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LLNL-TR-809446

Determination of Wind Exposure Category and Basic Wind Speed for B332 and Other Facilities Located within Superblock

AB-SBK-20-001

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This document assesses of the typical surface terrain for the LLNL Site 200 Campus surrounding B332 in accordance with ASCE 7-16 and demonstrates that wind Exposure Category B can be applied to B332 and the other buildings and structures located within the fenced perimeter of Superblock. When compensating for the Exposure Category B surface terrain surrounding B332 and Superblock, calculations show that the ANS 2.3 WDC-3 Basic Wind Speed for B332 is adjusted from 118 mph to 100 mph and the WDC-2 Basic Wind Speed is adjusted from 115 mph to 98 mph.

Disclaimer

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1. Facility	2. Calculation Number	3. Sheet
LLNL, Site 200, Superblock, B332, and Others	AB-SBK-20-001	1 of 3

4. Title:

Determination of Wind Exposure Category and Basic Wind Speed for B332 and Other Facilities Located within Superblock

5. ☐ Preliminary ☒ Final

6. Computer Program/s:	7. Version / Release No.:
N/A	N/A

8. Software verified against current 10 CFR 830 Software Inventory list: N/A

9. Purpose and Objective:

The primary purpose of the attached report is to determine the appropriate wind Exposure Category for B332 as defined in ASCE 7-16, and then to calculate the associated *Basic Wind Speed* in accordance with ANS 2.3-2011 (R2016).

The secondary purpose is to evaluate the results from the B332 wind Exposure Category assessment for application to all other facilities and structures located within Superblock.

10. Summary of Conclusions:

An assessment of the typical surface terrain for the LLNL Site 200 Campus surrounding B332 demonstrates that wind Exposure Category B can be applied to B332 and the other buildings and structures located within the fenced perimeter of Superblock.

When compensating for the Exposure Category B surface terrain surrounding B332 and Superblock, calculations show that the ANS 2.3 WDC-3 *Basic Wind Speed* for B332 is adjusted from 118 mph to 100 mph and the WDC-2 *Basic Wind Speed* is adjusted from 115 mph to 98 mph.

Revisions

11. Rev No.	12. Revision Description
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Sign Off

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0	DR	Mark E. Sampson Digitally signed by Mark E. Sampson Date: 2020.04.28 11:30:32 -07'00' Mark Sampson, S3853, Exp. 3/31/21	Yan Francis Oliver Lucille Digitally signed by Yan Francis Oliver Lucille Date: 2020.04.28 13:35:03 -07'00' Yan Lucille C85193, Exp. 06/30/20	Jennifer Leigh Delano Digitally signed by Jennifer Leigh Delano Date: 2020.04.30 10:32:54 -07'00' Jennifer DeLano C57925, Exp. 6/30/20	Robert Dean Carter Jr. Digitally signed by Robert Dean Carter Jr. Date: 2020.05.03 19:11:13 -07'00' DJ Carter

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Purpose and Objective

See AB-006 Routing Sheet

Existing Conditions

Wind obstructions documented in Appendix B of this document were based on existing conditions in February of 2020 and buildings & infrastructure under construction at the time.

Design Basis Criteria

- DOE-STD-1020-2016 [Ref. 1]
  - ASCE/SEI 7-16 [Ref. 2]
  - ANSI/ANS-2.3-2011 (R2016) [Ref. 3]
  - ASCE/SEI 7-10 [Ref. 10] (in conjunction with ANS 2.3)

Assumptions and Input

The "gross frontal areas" of non-building wind obstructions have been adjusted in accordance with ASCE 7, Section C26.7 [Ref. 2] by multiplying the frontal area by the following factors:

Conifers and Other Evergreen Trees.....0.50
Deciduous Trees.....0.15
Typical Chain Link Fencing.....0.17 (2" x 2" x #6 fabric, Cf_1 = 5.71) [Ref. 9]
Security Chain Link Fencing.....0.45 (½" x ½" x #9 fabric, Cf_1 = 2.20) [Ref. 9]

Superblock is encircled by a double 11' high chain link security fence with reinforced synthetic fabric netting to a height of 50 ft. The double chain link fence is included as a partial wind obstruction that contributes to the aerodynamic surface roughness; however, the netting is assumed to have failed in high winds and therefore is not included in the exposure calculation.

Analytical Methods and Computations

General engineering principles and United States Customary (USC) units were used. Wind exposure categories are defined in ASCE 7, including the expanded discussion in the Commentary. Analytical methods presented in the ASCE 7 Commentary were derived from site roughness studies performed at the University of Wisconsin, Madison for aerodynamic effects of upstream obstacles on wind-profile measurements by H. Lettau (1969) [Ref. 5], and atmospheric boundary layer gradient wind properties documented by P. Irwin (2006) [Ref. 6], E. Simiu (1996) [Ref. 7], and J. Holmes (2015) [Ref. 8].

Computer Programs

N/A

Results

An assessment of the typical surface terrain for the LLNL Site 200 Campus surrounding B332 presented in Appendix A demonstrates that wind Exposure Category B can be applied to B332 and the other buildings and structures located within the fenced perimeter of Superblock.

When compensating for the Exposure Category B surface terrain surrounding B332 and Superblock, the calculations in Appendix C show that the ANS 2.3 WDC-3 *Basic Wind Speed* for B332 is adjusted from 118 mph to 100 mph and the WDC-2 *Basic Wind Speed* is adjusted from 115 mph to 98 mph.

References

[1] DOE-STD-1020-2016, *Natural Phenomena Hazards Analysis and Design Criteria for DOE Facilities, U.S. Department of Energy, Washington, DC, December 2016.*

[2] ASCE/SEI 7-16, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures,* Structural Engineering Institute of the American Society of Civil Engineers (ASCE), Reston, VA, 2017

[3] ANSI/ANS-2.3-2011 (R2016), *Estimating Tornado, Hurricane, and Extreme Straight-Line Wind characteristics at Nuclear Facility Sites*, American Nuclear Society, La Grange Park, IL, 2011.

[4] 2019 California Building Code, Title 24, Vol. 2, Part 2, *California Building Standards Commission, Sacramento, CA, January 1, 2020.*

[5] Lettau (1969), *Note on the Aerodynamic Roughness-Parameter Estimation on the Basis of Roughness-Element Description*, Journal of Applied Meteorology, Volume 8, pp. 828-832, H. Lettau, Dept. of Meteorology, University of Wisconsin, Madison WI, 1969

[6] Irwin (2006), *Exposure Categories and Transitions for Design Wind Loads*, P. A. Irwin, Journal of Structural Engineering, ASCE, Nov. 2006, pp. 1755-1763

[7] Simiu (1996), *Wind Effects on Structures, Fundamentals and Applications to Design*, 3rd Ed., E. Simiu & R. H. Scanlan, john Wiley & Sons, Inc. New York, New York, 1996

[8] Holmes (2015), *Wind Loading of Structures*, 3rd Ed., CRC Press, Boca Raton FL, 2017

[9] WLG 2445, *Chain Link Fence Wind Load Guide for the Selection of Line Post and Line Post Spacing, Chain Link Fence Manufactures Institute, Columbia MD*, June 2016

[10] ASCE/SEI 7-10, Minimum Design Loads and Associated Criteria for Buildings and Other Structures, Structural Engineering Institute of the American Society of Civil Engineers (ASCE), Reston, VA, 2013

[11] B331 Construction Drawings, PLZ1958-0331-0003JA (Sht A-2), PLZ1958-0331-013J (Sht S-3)

[12] B332 Construction Drawings, PLZ1961-0332-0004JB (Sht A-4)

[13] B334 Construction Drawings, PLA1985-0334-0007D (Sht A-7)

[14] Superblock Overhead Deterrent System Drawings, PLZ2000-0099-0002J (Sht 2 of 6)

Appendix A

Determination of Wind Exposure Category

A-1.0 Background and Basis

Wind forces used in the design of buildings and other structures are derived from the velocity (speed) of the wind moving over and around the structure. The nominal wind speed, however, varies with height above the ground and the roughness of the surrounding terrain. This effect is fairly easy to observe in moving water when a stream or river slows as it nears the shoreline or flows around fixed objects like large boulders or sand bars. Likewise, air velocity slows as it nears the ground due to the aerodynamic drag from the ground surface. The number and size of objects in the vicinity of a selected location contribute the roughness characteristics of the ground surface and therefore increase the effective drag force upwind of the location (otherwise known as the fetch). This wind modification property is referred to as *Surface Roughness*, or *Exposure*.

