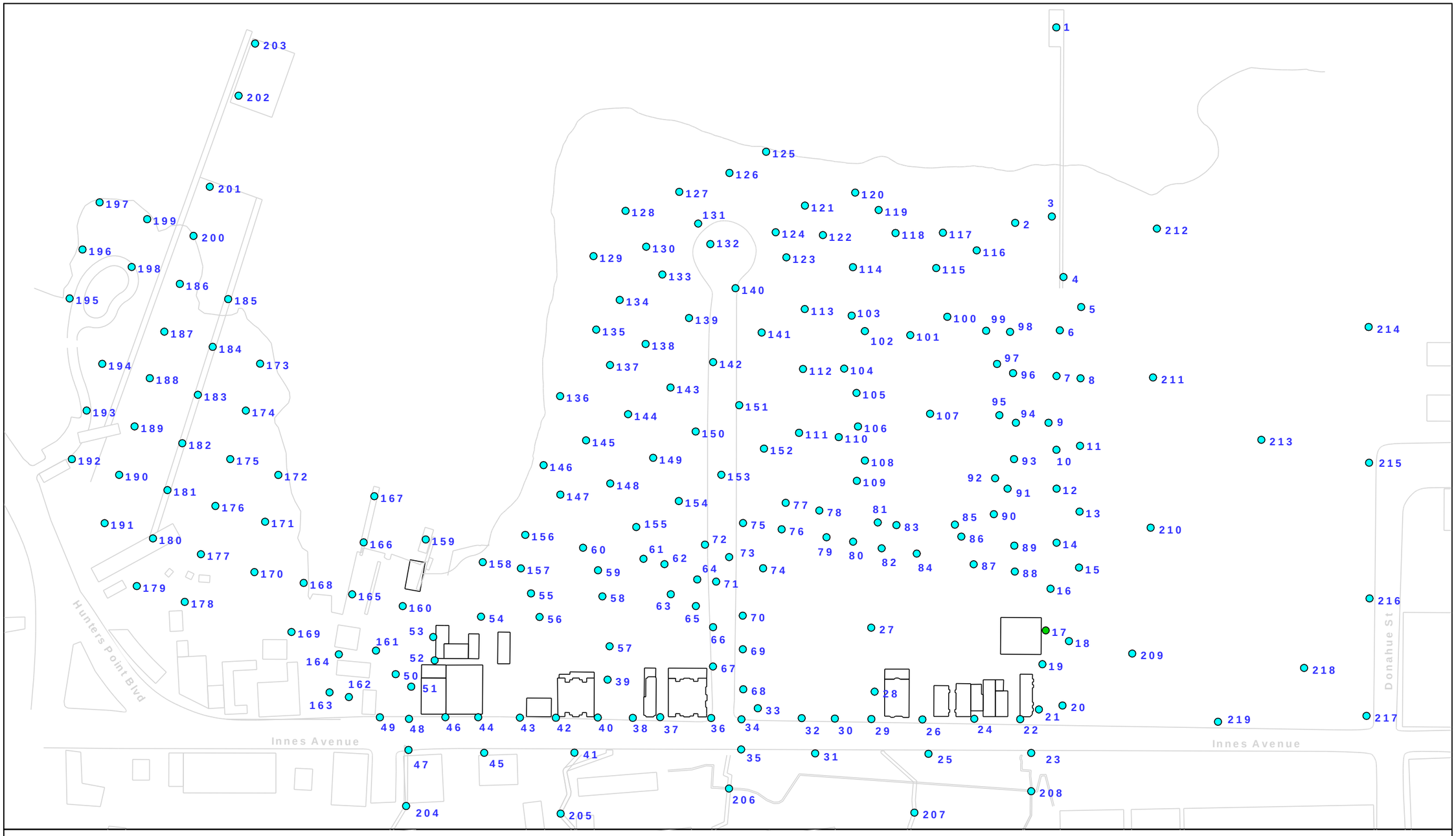


Figure 5.1b: Wind hazard results - Existing Scenario

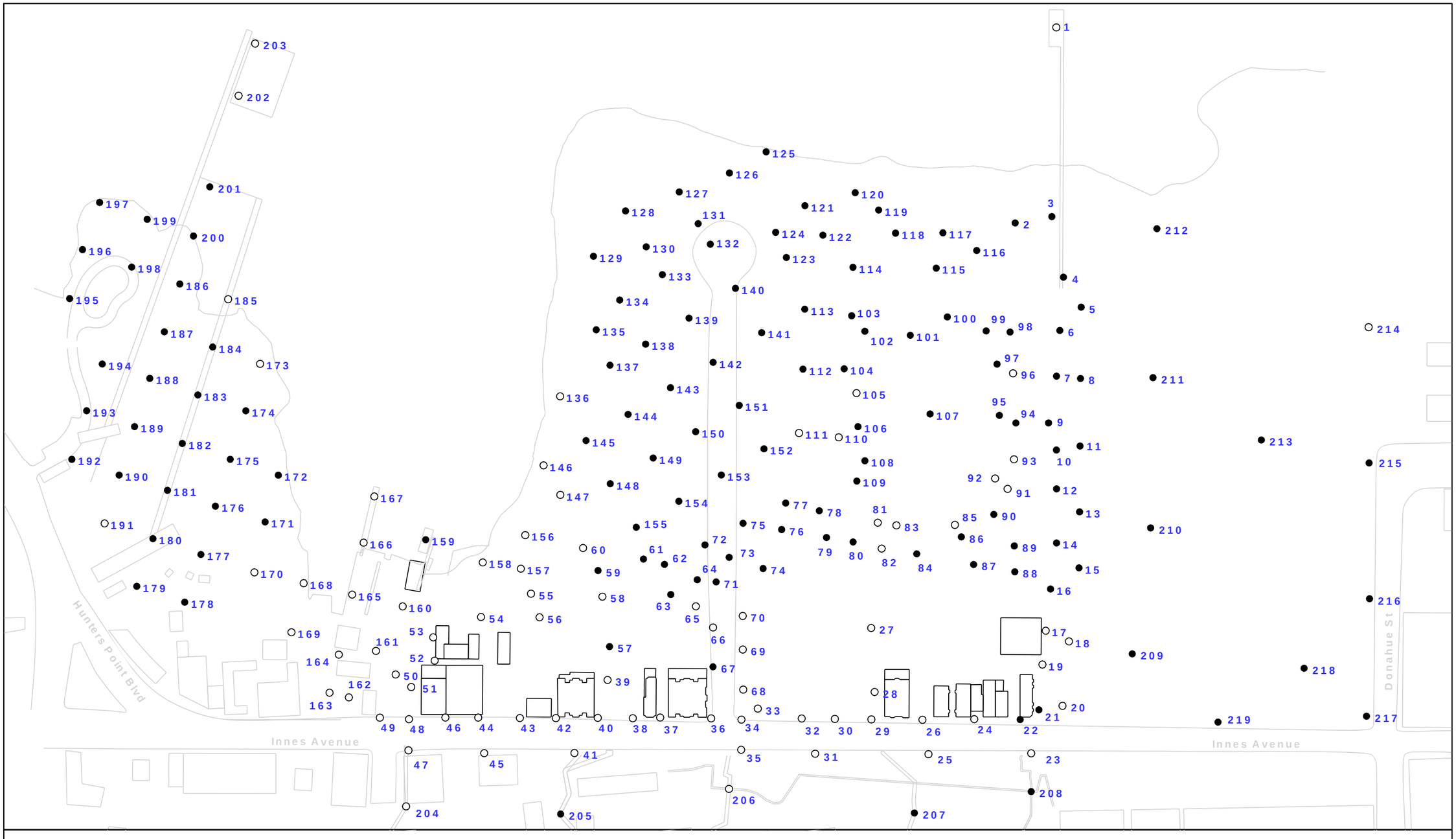


Figure 5.2a: Wind comfort results – Project Scenario

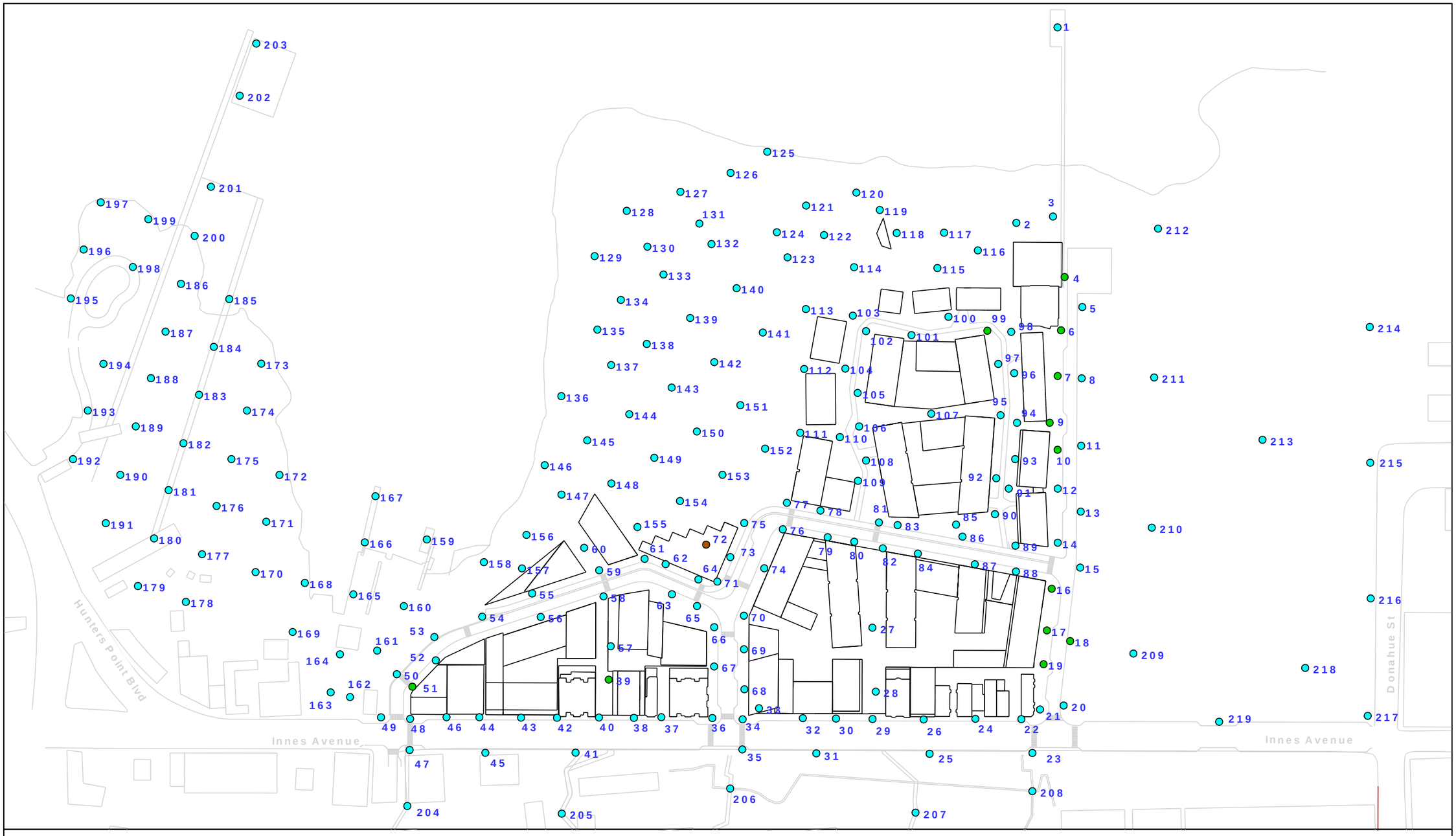


Figure 5.2b: Wind hazard results – Project Scenario

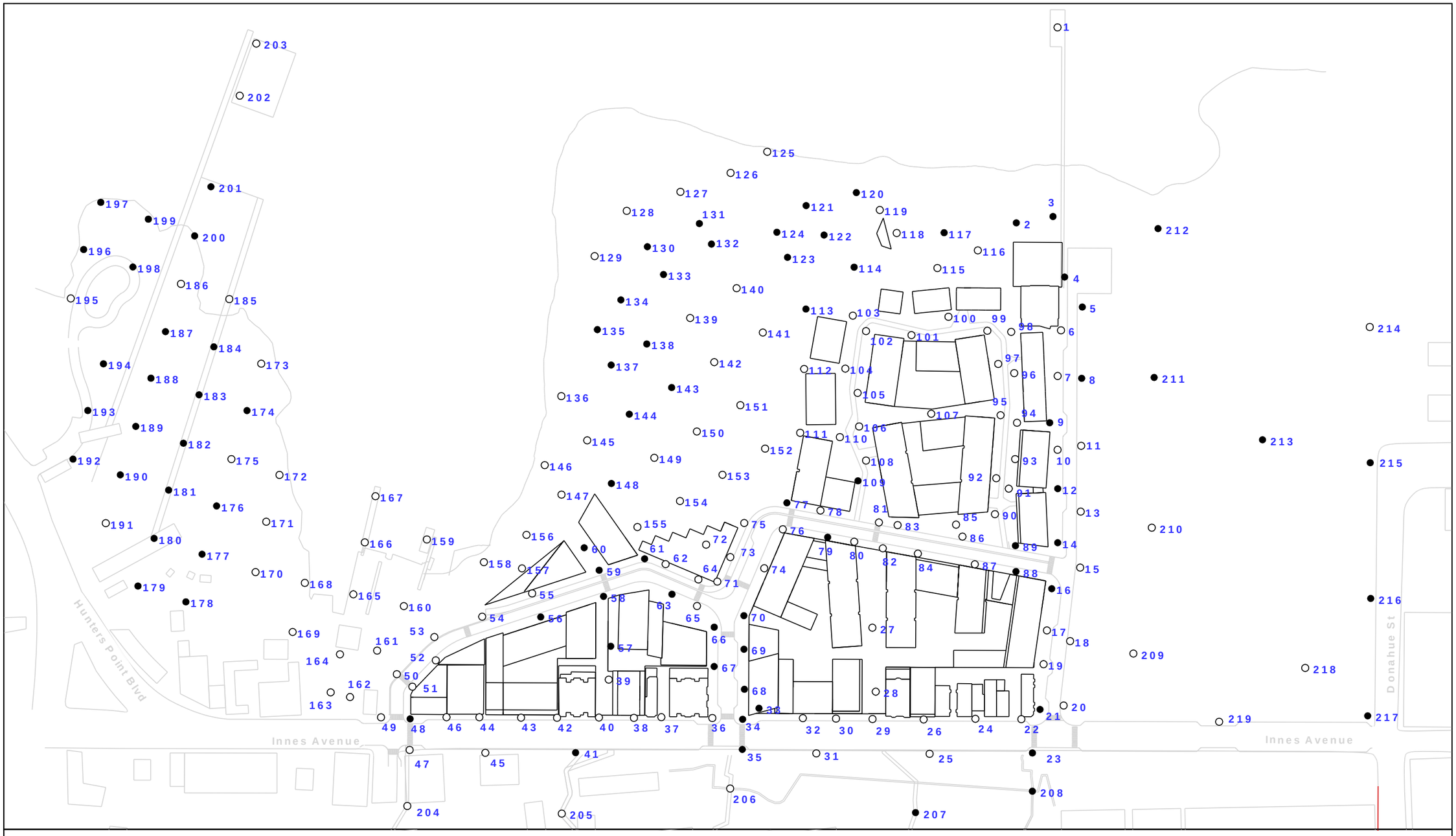


Figure 5.3a: Wind comfort results – Project Variant Scenario

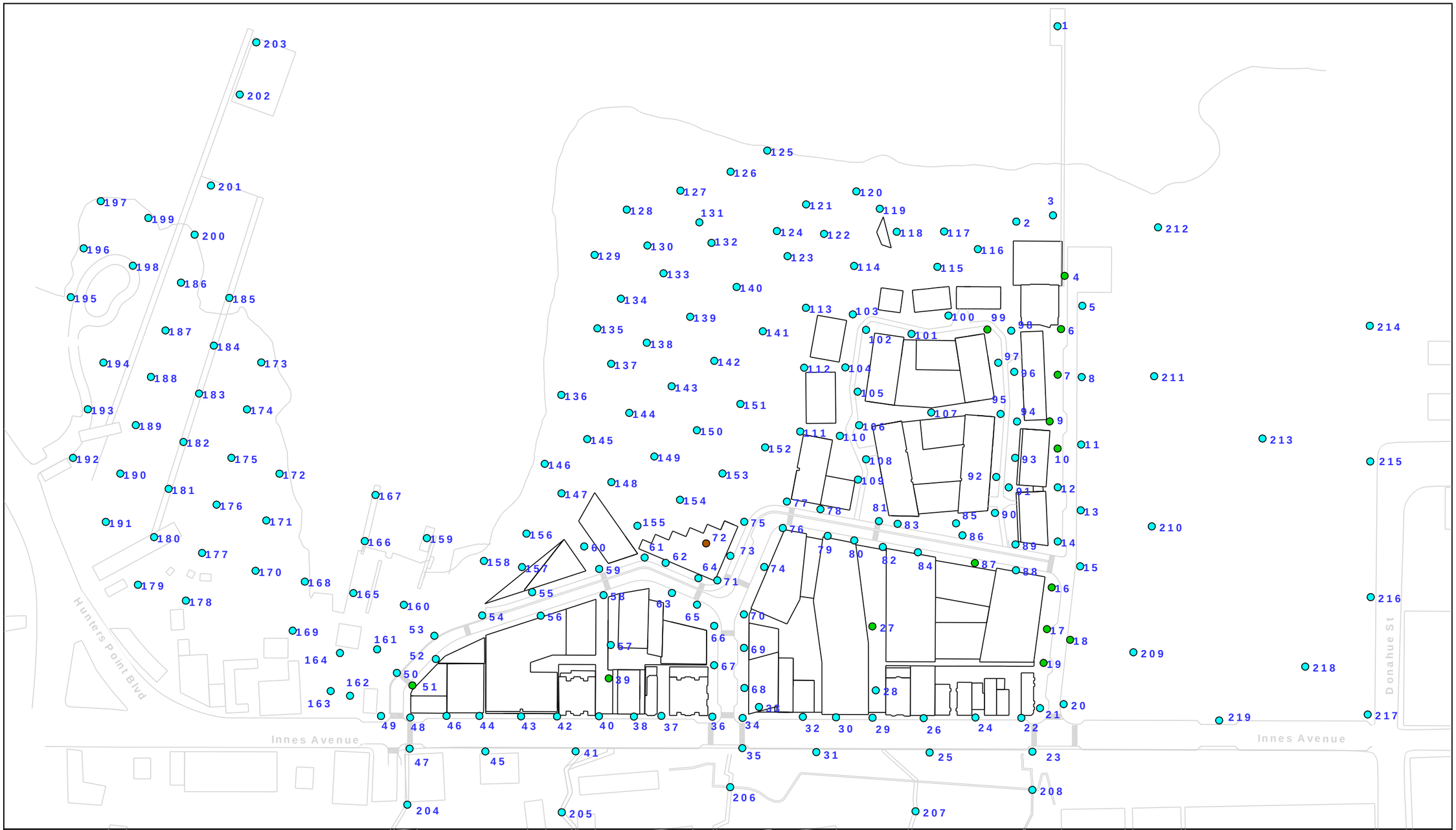
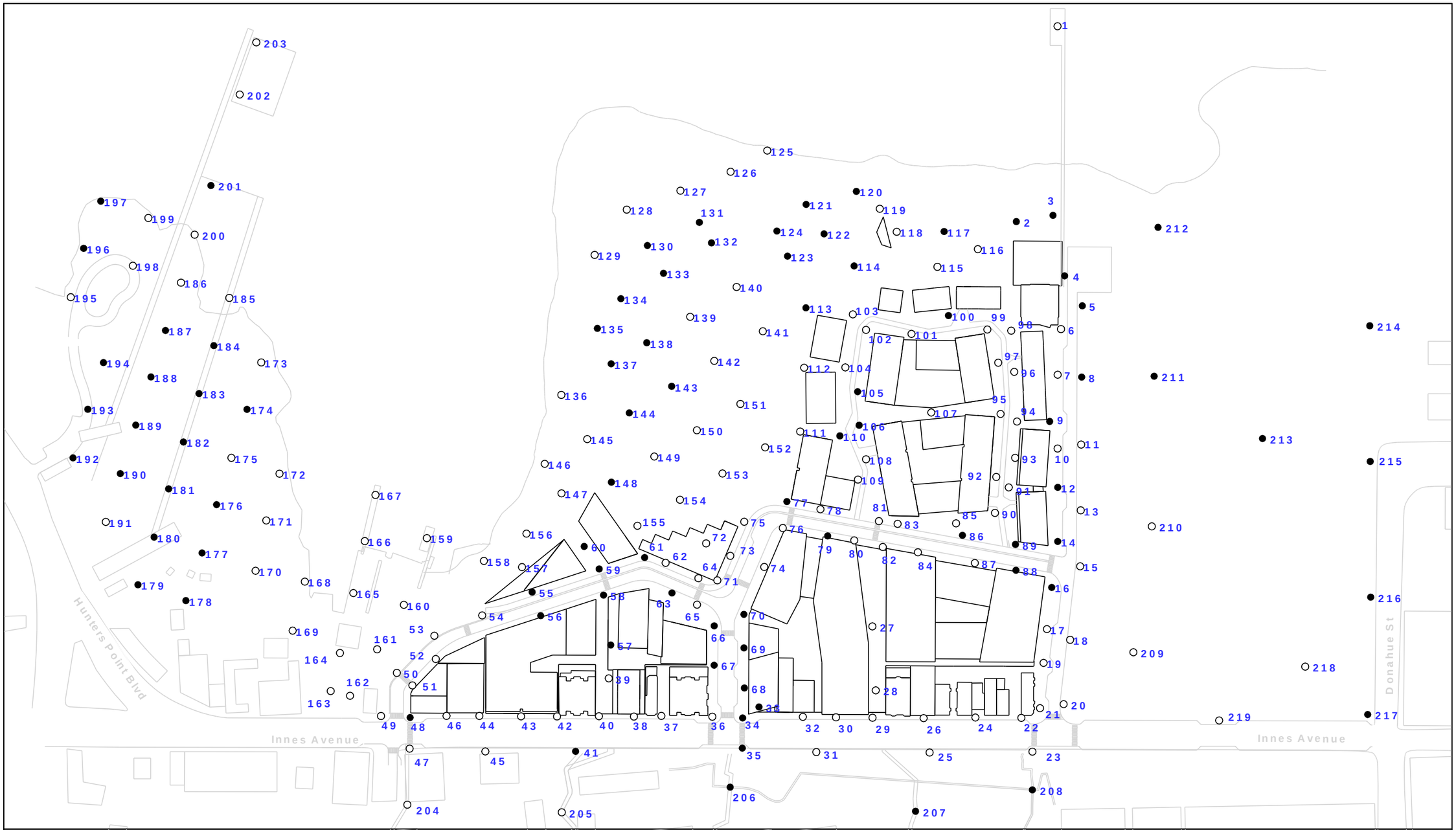


Figure 5.3b: Wind hazard results – Project Variant Scenario



6. Discussion of Results

Located on the eastern edge of the San Francisco peninsula, the project site is principally exposed to winds blowing across the Bay from the north to east. Relatively speaking, however, these winds are comparatively infrequent and calmer in comparison with prevailing winds, which principally blow from a quadrant centred on the west. From this direction, the project site sits on the downwind edge of the peninsula. While this is true, the upwind terrain, topography and building morphology do relatively little to impede strong prevailing winds originating from the Pacific. Low-rise, principally suburban neighborhoods occupy terrain with – in places – gentle hillsides. Thus, strong winds blow across the peninsula and, as might be expected, reach the project site which, in its immediate vicinity, is substantially exposed to the west.