Design codes define the site characteristics associated with the surrounding terrain in one of three Exposure Categories differentiated by corresponding Surface Roughness Categories. ASCE 7, Section 26.7 [Ref. 2] states that, "*For each wind direction considered, the upwind exposure shall be based on ground surface roughness that is determined from natural topography, vegetation, and constructed facilities*."

The three Surface Roughness and Exposure Categories are defined in ASCE 7 [Ref. 2] as follows:

***Surface Roughness B**: Urban and suburban areas, wooded areas, or other terrain with numerous, closely spaced obstructions that have the size of single-family dwellings or larger.*

> ***Exposure B**: For buildings or other structures with a mean roof height less than or equal to 30 ft (9.1 m), Exposure B shall apply where the ground surface roughness, as defined by Surface Roughness B, prevails in the upwind direction for a distance greater than 1,500 ft (457 m). For buildings or other structures with a mean roof height greater than 30 ft (9.1 m), Exposure B shall apply where Surface Roughness B prevails in the upwind direction for a distance greater than 2,600 ft (792 m) or 20 times the height of the building or structure, whichever is greater.*

***Surface Roughness C**: Open terrain with scattered obstructions that have heights generally less than 30 ft (9.1 m). This category includes flat, open country and grasslands.*

> ***Exposure C**: Exposure C shall apply for all cases where Exposure B or D does not apply.*

***Surface Roughness D**: Flat, unobstructed areas and water surfaces. This category includes smooth mud flats, salt flats, and unbroken ice.*

> ***Exposure D**: Exposure D shall apply where the ground surface roughness, as defined by Surface Roughness D, prevails in the upwind direction for a distance greater than 5,000 ft (1,524 m) or 20 times the building or structure height, whichever is greater. Exposure D shall also apply where the ground surface roughness immediately upwind of the site is B or C, and the site is within a distance of 600 ft (183 m) or 20 times the building or structure height, whichever is greater, from an Exposure D condition as defined in the previous sentence.*
>
> *For a site located in the transition zone between exposure categories, the category resulting in the largest wind forces shall be used.*

EXCEPTION: An intermediate exposure between the preceding categories is permitted in a transition zone, provided that it is determined by a rational analysis method defined in the recognized literature.

Exposure Categories B and C are depicted in the photos of Figure A1 on the following page.

FIGURE C26.7-5(a) Exposure B: Suburban Residential Area with Mostly Single-Family Dwellings. Low-Rise Structures, Less Than 30 ft (9.1 m) High, in the Center of the Photograph Have Sites Designated as Exposure B with Surface Roughness Category B Terrain around the Site for a Distance Greater Than 1,500 ft (457 m) in Any Wind Direction.

FIGURE C26.7-5(b) Exposure B: Urban Area with Numerous Closely Spaced Obstructions Having the Size of Single-Family Dwellings or Larger. For All Structures Shown, Terrain Representative of Surface Roughness Category B Extends More Than 20 Times the Height of the Structure or 2,600 ft (792 m), Whichever Is Greater, in the Upwind Direction.

FIGURE C26.7-6(a) Exposure C: Flat Open Grassland with Scattered Obstructions Having Heights Generally Less Than 30 ft (9.1 m).

FIGURE C26.7-6(b) Exposure C: Open Terrain with Scattered Obstructions Having Heights Generally Less Than 30 ft (9.1 m). For Most Wind Directions, all One-Story Structures with a Mean Roof Height Less Than 30 ft (9.1 m) in the Photograph are Less Than 1,500 ft (457 m) or 10 Times the Height of the Structure, Whichever Is Greater, from an Open Field that Prevents the Use of Exposure B.

Figure A1: Typical Photos of Category B and C Terrain Reproduced from ASCE 7-16 Commentary Section C26.7

Design wind speeds as required by California Building Code [Ref. 4] and as specified in ASCE 7 [Ref. 2] are based on a National Weather Service normalized baseline consisting of the 3-second gust wind speed measured at a height of 10 m (33 ft) surrounded by standard open country terrain, defined as Exposure Category C. Likewise, ANS 2.3 [Ref. 3], used for nuclear facilities, utilizes the ASCE 7 reference baseline wind definition. In general, conservative design of conventional facilities for wind forces (as practiced at LLNL) assumes an Exposure Category C for all designs, as does ANS 2.3 as documented in Section 3.3 and 3.4 for "extreme straight line wind events."

The Exposure Category is used to determine the value of the *Velocity Pressure Coefficient* (K_z). As previously stated, wind speeds (and thus wind pressures) vary with location and elevation. The design parameter K_z can be thought of as the difference in wind pressure for exposures and elevations that differ from those assumed for the *Basic Wind Speed* (i.e. Exposure C at 33 ft). Thus, the value of K_z is set to 1.0 at this reference height and exposure. For example, the value of K_z for a location 30 ft above the ground in an area categorized as Exposure B has a K_z value of 0.70 per ASCE Table 26.10-1 [Ref. 2]. In other words, the wind pressure at this location would be 70% of the wind pressure at 33 ft in an Exposure Category C region.

The main text of ASCE 7 [Ref. 2] only provides a general qualitative description of the terrains typified for the Exposure Categories described previously. However, the ASCE 7 Commentary includes a rational quantitative analysis method based on Irvin (2006) [Ref. 6] and Lettau (1969) [Ref. 5] for calculating surrounding surface roughness to justify other Exposure Categories through the calculation of the *Roughness Length Parameter* z_0 which is correlated to the value of K_z.

For Exposure C, the typical value of z_0 is assumed to vary between 0.033 ft and 0.50 ft with the tabulated ASCE 7 value for K_z corresponding to a z_0 value of 0.066 ft. Note that z_0 possesses the units of feet, however this does not correspond to an actual real world height or length. Likewise, for Exposure Category B, the value of z_0 ranges between 0.50 ft and 2.3 ft with the tabulated values of K_z assuming a z_0 value of 0.66 ft. Table A1 on page A8 presents Table C26.7-1 from ASCE 7 [Ref. 2] which gives the assumed values of z_0 for all exposure categories. Note that the table shows values for Exposure Category A which was carried over from older versions of the Standard for reference but is no longer recognized.

A-2.0 Goals and Objectives

The objective of this assessment is to determine whether an Exposure Category B can be justified for B332 in lieu of using the current more conservative default assumption of Exposure Category C. The resulting effect of using Exposure Category B will be a reduction in the minimum *Basic Wind Speed* and the corresponding wind pressure force required for use in new SSC design and the evaluation of existing SSCs.

Selection of the appropriate exposure category is described in Section 26.7.3 of ASCE 7 [Ref. 2]. As described previously, the Standard states that the conditions for selection of Exposure Category B are:

> ***Exposure B:*** *For buildings or other structures with a mean roof height less than or equal to 30 ft (9.1 m), Exposure B shall apply where the ground surface roughness, as defined by Surface Roughness B, prevails in the upwind direction for a distance greater than 1,500 ft (457 m). For buildings or other structures with a mean roof height greater than 30 ft (9.1 m), Exposure B shall apply where Surface Roughness B prevails in the upwind direction for a distance greater than 2,600 ft (792 m) or 20 times the height of the building or structure, whichever is greater.*

The average height to the top of the B332 parapet is roughly 28 ft [Ref. 12]. Consequently, the surrounding region within a radius of 1,500 ft must be demonstrated to meet Surface Roughness condition B characteristics to qualify for Exposure Category B. This condition is depicted in Figure C26.7-1 from ASCE 7 [Ref. 2] which is reproduced in Figure A2 below.