The existing site current microclimate is expectedly windy, with the comfort and hazard criteria exceeded at a number of locations prior to the introduction of any new buildings or development. With an existing microclimate of this nature, the eradication of these exceedances would represent challenges irrespective of the architecture.

6.1. Existing Scenario

Existing conditions in the project vicinity may be generally characterized as windy. The existing site and surrounding areas are subject to winds in excess of the City's comfort criterion for more than 10% of the time during the year. The project site and surrounding study area is also prone to exceedances of the wind hazard criterion at a number of locations.

6.1.1. Wind Comfort Criterion

As stated in Section 3.2 above, the Planning Code Section 148 establishes a wind comfort criterion. The study area is perceivably windy with an average wind speed of 19.6 mph, with conditions generally exceeding the City's 11 mph pedestrian comfort criterion more than 10% of the time. Within the study area, almost all points tested – 218 of the 219 points – exceed the comfort criterion specified in Section 148 of the San Francisco Planning Code (see **Table 5.1** and **Figure 5.1a**).

6.1.2. Wind Hazard Criterion

Within the existing scenario, almost two-thirds – 137 of the 219 test locations fail to comply with the hazard criterion, while the remaining 82 test locations comply with the hazard criterion, with the total number of hours exceeding the hazard criterion reaching 886 hours per year (see **Table 5.2** and **Figure 5.1b**).

6.2. Proposed Project Scenario

The assessment indicates that in the proposed project scenario located within the existing setting, wind conditions would substantially improve in terms of wind comfort and wind hazard, compared to the existing scenario.

6.2.1. Wind Comfort Criterion

In terms of comfort, average wind speeds would reduce from 19.6 mph to 17.2 mph. The project would eliminate 12 exceedances of the comfort criterion (a reduction from 218 to 206) (see **Table 5.1** and **Figure 5.2a**), with eliminated exceedances mainly located at the east side of the 700 Innes building. Compared to the existing scenario, there would be 12 exceedances in total, mainly located at the western sidewalk of Earl Street, which would be more suitable for pedestrians walking throughout the year. The project would create zero new exceedances for the pedestrian comfort criterion.

The highest increase in average mph compared to existing conditions is at the southwest corner of the "Hillside" parcel under the 14-story, 150- to 155-foot-tall building (test point #33), where the average wind speed would increase by 19 mph (from 13 mph to 32 mph). It would be mainly caused by wind downdraft from the 14-storey building and subsequent accelerations of prevailing westerly winds at the building corner.