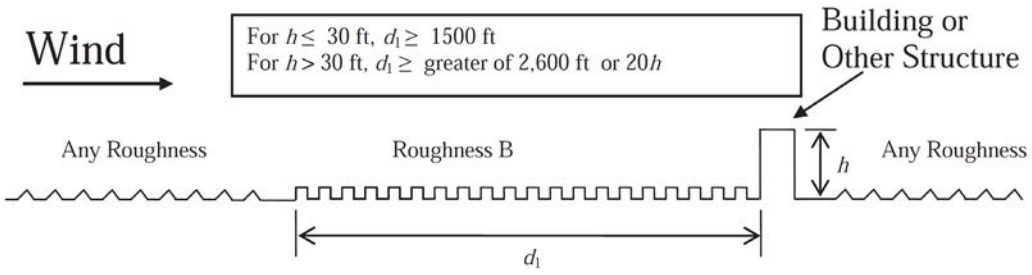

Figure A2: Upwind Surface Roughness Conditions Required for Exposure B
(reproduced from Figure C26.7-1 of ASCE 7-16 [Ref. 2])

Lawrence Livermore National Laboratory is bounded by urban residential neighborhoods to the west and industrial & high density housing to the north, which are typical of Surface Roughness B terrain. LLNL's eastern boundary and a portion of the southern boundary consist of open grassland, which is typical of Surface Roughness C terrain. However, Superblock and B332 are located within the central region of the one-mile square LLNL Site 200 campus and is surrounded by fairly dense industrial-type terrain consistent with Surface Roughness B within the required 1,500 ft radius specified by ASCE 7 [Ref. 2]. Figure A3 on the following page shows an aerial Google Earth image of LLNL and the surrounding region overlain with a 1,500 ft radius circle and the larger 2,600 ft radius circle required for structures taller than 30 ft.

Figure A4 presents four aerial photographs taken from an aircraft in 2007 looking down at a 30 to 45 degree angle. The photos are oriented in such way that they look across the campus in the four cardinal directions and provide a good view of the various buildings and trees surrounding Superblock. The photos also show a cleared one-block area directly to the southwest of Superblock on which three new buildings are under construction. These new buildings will be included in the surface roughness calculation.

Figure A3: Lawrence Livermore National Laboratory Aerial Image

(a) LLNL Site 200 Looking North

(b) LLNL Site 200 Looking East

(c) LLNL Site 200 Looking South

(d) LLNL Site 200 Looking West

Figure A4: LLNL Site 200 Aerial Photographs Showing the 1,500 ft Radius Wind Fetch Area Around B332 and Superblock *(photo date Sept. 2007)*

A-3.0 Analysis Methods

As noted earlier, the objective of this assessment is to determine whether the surface roughness surrounding Superblock conforms to the characteristics of Exposure Category B terrain. As shown in Table A1, from ASCE 7 [Ref. 2], Surface Roughness B is characterized by a *Roughness Length Parameter* z_0 between 0.5 ft and 2.3 ft, where the typical urban value is 1.0 ft but is assumed to be 0.66 ft for the wind properties provided in the other ASCE 7 tables for Exposure Category B.

The value of z_0 can be estimated from the typical dimensions of the wind obstructions that collectively account for the surface roughness using the empirical relationship first documented by Lettau (1969) [Ref. 5] and presented as equation C26.7-1 in ASCE 7 [Ref. 2], as follows:

$$z_0 = 0.5 H_{ob} \frac{S_{ob}}{A_{ob}} \qquad \text{[ASCE 7 Ref. 7, eq C26.7-1]}$$

where,

H_{ob} = the average height of the obstructions in the upwind direction,
S_{ob} = the average vertical frontal area per obstruction presented to the wind, and
A_{ob} = the average area of ground occupied by each obstacle, including the open area around it.

The 0.5 factor corresponds to the average drag coefficient of the characteristic individual obstacle of silhouette area *s* (Lettau (1996), [Ref. 5]).

Exposure Category	Lower Limit of z_0, ft (m)	Typical Value of z_0, ft (m)	Upper Limit of z_0, ft (m)	z_0 Inherent in Tabulated K_z Values in Table 26.10-1, ft (m)
A	$2.3\ (0.7) \le z_0$	6.6 (2)	—	
B	$0.5\ (0.15) \le z_0$	1.0 (0.3)	$z_0 < 2.3\ (0.7)$	0.66 (0.20)
C	$0.033\ (0.01) \le z_0$	0.066 (0.02)	$z_0 < 0.5$ (0.15)	0.066 (0.02)
D	—	0.016 (0.005)	$z_0 < 0.033$ (0.01)	0.016 (0.005)

Table A1: Range of z_0 by Exposure Category
Reproduced from Table C26.7-1 of ASCE 7-16 [Ref. 2]

Obstructions in the upwind fetch area include buildings, walls, fences, trees, bushes, and other objects that block the flow of wind. Some obstacles are porous and/or are deformed by strong winds which reduce their effective frontal areas. ASCE 7 [Ref. 2] specifies that the effective frontal area of conifers and other evergreens shall be no more than 50% of their gross frontal area, and deciduous trees and bushes be counted as no more than 15% of their gross frontal area. Gross frontal area is defined in this context as the projection onto a vertical plane (normal to the wind) of the area enclosed by the envelope of the tree or bush. Likewise, the effective gross area of chain link fences is calculated as the net solid area of the fence fabric which is 17% for typical 2" x 2" x #6 wire fabric (where Cf_1 = 5.71, i.e. 1/5.71 = 0.175) and 45% for security fence fabric consisting of 1/2" x 1/2" x #9 wire fabric (where Cf_1 = 2.20, i.e. 1/2.20 = 0.455). Fence Cf_1 values have been taken from the CLFMI *Chain Link Fence Wind Guide* [Ref. 9].

ASCE 7 further states that the surface roughness must be calculated for each of the 45 degree circular sectors circumscribed within the circle having the radius specified in Section 26.7.4 (1,500 ft). The eight wind sector fetch areas are shown in Figure A5 below. Each sector is identified by two letters (e.g. NE for the northern quadrant / eastern side). A detailed accounting of the wind obstructions in each sector and a calculation of the associated z_0 value is provided in Appendix B of this report.