6.2.2. Wind Hazard Criterion

In total, the proposed project would reduce exceedances of the wind hazard criterion to 83 locations compared to 137 locations for existing conditions, and would reduce the duration of hazardous winds from 888 hours per year to 767 hours per year, representing 54 fewer hazard exceedances and 121 fewer hours, respectively, compared to existing conditions (see **Table 5.2** and **Figure 5.2b**). The proposed project would result in an additional 54 locations, mainly located within the India Basin Open Space and the southeast of the "Big Green" of the 700 Innes, which would be suitable, in terms of pedestrian and cyclist's safety, throughout the year compared to the existing conditions.

Although the proposed project would be an overall improvement in terms of the number of hazard exceedances and the duration of hazardous winds, there would be localized increases in wind speed and the duration of hazardous winds on the site.

As shown in Table 5.2, the following locations would experience a substantial increase in the wind speed and the duration of hazardous winds: 33, 57, 58, 60, 66, 67, 68, and 148. The total number of hazard hour increases relative to existing conditions between these eight test locations would be 460 hours. At these test locations, pedestrians and cyclists would have a difficult time maintaining their balance while passing through these locations and could be at risk of physical injury. On balance, the substantial increase in wind speed and the duration of hazardous winds at these locations outweighs the overall improvement in wind conditions on the project site.

6.3. Project Variant Scenario

Similar to the proposed project scenario, wind conditions in the maximum commercial project variant scenario would substantially improve in terms of wind comfort and wind hazard, compared to the existing scenario. Compared to the proposed project, wind conditions for the variant would only have a marginal change in terms of wind comfort, and would improve in terms of wind hazard.

6.3.1. Wind Comfort Criterion

Compared to the existing scenario, the average wind speeds under the project variant scenario within the existing surrounding area would be reduced from 19.6 mph to 17.3 mph. The project variant would eliminate 14 exceedances when compared to existing setting, (a reduction from 218 to 204) (see **Table 5.1** and **Figure 5.3a**). The project variant would have a lower reduction when compared to the proposed project. Compared to the existing scenario, there are 14 exceedances in total, mainly located at the western sidewalk of Earl Street, which would be more suitable for pedestrians walking throughout the year under the variant compared to the existing conditions. The variant would create zero new exceedances of the pedestrian comfort criterion.

Compared to the proposed project, the project variant would have an average wind speed exceeded 10% of the time and would marginally increase from 17.2 mph to 17.3 mph, but the number of locations at which the 11 mph comfort criterion would be exceeded would be marginally reduced from 205 points to 204 points. Therefore, the overall difference in wind results between the proposed project and the project variant is nearly the same.

6.3.2. Wind Hazard Criterion

The results indicate that 85 locations would fail to comply with the hazard criterion under the project variant scenario, representing a net reduction of 52 exceedance locations compared to the existing scenario. Under the project variant, the total duration of hazardous winds would be reduced by 192 hours from 888 hours per year to 696 hours per year compared to the existing scenario (see **Table 5.2** and **Figure 5.3b**). The project variant would result in an additional 52 exceedances within the study area, mainly located within the India Basin Open Space and the southeast of the "Big

Green" of the 700 Innes, which would be suitable, in terms of pedestrian safety, throughout the year, compared to the existing conditions.

A total of 85 locations under the project variant scenario indicate an exceedance of the hazard criteria, compared to the 83 locations that would fail to comply with the hazard criterion under the proposed project scenario. However, under the project variant scenario the total duration of hazardous winds would be reduced by 71 hours, from 767 hours per year under the project scenario compared to 696 hours per year under the project variant scenario.

Although there would be an overall improvement in terms of the number of hazard exceedances and the duration of hazardous winds when compared to existing conditions, there would be localized increases in wind speed and the duration of hazardous winds under the project variant.

As with the proposed project, implementation of the project variant would reduce the total number of locations exceeding the hazard criterion and the total duration of hazardous winds when compared to existing conditions. As shown in Table 5.2 above, the following locations would experience a substantial increase in the wind speed and the duration of hazardous winds: 33, 57, 58, 60, 66, 67, 68, and 148. The total number of hazard hour increases relative to existing conditions between these eight test locations would be 396 hours. At these test locations, Pedestrians and cyclists would have a difficult time maintaining their balance while passing through these locations and which could increase the risk of physical injury. On balance, the substantial increase in wind speed and the duration of hazardous winds at these locations outweighs the overall improvement in wind conditions on the project site.

7. Findings

Construction of the proposed project is expected to occur in phases and take years to reach full build-out. Although the project at full build-out would generally improve wind conditions on the project site, interim wind impacts may occur prior to the completion of construction. Due to phased build-out, a particular building configuration resulting from partial completion of the proposed project could last for one or more years, creating the potential for interim wind impacts. Furthermore, if the proposed project were not completed, a partial build-out situation would occur, resulting in different wind characteristics than those tested in the wind tunnel.

This pedestrian wind study provides information about the wind conditions on sidewalks, parks, and open spaces within and in the vicinity of the project only at full build-out for the program in the two configurations tested (project scenario and project variant scenario). The wind study assumes full build-out, with massing models for future proposed buildings in the project site providing shelter from prevailing winds for buildings downwind. Prior to full build-out, stronger pedestrian-level winds are likely to occur on open spaces and at individual building sites. Thus, potential wind hazard criterion exceedances could occur at locations not identified in the tested scenarios. Additionally, the ultimate build-out of the project might not maximize the development potential under either of the project or project variant scenarios.

This wind study does not provide quantitative results about wind conditions during interim stages of development and, as a practical matter, cannot provide such information, due to the number of possible permutations of development. For both project and project scenario, the maximum envelope was assessed in the wind tunnel study. Once surrounding buildings have been completed and provide effective wind shelter, it is possible that these temporary impacts would cease; however, they may not, depending on the architectural designs of those buildings. Depending upon the circumstances of the construction, these temporary impacts could continue until the full build-out. Because potential wind hazards could result from a very large number of possible combinations of different building designs, and permutations of construction sequences during the build-out of the project, predicting the occurrence of all such hazards is not possible.

Based on the wind tunnel study and knowledge of the prevailing wind directions, development of buildings on the project site generally from the west to the east would provide the best protection from potential wind hazards. The amount of sheltering provided by then-existing buildings on adjacent parcels or areas located upwind (to the west-southwest, west, west-northwest and northwest) of a subsequent development site should be considered. Depending on circumstances, such as the heights and proximity of surrounding buildings, buildings under 100 feet in height, would be less likely to create wind hazard conditions.

As described above, in addition to the effects identified in this wind study, at full build-out there may be potential temporary wind hazard effects associated with certain new

structures within the project site where insufficient protection from strong winds exist at the time of construction and occupancy. This is most likely to occur to the proposed buildings over 100 feet in height. During the period before full build-out of the project, wind hazards could occur at public locations that were not identified in the wind study and / or identified wind hazards could be increased in severity or extent. Such wind hazards would likely exist until buildings on adjacent parcels are completed and provide shelter from the wind. Mitigation measures, as described in Section 8 below, would offer wind protection and / or to limit access to the hazardous areas, and would be recommended to prevent exposure of pedestrians and cyclists to hazardous winds in pedestrian areas during that temporary interval.

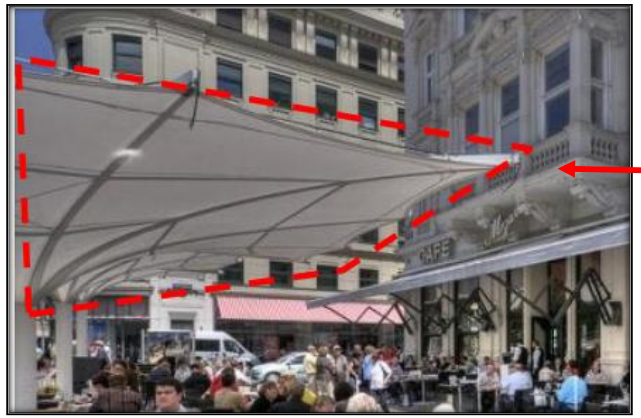
8. Recommendations for Mitigation Measures

In order to enhance the local wind conditions and to ensure the presence of amenable conditions within the project site and surrounding area, it is recommended to develop landscaping proposals / mitigation measures, which might include, but would not be limited to those outlined below, and to verify the effectiveness of these via wind tunnel testing.

- Introduce hard landscaping such as localised porous / solid screens, soft landscaping such as localised tree or hedge planting at buildings corners
- Recess entrances or introduce entrance side screens
- Introduce canopies along the building façade on the pedestrian level
- Introduce sheltered bus stops with vertical screens and roofs
- Introduce solid / porous screens and soft landscaping to create localised pockets suitable for recreational spaces uses or long periods of outdoor seating
- Introduce parapets, canopies and cabanas at outdoor seating areas

Examples of practical wind mitigation measures are presented in Figures 8.1 and 8.2.