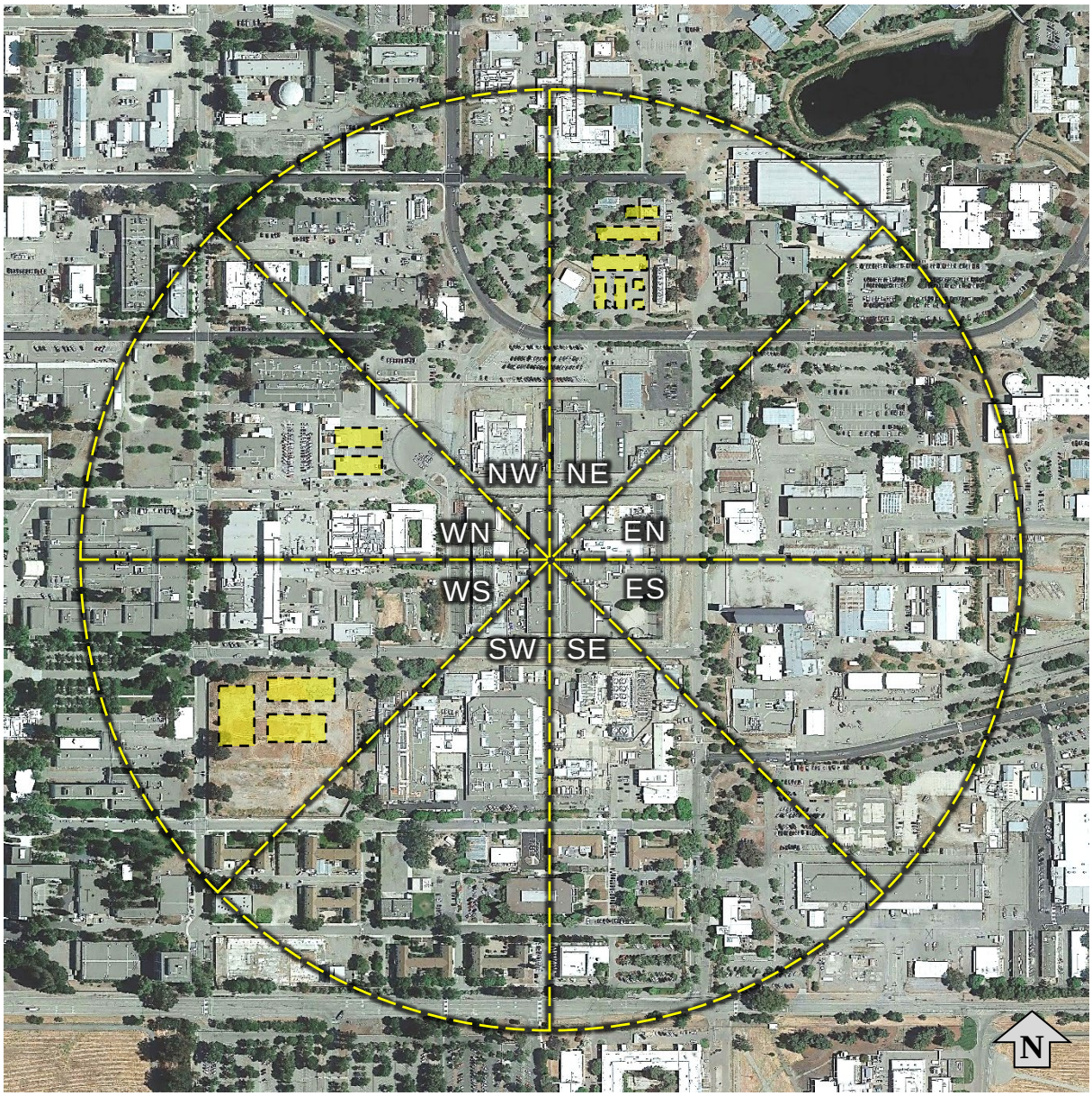

Figure A5: LLNL Aerial Photo Showing the Eight 45 Degree Wind Sector Fetch Areas Defined by a 1,500 ft Radius Area Centered on B332

A-4.0 Building 332 Results

A summary of the terrain roughness lengths for the eight wind sector fetch areas calculated in accordance with the procedure described above and presented in detail in Appendix B of this report is summarized in Table A2 below.

	Upwind Fetch Area							
	NE	EN	ES	SE	SW	WS	WN	NW
H_{ob} (1)	29.43 ft	23.05 ft	27.72 ft	25.87 ft	31.00 ft	32.66 ft	29.91 ft	30.27 ft
S_{ob} (1)	624 ft^2	483 ft^2	419 ft^2	453 ft^2	989 ft^2	1,015 ft^2	620 ft^2	332 ft^2
A_{ob} (1)	8,496 ft^2	7,425 ft^2	7,751 ft^2	7,363 ft^2	14,025 ft^2	16,992 ft^2	10,908 ft^2	5,890 ft^2
z_0 (1)	**1.08 ft**	**0.75 ft**	**0.75 ft**	**0.80 ft**	**1.09 ft**	**0.98 ft**	**0.85 ft**	**0.85 ft**
z_H (2)	24.0 ft	17.2 ft	17.0 ft	16.2 ft	21.9 ft	21.1 ft	21.4 ft	16.9 ft

(1) See Section A-3.0 for definitions of coefficients H_{ob}, S_{ob}, A_{ob}, & z_o.

(2) The value Z_H represents the "typical height of obstructions" used in Appendix C to calculate the value of the Zero Plane Displacement (z_d) for use in calculating the Basic Wind Speed.

Table A2: Summary of Roughness Length Parameter (z_0) for Each Wind Fetch Area

The average *Roughness Length* z_0 for the eight upwind fetch areas making up the entire area surrounding Superblock is 0.89 ft, however, to be conservation the minimum value of 0.75 ft calculated for the sector EN and ES fetches will be used. Exposure Category B is defined in the Table C26.7-1 of the ASCE 7 [Ref.2] Commentary (Table A1) and has a value of z_0 between 0.5 ft and 2.3 ft, therefore the terrain surrounding Building 332 can be classified as Exposure Category B in accordance with ASCE 7-16 [Ref. 2].

A-5.0 Superblock Results

Although the preceding assessment was prepared with a focus on B332, the findings also apply to other nearby buildings located within Superblock that are 30 ft or less in height (e.g. B331 [Ref. 11]). However, other Superblock buildings and structures are taller than 30 ft, such as: B334 which is approx. 38 ft high [Ref. 13], the Overhead Deterrent System which is 75 ft tall [Ref. 14], and the two B331 stacks which are 100 ft tall [Ref. 11]. ASCE 7, Section 26.7.3 [Ref.2] requires the upwind fetch area for structures greater the 30 ft conform to Surface Roughness Category B for 2,600 ft or 20h (= 20 x 100 ft = 2,000 ft) whichever is greater.

A comprehensive examination of the land uses evaluated within the 1,500 ft radius circle identified in Figure A3 reveals that this region contains the same fully developed urban/industrial land use typified by the rest of the LLNL Site 200 campus, see Figures A3 and A4. Therefore Surface Roughness Category B it can be safely assumed to apply to the larger 2,600 ft radius circle shown in Figure A3 by inspection. As a result, Exposure Category B applies to all other structures enclosed within the fenced perimeter of Superblock.

A-6.0 Conclusion

An assessment of the typical surface terrain for the LLNL Site 200 Campus surrounding B332 demonstrates that wind Exposure Category B can be applied to B332 and the other buildings and structures located within the fenced perimeter of Superblock.

Appendix B

Calculation of Roughness Length Parameter z_0
for Each Wind Fetch Sector

Wind Obstruction Summary for Surface Roughness Assessment

Summary of Wind Obstruction Cataloging

An overview of the assessment presented in the following pages of Appendix B can be found in Appendix A, and conform the recommendations of ASCE 7-16 [Ref. 2].

Wind obstructions have been identified and marked up on aerial photos from Google Earth. Field observation were conducted to confirm current conditions and to estimate obstruction heights. Objects heights were estimated to ±5 ft, then spot checked from available documentation.

This page summarizes the results from each of the eight 45 degree wind sections found on the following pages. Annotations on a photo of each sector is provided for reference. See Figure A5 for an aerial photo identifying all eight sectors.

Upwind Fetch Site Area

R_{ud} = 1,500 ft = Minimum Upwind Distance Radius [ASCE 7-16 §26.7.3]

Angle = 45 deg = Fetch Sector Angle

A_{uc} = 883,573 sf = $\pi R_{ud}^2/(360/\text{Angle})$ = Area of Upwind Fetch Sector

Roughness Length Parameter Calculation

n = No. of Wind Obstructions

H_{ob} = Average Obstruction Height

S_{ob} = Average Obstruction Surface Area (Normal Silhouette Area)

A_{ob} = Average Upwind Site Fetch Area per Obstruction

z_0 = Terrain Roughness Length = $0.5 \cdot H_{ob}(S_{ob}/A_{ob})$ [ASCE 7-16, Eq C26.7, Lettau 1969 (Ref. 5)]

	Upwind Fetch Sector							
	NE	**EN**	**ES**	**SE**	**SW**	**WS**	**WN**	**NW**
Ref. Pg.	**B4-B5**	**B7-B8**	**B10-B11**	**B13-B14**	**B16-B17**	**B19-B20**	**B22-B23**	**B25-B26**
H_{ob} =	29.43 ft	23.05 ft	27.72 ft	25.87 ft	31.00 ft	32.66 ft	29.91 ft	30.27 ft
S_{ob} =	624 sf	483 sf	419 sf	453 sf	989 sf	1,015 sf	620 sf	332 sf
A_{ob} =	8,496 sf	7,425 sf	7,751 sf	7,363 sf	14,025 sf	16,992 sf	10,908 sf	5,890 sf
z_0 =	1.081 ft	0.750 ft	0.750 ft	0.796 ft	1.093 ft	0.975 ft	0.850 ft	0.852 ft
z_H (H_{avg}) =	24.0 ft	17.2 ft	17.0 ft	16.2 ft	21.9 ft	21.1 ft	21.4 ft	16.9 ft

$z_{0\,(min)}$ = 0.75 ft = the min. average of two adjacent sectors

$z_{0\,(avg)}$ = 0.89 ft = the overall average of all 8 sectors

Wind Sector NE Fetch Area

Figure B15: Google Maps Aerial Photo of B332 Wind Sector NE Fetch

Obstructions in NE Wind Sector Fetch

Item No.	Sub-sector	Description	Qty of Similar Objects	Frontal Height [H_o] (ft)	Frontal Width [W_o] (ft)	Frontal Surface Area [1][3] [S] (sf)	Effective Area Factor[2]	Effective Frontal Surface Area[3] [S_o] (sf)
1	**74**	Tree - Deciduous	3	**30**	20	360	0.15	**54**
2	**75**	Tree - Deciduous	13	**15**	10	68	0.15	**10**
3	**77**	Tree - Deciduous	1	**25**	15	214	0.15	**32**
4	**77**	Tree - Deciduous	1	**15**	5	34	0.15	**5**
5	**77**	Tree - Deciduous	1	**30**	18	324	0.15	**49**
6	**85**	Tree - Deciduous	5	**25**	15	214	0.15	**32**
7	**85**	Tree - Deciduous	10	**15**	10	68	0.15	**10**
8	**85**	Tree - Evergreen	1	**45**	25	731	0.50	**366**
9	**86**	Tree - Evergreen	5	**40**	20	510	0.50	**255**
10	**86**	Tree - Evergreen	4	**30**	15	270	0.50	**135**
11	**90**	Tree - Evergreen	5	**35**	15	326	0.50	**163**
12	**90**	Tree - Evergreen	7	**30**	15	270	0.50	**135**
13	**91**	Tree - Evergreen	1	**55**	35	1,286	0.50	**643**
14	**87**	Tree - Evergreen	1	**30**	15	270	0.50	**135**
15	**87**	Tree - Evergreen	1	**30**	10	180	0.50	**90**
16	**87**	Tree - Evergreen	1	**25**	8	114	0.50	**57**
17	**87**	Tree - Evergreen	1	**30**	20	360	0.50	**180**
18	**82**	Tree - Evergreen	7	**35**	15	326	0.50	**163**
19	**82**	Tree - Evergreen	1	**50**	40	1,320	0.50	**660**
20	**82**	Tree - Evergreen	7	**45**	30	878	0.50	**439**
21	**82**	Tree - Deciduous	2	**30**	20	360	0.15	**54**
22	**82**	Tree - Evergreen	3	**25**	10	143	0.50	**71**
23	**92**	Tree - Evergreen	2	**45**	30	878	0.50	**439**
24	**84**	Security Fence	2	**11**	259	2,849	0.17	**484**
25	**70**	T3340	1	**12**	69	828	1.00	**828**
26	**88**	Perimeter Security Poles	7	**50**	2	100	1.00	**100**
27	**71**	B341	1	**25**	188	4,700	1.00	**4,700**
28	**72**	B345	1	**15**	118	1,770	1.00	**1,770**
29	**73**	B3427	1	**15**	95	1,425	1.00	**1,425**
30	**76**	B3527	1	**15**	75	1,125	1.00	**1,125**
31	**78**	Building	1	**25**	61	1,525	1.00	**1,525**
32	**79**	B451	1	**30**	244	7,320	1.00	**7,320**
33	**80**	B4525	1	**15**	96	1,440	1.00	**1,440**
34	**83**	B3577	1	**15**	91	1,365	1.00	**1,365**
35	**84**	B361	1	**15**	202	3,030	1.00	**3,030**
36	**81A**	B453	1	**74**	251	18,574	1.00	**18,574**
37	**81B**	B453	1	**48**	175	8,400	1.00	**8,400**
38						0		**0**
39						0		**0**
40						0		**0**
41						0		**0**
42						0		**0**
43						0		**0**
44						0		**0**
45						0		**0**
46						0		**0**
47						0		**0**
48						0		**0**
49						0		**0**
50						0		**0**

51						0		**0**
52						0		**0**
53						0		**0**
54						0		**0**
55						0		**0**
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62						0		**0**
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66						0		**0**
67						0		**0**
68						0		**0**
69						0		**0**
70						0		**0**
71						0		**0**
72						0		**0**
73						0		**0**
74						0		**0**
75						0		**0**
76						0		**0**
77						0		**0**
78						0		**0**
79						0		**0**
80						0		**0**
81						0		**0**
82						0		**0**
83						0		**0**
84						0		**0**
85						0		**0**
86						0		**0**
87						0		**0**
88						0		**0**
89						0		**0**
90						0		**0**
91						0		**0**
92						0		**0**
93						0		**0**
95						0		**0**
96						0		**0**
			n =	104	**3,061 ft**	3,538 ft	84,914 ft	**64,930 sf**

$z_H = H_{avg}$ = 24.00 ft = $\Sigma S / \Sigma W_{ob}$ = Width Weighted Average Height

H_{ob} = 29.43 ft = $\Sigma H_0 / n$ = Average Obstruction Height

S_{ob} = 624 sf = $\Sigma S_0 / n$ = Average Obstruction Surface Area

A_{ob} = 8,496 sf = A_{uc} / n = Average Site Fetch Area per Obstruction (A_{uc} from pg B2)

Terrain Roughness Length

z_0 = 1.081 ft = $0.5H_{ob}(S_{ob}/A_{ob})$ [ASCE 7-16, Eqn C26.7, Lettau 1969]

Notes: 1) Single Tree So = 0.75·(Ho - 6 ft)·Wo, where tree foliage is assumed to start at 6 ft. above the ground and the 0.75 factor adjusts for the rectangular dimensions assumed for irregular tree shapes.

2) Eff. Area Factor adjusts for reduced wind resistance of non-solid objects likes trees, see Appendix A.

3) Surface areas shown are for a single object, Item No's with multiple objects are summed at the bottom.