Figure 8.1: Mitigation examples



Porous or solid canopies to mitigate downdrafts on podium level and ground level

Verticalscreens to mitigate local wind speeds

Figure 8.2: Mitigation examples

9. Conclusions

The wind study concludes that implementing the proposed project, in terms of comfort, would reduce the average wind speed of all test points exceeded 10% of the time from 19.6 mph in the existing scenario to 17.2 mph. The proposed project would result in 206 test points exceeding the established 11 mph comfort criterion, a net decrease of 12 exceedances over the existing conditions. The total exceedances of the wind hazard criterion would be reduced by 54 (from 137 to 83) and would reduce duration of hazardous winds by 121 hours in the proposed project scenario compared to the existing conditions (from 888 hours to 767 hours). The greatest increment in wind speeds and wind hazard exceedance hours of the test points would be located at the southwest corner of the 700 Innes "Hillside" parcel under the 14-storey building.

For the maximum commercial project variant scenario located within the existing setting, wind conditions would also improve, in terms of wind comfort and hazard, compare to the existing scenario. The average wind speed of all test points would be reduced from 19.6 mph to 17.3 mph. There would be 204 exceedances in total, representing a net decrease of 14 exceedances of the wind comfort criterion. The total exceedances of hazard criterion would be exceeded would reduce by 52 (from 137 to 85), and would reduce the total duration of hazardous winds by 192 hours (from 888 hours to 696 hours).

Wind conditions under the variant would be similar in terms of comfort, and would be a slight improvement in terms of hazard, compared to the proposed project. A marginal increment of 0.1 mph for average comfort wind speed of all test points exceeded 10% of the time would occur under the variant compared to the proposed project. The total number of hazard exceedances would increase by two but the total duration of hazardous winds would reduce by 71 hours per year.

On balance, the proposed project and variant would introduce an obstruction to wind blowing across the site compared to the current open existing condition that occurs at the site. Generally therefore, the proposed project and variant would have a broadly positive effect upon the wind microclimate, reducing both the average wind speed exceeded 10% of the time and the total number of locations that exceed the hazard criteria, relative to the existing conditions. Naturally with many regions where wind speeds would decrease, there are areas of localised acceleration, and as a result of the innate windiness of the site, these and numerous other areas continue to exceed criteria. With this in mind it would be of notable benefit to incorporate a series of design measures that locally alleviate accelerated winds and enhance the microclimate. These might include, but not be limited to, wind canopies, solid/porous screens and building fins.

APPENDIX A. SAN FRANCISCO PLANNING CODE SECTION 148

A.1. Reduction of Ground Level Wind Currents

1. ***Requirement***: New buildings and additions to existing buildings shall be shaped, or other wind-baffling measures shall be adopted, so that the developments would not cause ground-level wind currents to exceed, more than 10 percent of the time year-round, between 7:00 am and 6:00 pm, the comfort level of 11 m.p.h. equivalent wind speed in areas of substantial pedestrian use and seven m.p.h. equivalent wind speed in public seating areas. The term "***equivalent*** wind speed" shall mean the wind speed adjusted to incorporate the effects of gustiness or turbulence on pedestrians.

2. When pre-existing ambient wind speeds exceed the comfort level, or when a proposed building or addition may cause ambient wind speeds to exceed the comfort level, the building shall be designed to reduce the ambient wind speeds to meet the requirements.

3. ***Exception:*** The Zoning Administrator may allow the building or addition to add to the amount of time the comfort level is exceeded by the least practical amount if (i) it can be shown that a building or addition cannot be shaped and other wind-baffling measures cannot be adopted to meet the foregoing requirements without creating an unattractive and ungainly building form and without unduly restricting the development potential of the project site in question, and (ii) ***the*** Zoning Administrator concludes that, because of the limited amount by which the comfort level is exceeded, the addition is insubstantial. The Zoning Administrator shall not grant an exception, and, no building or addition shall be permitted that causes equivalent winds speeds to reach or exceed the hazard level of 26 miles per hour for a single hour of the year.

4. ***Procedures:*** Procedures and methods for implementing this Section shall be specified by the Environmental Review Officer of the Planning Department.

APPENDIX B. QUALITY ASSURANCE

BMT Fluid Mechanics Ltd. is an accredited boundary layer wind tunnel testing facility and computational flow modelling organization. BMT holds certification for quality assurance of wind engineering services to ISO 9001:2008.

Each project that BMT carries out has a project manager that deals with the day-to-day tasks of the project, including: coordination of the wind tunnel model build, quality assurance of the wind tunnel model, coordination of the CAD team and the project engineering analysis staff. The project manager reports to a Line Group Manager and along with the Head of Wind Engineering would hold joint overall responsibility for the works on the project.

Each and every member of the team has considerable experience in relation to wind environment testing for numerous developments across the globe ranging from masterplans to high-rise buildings to large-span roof structures.

For the all works completed standardized technical procedures are applied.

APPENDIX C. WIND TUNNEL & MODEL DETAILS

C.1. Wind Tunnel Specifications

All the tests were conducted in BMT's Boundary Layer Wind Tunnel which has a test section 15.7ft wide, 7.9ft high and 49.2ft long with a 14.4ft diameter multiple plate turntable and a remotely controlled 3-dimensional traversing system. The operating wind speed range is 0.45 – 100.7mph.

The turbulent boundary layer is set up using an arrangement of roughness elements distributed over the floor of the wind tunnel, vertical posts and a 2D barrier placed at the entrance to the test section according to the upwind fetch.

C.2. Model

C.2.1. Information

The models of the proposed development were constructed based on 3D drawing information supplied by the project sponsor and the design teams. The wind tunnel models representative of the surrounding building morphology were constructed by BMT based on information provided by the project sponsor, in conjunction with a BMT site survey. The models were reviewed and approved by the design team, prior to testing.

C.2.2. Scale

A model scale of *1:300* has been adopted. At this scale the model is large enough to allow a good representation of the details that are likely to affect the local and overall wind flows at full scale. In addition, this scale enables a good simulation of the turbulence properties of the wind to be achieved.

C.2.3. Construction

The surrounding buildings are represented by high-density foam blocks to a sufficient level of detail to reproduce the wind flows at the location of the proposed building. The model is mounted on a 9.8ft diameter baseboard and installed on the 14.4ft diameter large turntable of BMT's Boundary Layer Wind Tunnel. In the region beyond the detailed surrounds model, the terrain is modelled as generalized roughness.

C.2.4. Model Photos

Images of the wind tunnel model are presented as follows:

- **Figures C.1** and **C.2** - Existing Scenario
- **Figures C.3** and **C.4** - Project Scenario
- **Figures C.5** and **C.6** - Project Variant Scenario