Wind Sector EN Fetch Area

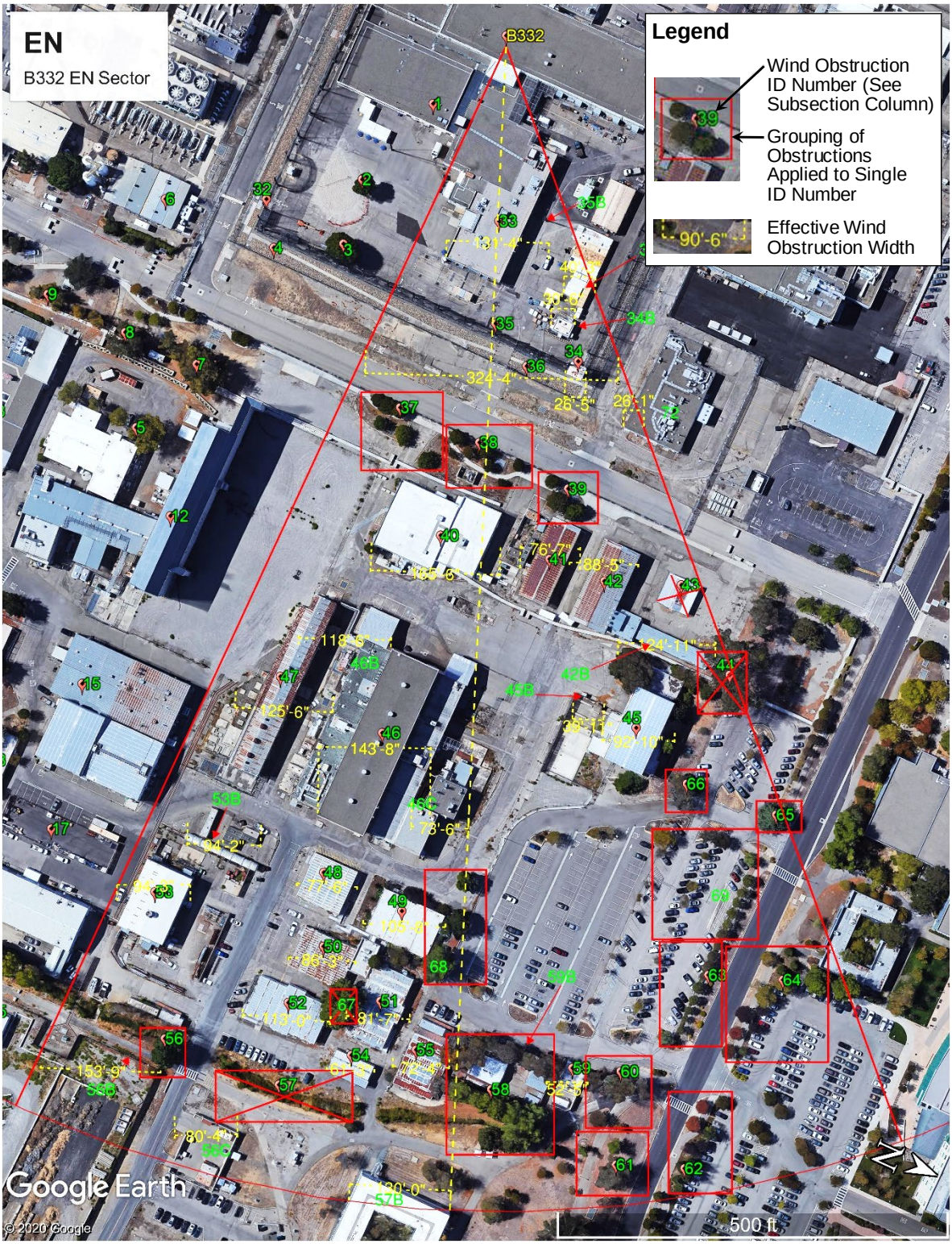

Figure B5: Google Maps Aerial Photo of B332 Wind Sector EN Fetch

Obstructions in EN Wind Sector Fetch

Item No.	Sub-sector	Description	Qty of Similar Objects	Frontal Height [H_o] (ft)	Frontal Width [W_o] (ft)	Frontal Surface Area [S] (sf) (1)(3)	Effective Area Factor (2)	Effective Frontal Surface Area [S_o] (sf) (3)
1	**56**	Tree - Evergreen	1	**55**	25	919	0.50	**459**
2	**58**	Tree - Evergreen	6	**50**	20	660	0.50	**330**
3	**58**	Tree - Deciduous	1	**40**	15	383	0.15	**57**
4	**58**	Tree - Deciduous	1	**35**	5	109	0.15	**16**
5	**58**	Tree - Evergreen	1	**40**	15	383	0.50	**191**
6	**58**	Tree - Evergreen	1	**45**	15	439	0.50	**219**
7	**61**	Tree - Evergreen	1	**35**	12	261	0.50	**131**
8	**60**	Tree - Deciduous	1	**10**	5	15	0.15	**2**
9	**60**	Tree - Deciduous	1	**12**	10	45	0.15	**7**
10	**60**	Tree - Deciduous	1	**15**	15	101	0.15	**15**
11	**60**	Tree - Deciduous	1	**15**	5	34	0.15	**5**
12	**62**	Tree - Deciduous	5	**12**	12	54	0.15	**8**
13	**62**	Tree - Deciduous	1	**15**	10	68	0.15	**10**
14	**62**	Tree - Evergreen	3	**40**	15	383	0.50	**191**
15	**62**	Tree - Evergreen	1	**35**	15	326	0.50	**163**
16	**62**	Tree - Evergreen	1	**30**	10	180	0.50	**90**
17	**64**	Tree - Deciduous	7	**15**	10	68	0.15	**10**
18	**64**	Tree - Deciduous	2	**25**	15	214	0.15	**32**
19	**64**	Tree - Evergreen	2	**30**	15	270	0.50	**135**
20	**64**	Tree - Evergreen	1	**15**	10	68	0.50	**34**
21	**64**	Tree - Evergreen	1	**45**	25	731	0.50	**366**
22	**69**	Tree - Deciduous	7	**15**	10	68	0.15	**10**
23	**69**	Tree - Evergreen	1	**15**	10	68	0.50	**34**
24	**69**	Tree - Deciduous	2	**20**	15	158	0.15	**24**
25	**69**	Tree - Deciduous	1	**10**	10	30	0.15	**5**
26	**63**	Tree - Deciduous	9	**15**	10	68	0.15	**10**
27	**63**	Tree - Deciduous	1	**25**	15	214	0.15	**32**
28	**68**	Tree - Evergreen	1	**35**	20	435	0.50	**218**
29	**66**	Tree - Evergreen	2	**35**	20	435	0.50	**218**
30	**67**	Tree Removed	0	**0**	0	0	0.15	**0**
31	**39**	Tree - Deciduous	1	**15**	15	101	0.15	**15**
32	**39**	Tree - Deciduous	1	**20**	15	158	0.15	**24**
33	**39**	Tree - Deciduous	1	**15**	15	101	0.15	**15**
34	**38**	Tree - Deciduous	6	**15**	15	101	0.15	**15**
35	**38**	Tree - Deciduous	4	**10**	5	15	0.15	**2**
36	**37**	Tree - Deciduous	4	**15**	12	81	0.15	**12**
37	**43**	Building Removed	0	**0**	0	0	0.00	**0**
38	**57**	Brush Removed	0	**0**	0	0	0.00	**0**
39	**36**	Security Fence	2	**11**	324	3,564	0.17	**606**
40	**35**	Perimeter Security Poles	6	**50**	2	100	1.00	**100**
41	**35B**	Interior Pole	1	**75**	2	150	1.00	**150**
42	**34**	NE Tower	1	**30**	26	780	1.00	**780**
43	**34B**	Security Post	1	**10**	30	300	1.00	**300**
44	**34C**	Storage Containers	1	**8**	40	320	1.00	**320**
45	**56C**	Wood Fence	1	**10**	80	240	1.00	**240**
46	**33**	B335	1	**18**	142	2,556	1.00	**2,556**
47	**40**	B439	1	**18**	165	2,970	1.00	**2,970**
48	**41**	B442	1	**20**	76	1,520	1.00	**1,520**
49	**42**	B443	1	**27**	88	2,376	1.00	**2,376**
50	**42B**	B443	1	**14**	124	1,736	1.00	**1,736**

51	**47**	B436	1	**30**	125	3,750	1.00	**3,750**
52	**46**	B435	1	**50**	143	7,150	1.00	**7,150**
53	**46B**	B435	1	**23**	118	2,714	1.00	**2,714**
54	**46C**	B435	1	**23**	73	1,679	1.00	**1,679**
55	**45**	B445	1	**42**	92	3,864	1.00	**3,864**
56	**45B**	Solid Metal Fence	1	**7**	39	273	1.00	**273**
57	**53**	B433	1	**22**	94	2,068	1.00	**2,068**
58	**53B**	Tank	1	**10**	94	940	1.00	**940**
59	**48**	T4382	1	**15**	77	1,155	1.00	**1,155**
60	**49**	T4377	1	**15**	98	1,470	1.00	**1,470**
61	**50**	T4302	1	**15**	86	1,290	1.00	**1,290**
62	**51**	T4378	1	**15**	81	1,215	1.00	**1,215**
63	**52**	T4383	1	**15**	113	1,695	1.00	**1,695**
64	**54**	T4384	1	**15**	61	915	1.00	**915**
65	**55**	T4387	1	**12**	72	864	1.00	**864**
66	**72**	B345	1	**15**	26	390	1.00	**390**
67	**56B**	Fence (75% opacity)	1	**7**	153	1,071	0.75	**803**
68	**57B**	B543	1	**28**	130	3,640	1.00	**3,640**
69	**59B**	Solid Metal Fence	1	**8**	40	320	1.00	**320**
70	**59**	U448	1	**12**	52	624	1.00	**624**
71								
72						0		**0**
73						0		**0**
74						0		**0**
75						0		**0**
76						0		**0**
77						0		**0**
78						0		**0**
79						0		**0**
80						0		**0**
81						0		**0**
82						0		**0**
83						0		**0**
84						0		**0**
85						0		**0**
86						0		**0**
87						0		**0**
88						0		**0**
89						0		**0**
90						0		**0**
91						0		**0**
92						0		**0**
93						0		**0**
95						0		**0**
96						0		**0**
		n =	119	**2,743 ft**	4,235 ft	73,003 ft		**57,479 sf**

$z_H = H_{avg}$ = 17.24 ft = $\Sigma S / \Sigma W_{ob}$ = Width Weighted Average Height

H_{ob} = 23.05 ft = $\Sigma H_0 / n$ = Average Obstruction Height

S_{ob} = 483 sf = $\Sigma S_0 / n$ = Average Obstruction Surface Area

A_{ob} = 7,425 sf = A_{uc} / n = Average Site Fetch Area per Obstruction (A_{uc} from pg B2)

Terrain Roughness Length

z_0 = 0.750 ft = $0.5H_{ob}(S_{ob}/A_{ob})$ [ASCE 7-16, Eqn C26.7, Lettau 1969]

Notes: 1) Single Tree So = 0.75·(Ho - 6 ft)·Wo, where tree foliage is assumed to start at 6 ft. above the ground and the 0.75 factor adjusts for the rectangular dimensions assumed for irregular tree shapes.

2) Eff. Area Factor adjusts for reduced wind resistance of non-solid objects likes trees, see Appendix A.

3) Surface areas shown are for a single object, Item No's with multiple objects are summed at the bottom.

Wind Sector ES Fetch Area

Figure B5: Google Maps Aerial Photo of B332 Wind Sector ES Fetch

Rev	Prepared	Date	Reviewed
0	Y. Lucille	03/03/20	M. Sampson

Title: Determination of Wind Exposure Category and Basic Wind Speed for Facilities Located within Superblock

Obstructions in ES Wind Sector Fetch

Item No.	Sub-sector	Description	Qty of Similar Objects	Frontal Height [H_o] (ft)	Frontal Width [W_o] (ft)	Frontal Surface Area [1][3] [S] (sf)	Effective Area Factor[2]	Effective Frontal Surface Area[3] [S_o] (sf)
1	**1**	B332 Office	1	**14**	91	1,274	1.00	**1,274**
2	**2**	Tree - Evergreen	1	**30**	30	540	0.50	**270**
3	**3**	Tree Removed	0	**0**	0	0	0.00	**0**
4	**4**	Security Fence	2	**11**	294	3,234	0.17	**550**
5	**5**	Tree - Deciduous	1	**30**	20	360	0.15	**54**
6	**6**	U325	1	**16**	67	1,072	1.00	**1,072**
7	**7**	Tree - Evergreen	2	**40**	15	383	0.50	**191**
8	**7**	Tree - Evergreen	1	**35**	15	326	0.50	**163**
9	**7**	Tree - Evergreen	1	**40**	10	255	0.50	**128**
10	**7**	Tree - Evergreen	2	**35**	10	218	0.50	**109**
11	**7**	Tree - Evergreen	1	**20**	8	84	0.50	**42**
12	**7**	Tree - Evergreen	1	**15**	5	34	0.50	**17**
13	**7**	Tree - Evergreen	1	**15**	10	68	0.50	**34**
14	**7**	Tree - Evergreen	3	**25**	5	71	0.50	**36**
15	**8**	Tree - Deciduous	3	**15**	10	68	0.15	**10**
16	**8**	Tree - Deciduous	5	**10**	5	15	0.15	**2**
17	**8**	Tree - Evergreen	1	**45**	15	439	0.50	**219**
18	**8**	Tree - Evergreen	1	**40**	15	383	0.50	**191**
19	**8**	Tree - Evergreen	1	**40**	10	255	0.50	**128**
20	**8**	Tree - Evergreen	1	**35**	5	109	0.50	**54**
21	**8**	Tree - Evergreen	1	**35**	15	326	0.50	**163**
22	**9**	Tree - Evergreen	1	**25**	20	285	0.50	**143**
23	**9**	Tree - Evergreen	3	**15**	10	68	0.50	**34**
24	**9**	Tree - Evergreen	1	**20**	5	53	0.50	**26**
25	**9**	Tree - Evergreen	1	**20**	10	105	0.50	**53**
26	**9**	Tree - Evergreen	2	**20**	5	53	0.50	**26**
27	**10**	Tree - Evergreen	2	**20**	10	105	0.50	**53**
28	**10**	Tree - Evergreen	1	**20**	15	158	0.50	**79**
29	**10**	Tree - Evergreen	1	**20**	5	53	0.50	**26**
30	**11**	Tree - Evergreen	1	**20**	15	158	0.50	**79**
31	**11**	Tree - Evergreen	4	**10**	10	30	0.50	**15**
32	**11**	Tree - Evergreen	1	**15**	20	135	0.50	**68**
33	**11**	Tree - Evergreen	1	**15**	10	68	0.50	**34**
34	**16**	Tree - Evergreen	1	**40**	30	765	0.50	**383**
35	**16**	Tree - Evergreen	1	**35**	20	435	0.50	**218**
36	**16**	Tree - Evergreen	1	**25**	15	214	0.50	**107**
37	**20**	Tree - Evergreen	1	**30**	30	540	0.50	**270**
38	**20**	Tree - Evergreen	1	**30**	20	360	0.50	**180**
39	**21**	Tree - Evergreen	1	**40**	10	255	0.50	**128**
40	**21**	Tree - Evergreen	3	**35**	10	218	0.50	**109**
41	**21**	Tree - Evergreen	1	**30**	10	180	0.50	**90**
42	**21**	Tree - Evergreen	1	**20**	10	105	0.50	**53**
43	**22**	Tree - Evergreen	2	**40**	10	255	0.50	**128**
44	**22**	Tree - Evergreen	1	**40**	15	383	0.50	**191**
45	**22**	Tree - Evergreen	1	**35**	10	218	0.50	**109**
46	**22**	Tree - Evergreen	1	**15**	5	34	0.50	**17**
47	**23**	Tree - Evergreen	1	**35**	20	435	0.50	**218**
48	**23**	Tree - Evergreen	1	**35**	15	326	0.50	**163**
49	**23**	Tree - Evergreen	1	**20**	15	158	0.50	**79**
50	**28**	Tree - Evergreen	1	**40**	20	510	0.50	**255**

51	**28**	Tree - Evergreen	1	**40**	15	383	0.50	**191**
52	**28**	Tree - Evergreen	1	**40**	25	638	0.50	**319**
53	**28**	Tree - Evergreen	1	**35**	15	326	0.50	**163**
54	**31**	Bush/Hedge	1	**10**	20	200	0.15	**30**
55	**31**	Bush/Hedge	1	**10**	15	150	0.15	**23**
56	**31**	Bush/Hedge	1	**8**	15	120	0.15	**18**
57	**31**	Bush/Hedge	1	**8**	10	15	0.15	**2**
58	**26**	Tree - Evergreen	1	**40**	15	383	0.50	**191**
59	**26**	Tree - Evergreen	1	**40**	20	510	0.50	**255**
60	**26**	Tree - Evergreen	1	**35**	10	218	0.50	**109**
61	**26**	Tree - Evergreen	1	**30**	5	90	0.50	**45**
62	**30**	Tree - Deciduous	1	**35**	10	218	0.15	**33**
63	**30**	Tree - Deciduous	1	**30**	10	180	0.15	**27**
64	**30**	Tree - Deciduous	1	**30**	15	270	0.15	**41**
65	**30**	Tree - Deciduous	1	**20**	8	84	0.15	**13**
66	**30**	Tree - Deciduous	2	**15**	5	34	0.15	**5**
67	**29**	Tree - Deciduous	1	**35**	15	326	0.15	**49**
68	**29**	Tree - Deciduous	2	**30**	10	180	0.15	**27**
69	**29**	Tree - Deciduous	1	**25**	5	71	0.15	**11**
70	**10B**	Vehicle Barrier	1	**3.8**	548	2,082	1.00	**2,082**
71	**12**	B431 High Gabled Roof	1	**65**	121	7,865	1.00	**7,865**
72	**12A**	B431 Flat Roof	1	**25**	144	3,600	1.00	**3,600**
73	**13**	U426	1	**14**	184	2,576	1.00	**2,576**
74	**14**	4298	1	**22**	90	1,980	1.00	**1,980**
75	**15**	B432	1	**25**	206	5,150	1.00	**5,150**
76	**18**	4385	1	**12**	67	804	1.00	**804**
77	**19**	4297/4299	1	**16**	115	1,840	1.00	**1,840**
78	**24**	B438	1	**30**	184	5,520	1.00	**5,520**
79	**25**	4399	1	**14**	64	896	1.00	**896**
80	**27**	B411	1	**20**	157	3,140	1.00	**3,140**
81	**32**	Perimeter Security Poles	11	**50**	2	100	1.00	**100**
82	**32B**	Interior Security Poles	1	**75**	2	150	1.00	**150**
83						0		**0**
84						0		**0**
85						0		**0**
86						0		**0**
87						0		**0**
88						0		**0**
89						0		**0**
90						0		**0**
91						0		**0**
92						0		**0**
93						0		**0**
95						0		**0**
96						0		**0**
		n =	114	**3,160 ft**	3,681 ft	62,723 ft		**47,807 sf**