Figure C.1: Existing Scenario, viewed from Southeast

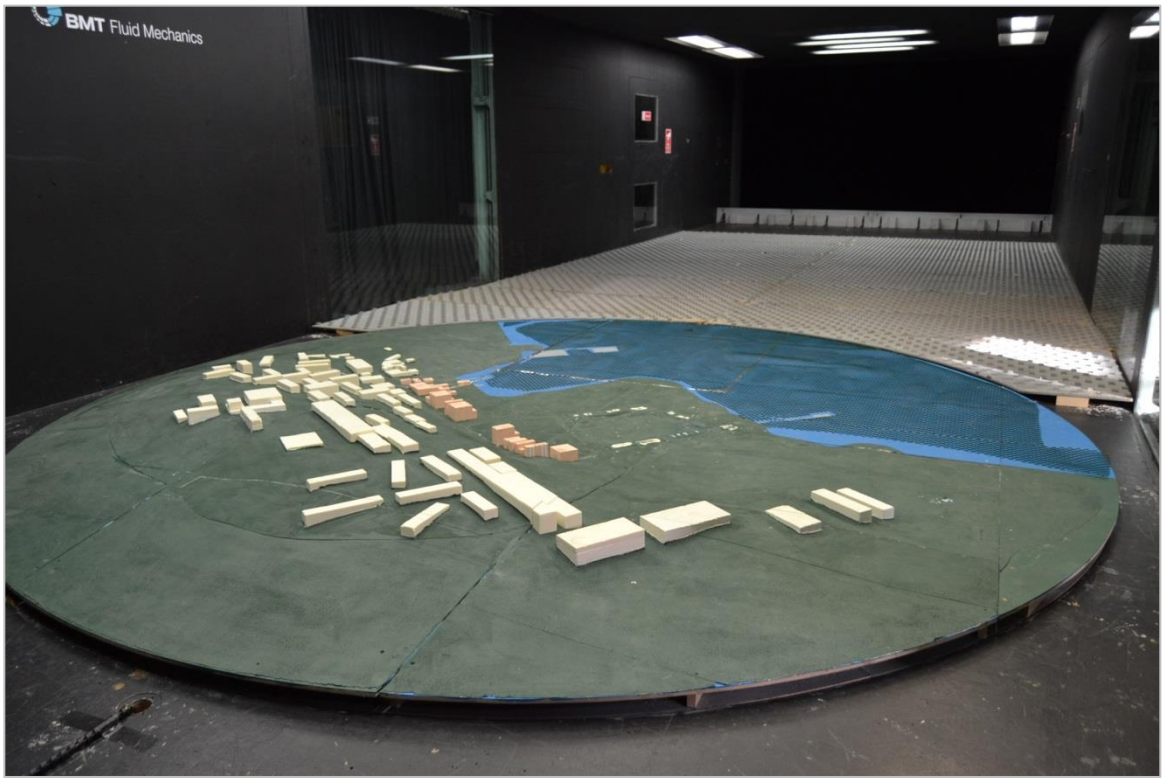


Figure C.2: Existing Scenario, viewed from Northwest

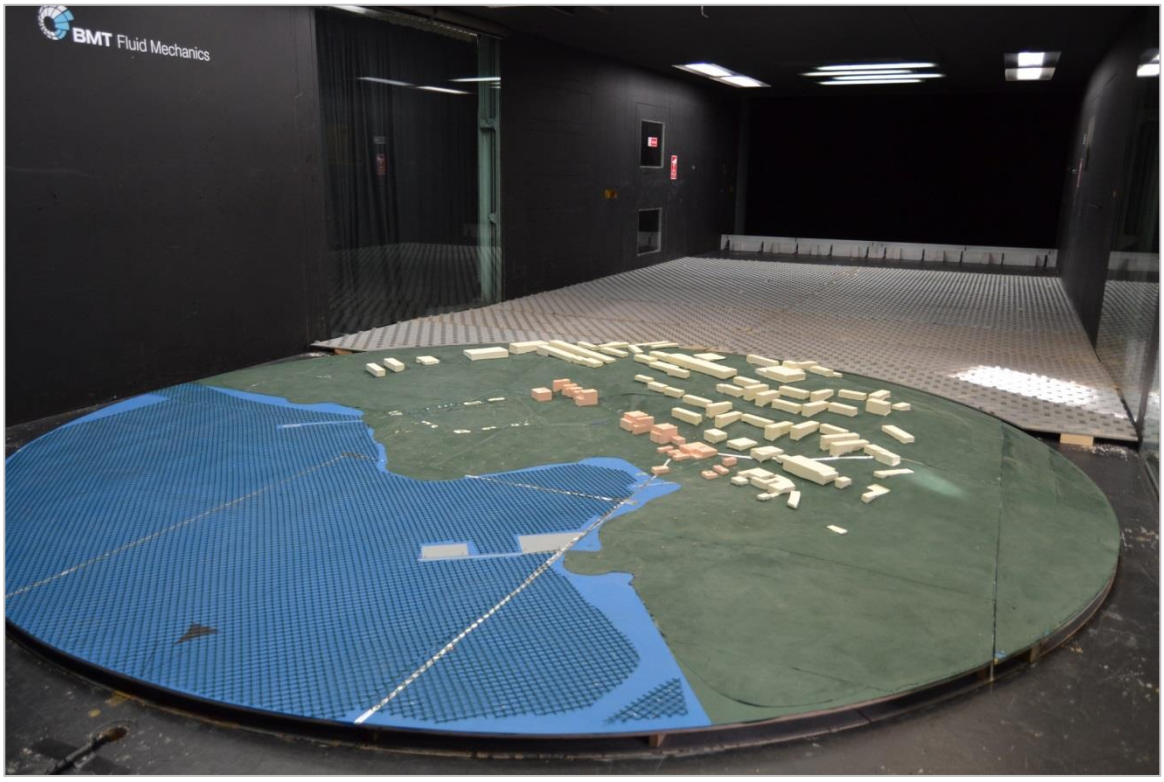


Figure C.3: Project Scenario, viewed from Southeast

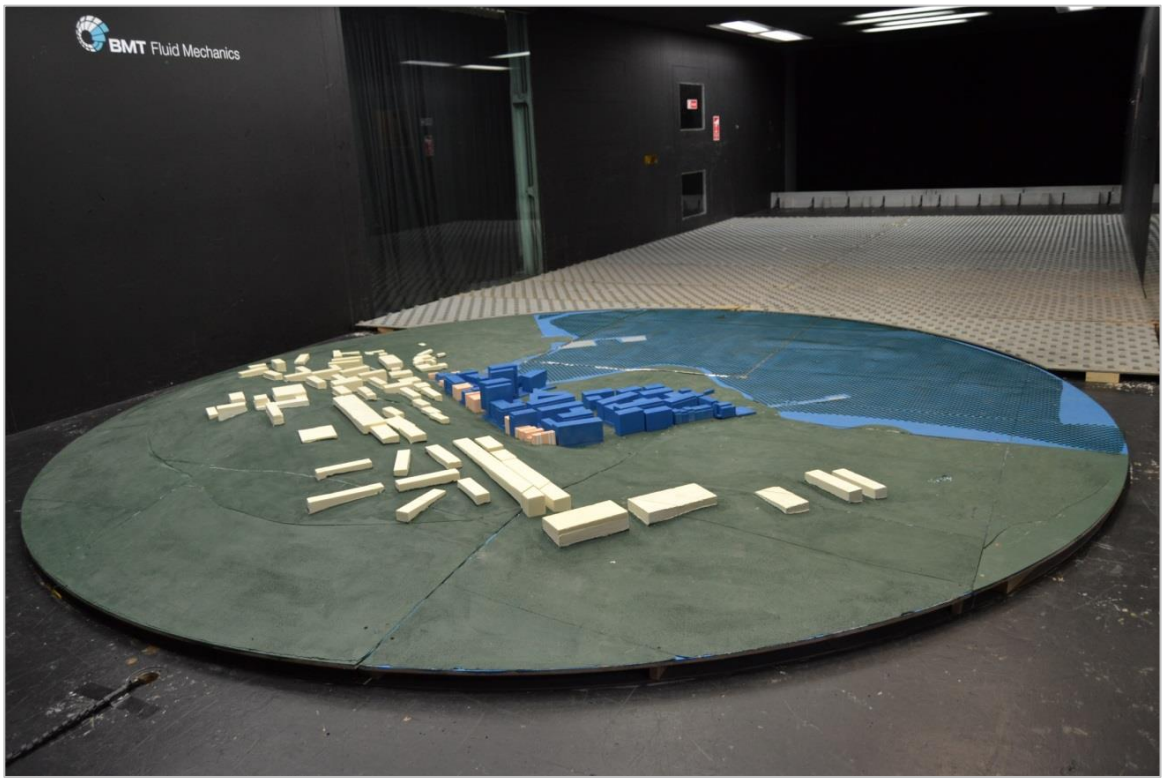


Figure C.4: Project Scenario, viewed from Northwest

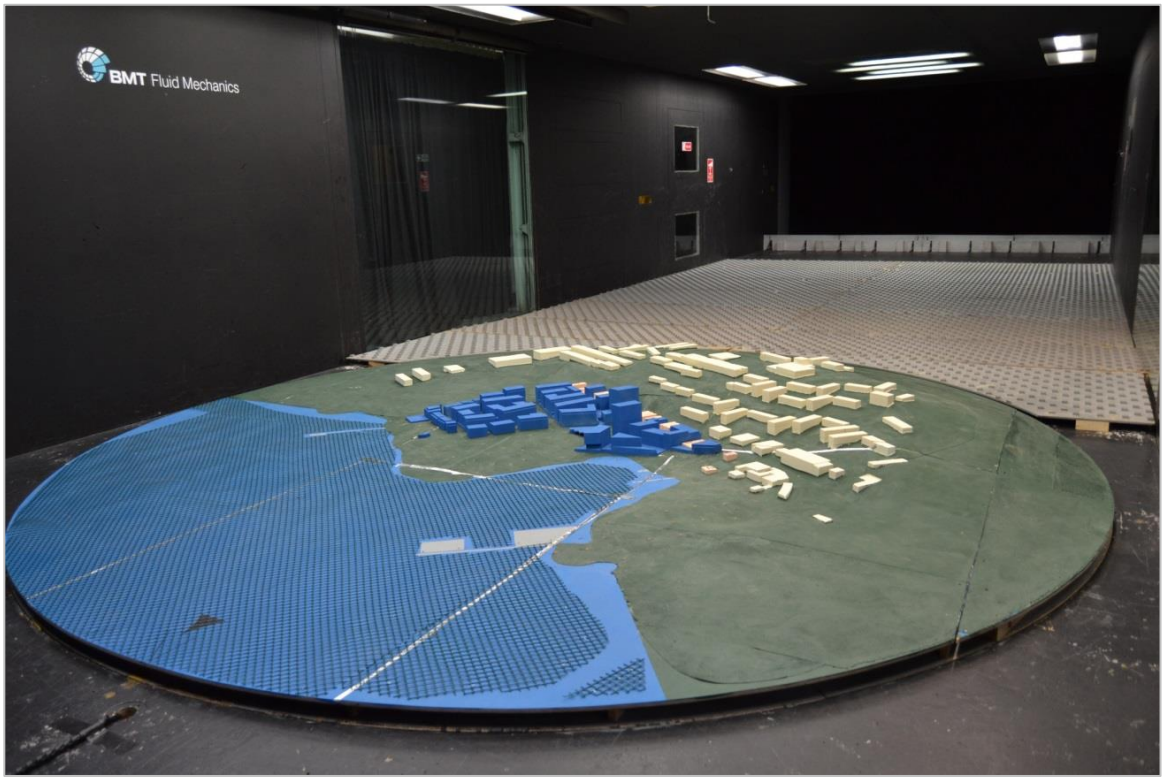


Figure C.5: Project Variant Scenario, viewed from Southeast

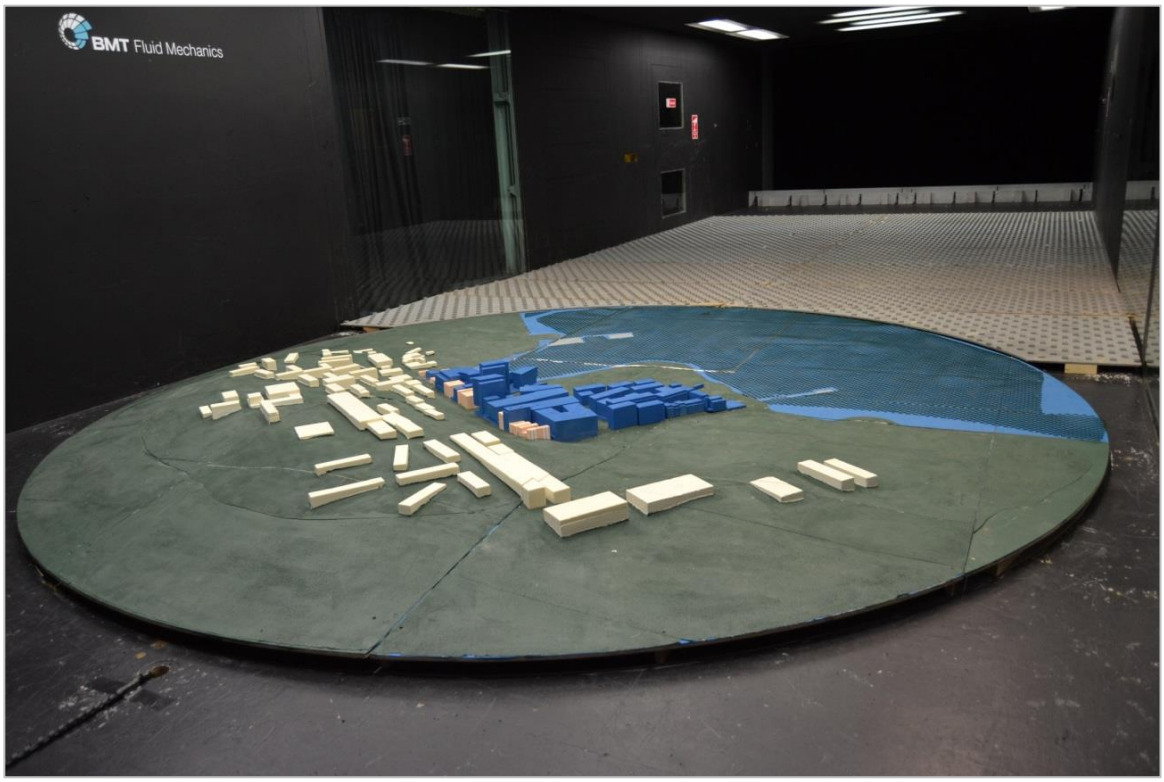
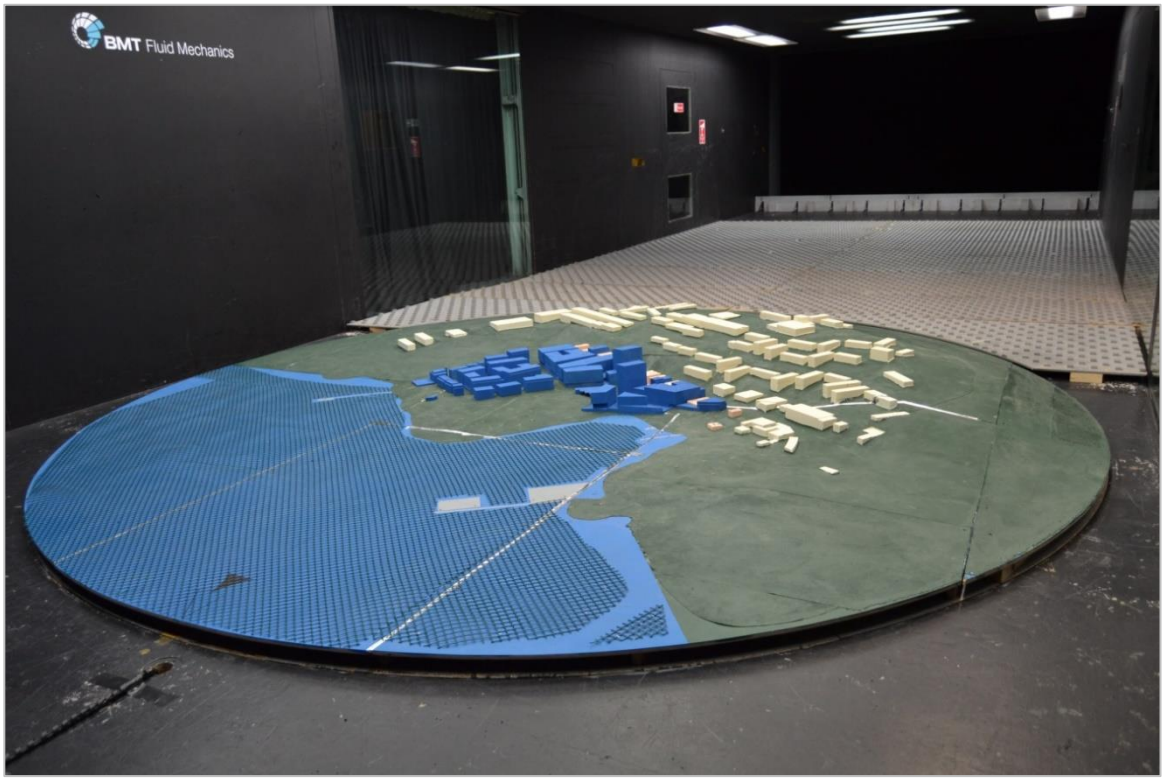


Figure C.6: Project Variant Scenario, viewed from Northwest



APPENDIX D. MEASUREMENTS AND ANALYSIS

D.1. Physical Measurements

Wind speed measurements were made using so-called 'Irwin probes', capable of measuring fluctuating pressure differences that are calibrated against wind speed. All the probes were calibrated to an accuracy of within 2% before the test procedure was begun. A system of probes running simultaneously was used to obtain results from up to 219 locations at a height corresponding to ~5ft at full scale.

The wind velocity scale (ratio of model scale velocity to full scale velocity) of the wind tunnel test was 1/1, where the frequency scale (ratio of model scale frequency to full scale frequency) was 1/300. The freestream wind speed of the test was approximately 55mph. The data was sampled at a full-scale frequency of 5 samples per second (600Hz at model scale). Data were recorded for 50 seconds for each wind direction to determine the mean wind speeds. The turbulence intensity was derived based on the measured mean and standard deviation of the wind speeds.

The ratio between the measured wind speeds at a height of 5ft above the surface level and the wind speed at the reference height, namely the "wind speed-up ratio", was derived from each of the Irwin probe measurements, for 16 wind directions in increments of 22.5°. The wind speed-up ratios are usually less than 1, as the speed of the lowest part of an air mass is slowed down when the air moves across the buildings.

For each location, the wind speed-up ratio at each wind direction combines with the wind statistics derived from data measured at San Francisco International Airport weather station. The summation of the combined results of wind speed-up ratios and wind statistics for all wind directions are used to assess the wind conditions in terms of the exceedance of threshold wind speeds that relate to safety and comfort levels defined in the Planning Code Section 148.

D.2. Wind Properties at Project Site

A detailed wind analysis was carried out to determine the wind properties at the Project site. The wind analysis is based on the widely accepted Deaves and Harris log law wind model of the atmospheric boundary layer, as defined in ESDU (Engineering Sciences Data Unit) Item 01008, and has provided wind profiles describing the variation of wind speed and turbulence intensity with height for the wind directions of interest. From this analysis representative profiles were defined as targets for the atmospheric boundary layer simulation in the wind tunnel.

Due to the variation of upstream terrain surrounding the proposed development site, two target profiles / exposures have been selected for the boundary layer simulation. The target profiles and range of wind angles for each wind tunnel profile are as follows:

Profile	Wind Angle Range	Target Angle
Exposure 1	0° to 157.5°, 337.5°	150°
Exposure 2	180° to 315°	270°

Figures D.1 and **D.2** present the profiles of mean wind speed and longitudinal turbulence intensity used in the tests. The wind speed profiles are normalised by the mean wind speed at a height of 150 feet, which is the overall height of the Project. It can be seen that, over the range of heights of interest, the boundary layer simulation used in the tests was a good representation of that expected for the site at full scale.

Figure D.1: Mean wind speed and longitudinal turbulence intensity profiles used in the study (Exposure 1)

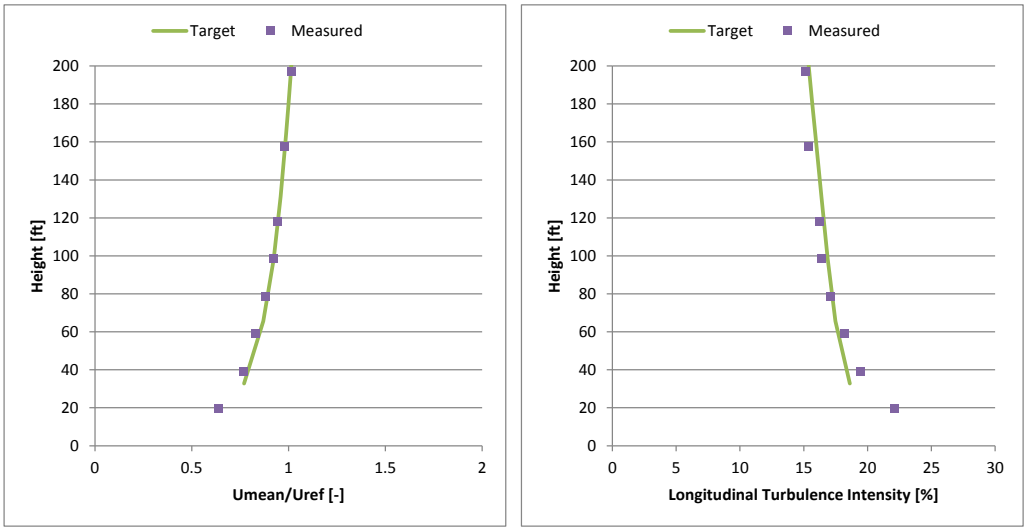
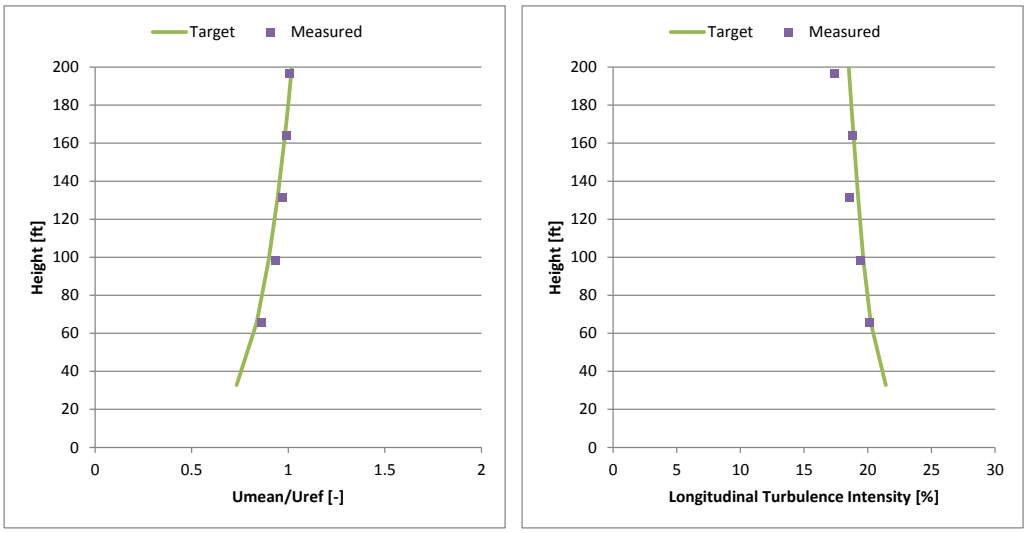


Figure D.2: Mean wind speed and longitudinal turbulence intensity profiles used in the study (Exposure 2)



D.3. Wind Properties at Project Site

Wind microclimate studies require that wind speed data obtained from a measurement station be transposed to the site of interest. In the case of the current study, following agreement with the City of San Francisco Planning Department, wind speed data obtained from the San Francisco International Airport weather station was transposed to the site of interest.

The wind speed history is reformatted into the number of observations of mean hourly wind speeds within each of several wind speed ranges, for each wind direction and for each month of the year. To facilitate the transposition of the wind data, the months are grouped into the seasons and a Weibull distribution is fitted to the wind speed distribution for each wind direction, for each season.

From the Weibull cumulative distribution the probability that, for a given wind direction, a wind speed, V, will be exceeded is given by:

$$P(>V) = e^{-(\frac{V}{c})^k}$$

where c is the dispersion parameter and k is the shape parameter.

To these parameters is further added the probability, p, of each wind direction occurring. Thus for each month of the year the probability that a specified wind speed is exceeded for a specified wind direction may be calculated.

The resulting weather centre wind data is transposed to open country terrain at sea-level, accounting for upwind terrain, topography and altitude for the weather centre.

The open country wind data is then transposed to reference height at the site of the proposed development, accounting for upwind terrain, topography and altitude for the target site.

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Case No. 2014-002541ENV
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India Basin Development – Wind Microclimate Studies

As an addendum to BMT's Wind Microclimate Study Report (432091rep2v5) dated January 24th, 2017 for the India Basin Development, a qualitative appraisal of three additional Project Alternatives has been undertaken to evaluate the potential for changes to the wind microclimate. The following project alternatives are considered:

- No Project Alternative
- Code Compliant Alternative
- Reduced Development Alternative

The No Project Alternative would involve no construction and the site would remain the same as currently exists. The Code Compliant Alternative would include more total built square footage. However, the proposed structures would be lower in height with approximate 10-100 feet when compared to the Proposed Project and Project Variant. The Reduced Development Alternative would include less total built square footage with structures lower in height with approximate 10-70 feet than the Proposed Project and Project Variant. A complete summary of the alternative descriptions was issued to BMT by AECOM on June 27th, 2017.

The wind microclimate analysis for the alternatives was evaluated based on BMT's considerable experience in the assessment of wind effects in the built environment, formed from detailed boundary layer wind tunnel studies for similarly massed schemes in the urban environment around San Francisco, including previous wind tunnel studies on the India Basin Development.

No Project Alternative

The No Project Alternative would involve no additional construction to the site and therefore would match the Existing Scenario that was assessed in the wind tunnel study. In the Existing Scenario the study area is windier than under the Proposed Project and Project Variant. Accordingly, the wind conditions for the No Project Alternative would result in higher and notable pedestrian level wind speeds compared to the Proposed Project or Project Variant.

Code Compliant Alternative

The Code Compliant Alternative would include the same recreational and commercial development and associated parking and access on the 900 Innes and India Basin Shoreline Park properties as under the Proposed Project and Project Variant. Therefore, wind conditions in this area would be same as in both Proposed Project and Project Variant. On 700 Innes property, the Code Compliant Alternative would have more built area on the site, with lower building heights. As observed in wind tunnel testing of the Proposed Project, the addition of buildings on the site would provide shielding both near the development and farther downwind from the prevailing west-northwest and westerly winds. The Code Compliant Alternative would add buildings to the Big Green Park area thus resulting in more shielded area with calmer wind conditions compared to the Proposed Project. Additionally the uniform building heights along the development would reduce the chances of downdrafts, and thus the high pedestrian level winds associated with them. The wind climate as a whole would be expected to improve, but local wind conditions could deteriorate at certain locations. Specifically there is a potential of wind channeling along the east-west roads / pathways (e.g. Hudson Avenue) of the study area, where prevailing westerly and west-northwesterly winds would be expected to accelerate around the corners adjacent to India Basin Open Space creating a windier microclimate compared to the Proposed Project and Project Variant. Overall the Code Compliant Alternative would be expected to have a similar or slightly better wind microclimate compared to the Proposed Project and Project Variant.

Reduced Development Alternative

The Reduced Development Alternative would reduce the height of buildings throughout the development, most notably the two tower locations. Wind conditions at locations near the two towers would exceed the hazard criterion in the Proposed Project and Project Variant scenarios. Reducing the tower height would reduce the frequency and strengths of the downdrafts caused by the towers and thus wind conditions near the base of the towers would improve. The largest improvement would be expected along Arelious Walker Drive. The reduced building heights would still be sufficient to provide shielding from the wind in the interior areas of the development, and wind conditions along the east portion of New Hudson Avenue, Beach Lane, Fairfax Lane, and Spring Lane would be similar to the Proposed Project and Project Variant. The reduced building heights would provide slightly less shielding to India Basin Open Space and Big Green Park. Therefore some localized areas may experience slightly greater wind speeds compared to the Proposed Project and Project Variant. Overall the Reduced Development Alternative would create similar or slightly better wind microclimate compared to the Proposed Project and Project Variant.

Summary

In summary, the wind conditions for the No Project Alternative would result in higher pedestrian level wind speeds compared to the Proposed Project and Project Variant. The Code Compliant Alternative and Reduced Development Alternative would result in similar or slightly better wind microclimate compared to the Proposed Project and Project Variant.