$z_H = H_{avg}$ = 17.04 ft = $\Sigma S / \Sigma W_{ob}$ = Width Weighted Average Height

H_{ob} = 27.72 ft = $\Sigma H_0 / n$ = Average Obstruction Height

S_{ob} = 419 sf = $\Sigma S_0 / n$ = Average Obstruction Surface Area

A_{ob} = 7,751 sf = A_{uc} / n = Average Site Fetch Area per Obstruction (A_{uc} from pg B2)

Terrain Roughness Length

z_0 = 0.750 ft = $0.5H_{ob}(S_{ob}/A_{ob})$ [ASCE 7-16, Eqn C26.7, Lettau 1969]

Notes: 1) Single Tree So = 0.75·(Ho - 6 ft)·Wo, where tree foliage is assumed to start at 6 ft. above the ground and the 0.75 factor adjusts for the rectangular dimensions assumed for irregular tree shapes.

2) Eff. Area Factor adjusts for reduced wind resistance of non-solid objects likes trees, see Appendix A.

3) Surface areas shown are for a single object, Item No's with multiple objects are summed at the bottom.

Wind Sector SE Fetch Area

Figure B5: Google Maps Aerial Photo of B332 Wind Sector SE Fetch

Obstructions in SE Wind Sector Fetch

Item No.	Sub-sector	Description	Qty of Similar Objects	Frontal Height [H_o] (ft)	Frontal Width [W_o] (ft)	Frontal Surface Area [1][3] [S] (sf)	Effective Area Factor[2]	Effective Frontal Surface Area[3] [S_o] (sf)
1	**189**	2nd St South Fence (1/8in, 2.25in)	1	**8**	226	1,808	0.17	**307**
2	**194**	Tank	3	**30**	12	360	1.00	**360**
3	**198**	Fence (1/8in, 2.25in)	1	**8**	490	3,920	0.17	**666**
4	**205**	Security Fence	2	**11**	300	3,300	0.17	**561**
5	**205**	Tree - Evergreen	5	**55**	15	551	0.50	**276**
6	**205**	Tree - Evergreen	1	**35**	10	218	0.50	**109**
7	**205**	Tree - Evergreen	2	**20**	15	158	0.50	**79**
8	**205**	Tree - Evergreen	1	**15**	10	68	0.50	**34**
9	**204**	Tree - Deciduous	3	**50**	25	825	0.15	**124**
10	**201**	Tree - Evergreen	1	**10**	10	30	0.50	**15**
11	**201**	Tree - Evergreen	1	**15**	15	101	0.50	**51**
12	**201**	Tree - Deciduous	1	**20**	15	158	0.15	**24**
13	**201**	Tree - Evergreen	1	**40**	25	638	0.50	**319**
14	**201**	Tree - Evergreen	1	**25**	20	285	0.50	**143**
15	**201**	Tree - Evergreen	2	**35**	20	435	0.50	**218**
16	**202**	Tree - Evergreen	13	**30**	15	270	0.50	**135**
17	**202**	Tree - Evergreen	3	**25**	10	143	0.50	**71**
18	**202**	Tree - Deciduous	6	**20**	15	158	0.15	**24**
19	**202**	Tree - Deciduous	3	**15**	10	68	0.15	**10**
20	**206**	Tree - Deciduous	1	**35**	25	544	0.15	**82**
21	**206**	Tree - Deciduous	1	**20**	10	105	0.15	**16**
22	**206**	Tree - Deciduous	1	**35**	20	435	0.15	**65**
23	**206**	Tree - Deciduous	1	**15**	10	68	0.15	**10**
24	**212**	Tree - Deciduous	3	**15**	10	68	0.15	**10**
25	**212**	Tree - Deciduous	3	**20**	15	158	0.15	**24**
26	**212**	Tree - Deciduous	2	**10**	5	15	0.15	**2**
27	**213**	Trees Removed	0	**0**	0	0	0.00	**0**
28	**211**	Tree - Deciduous	1	**10**	3	9	0.15	**1**
29	**211**	Tree - Deciduous	2	**20**	15	158	0.15	**24**
30	**211**	Tree - Deciduous	2	**10**	5	15	0.15	**2**
31	**211**	Tree - Deciduous	1	**15**	10	68	0.15	**10**
32	**211**	Tree - Deciduous	1	**25**	15	214	0.15	**32**
33	**209**	Tree - Deciduous	5	**30**	20	360	0.15	**54**
34	**209**	Tree - Deciduous	1	**20**	15	158	0.15	**24**
35	**209**	Tree - Deciduous	11	**15**	10	68	0.15	**10**
36	**208**	Tree - Evergreen	4	**40**	20	510	0.50	**255**
37	**208**	Tree - Evergreen	3	**30**	20	360	0.50	**180**
38	**208**	Tree - Evergreen	1	**30**	15	270	0.50	**135**
39	**216**	Tree - Evergreen	1	**30**	25	450	0.50	**225**
40	**216**	Tree - Evergreen	1	**25**	15	214	0.50	**107**
41	**215**	Fence (3/32in, 2.25in)	1	**8**	318	2,544	0.17	**432**
42	**214**	Tree - Evergreen	1	**45**	30	878	0.50	**439**
43	**190**	B322	1	**15**	98	1,470	1.00	**1,470**
44	**191**	3203	1	**35**	71	2,485	1.00	**2,485**
45	**192**	Tanks/Mechanical	1	**10**	87	870	1.00	**870**
46	**193**	B329	1	**15**	127	1,905	1.00	**1,905**
47	**196**	B324	1	**20**	104	2,080	1.00	**2,080**
48	**197**	B323	1	**30**	132	3,960	1.00	**3,960**
49	**199**	B316	1	**30**	182	5,460	1.00	**5,460**
50	**200**	B315	1	**30**	199	5,970	1.00	**5,970**

51	**168**	B311	1	**27**	75	2,025	1.00	**2,025**
52	**203**	B314	1	**30**	151	4,530	1.00	**4,530**
53	**207**	B312	1	**15**	171	2,565	1.00	**2,565**
54	**210**	B415	1	**25**	129	3,225	1.00	**3,225**
55	**27**	B411	1	**20**	199	3,980	1.00	**3,980**
56	**187**	Perimeter Security Poles	5	**50**	2	100	1.00	**100**
57	**188**	Security Fence	2	**11**	193	2,123	0.17	**361**
58	**1**	B332 Office	1	**14**	98	588	1.00	**588**
59						0		**0**
60						0		**0**
61						0		**0**
62						0		**0**
63						0		**0**
64						0		**0**
65						0		**0**
66						0		**0**
67						0		**0**
68						0		**0**
69						0		**0**
70						0		**0**
71						0		**0**
72						0		**0**
73						0		**0**
74						0		**0**
75						0		**0**
76						0		**0**
77						0		**0**
78						0		**0**
79						0		**0**
80						0		**0**
81						0		**0**
82						0		**0**
83						0		**0**
84						0		**0**
85						0		**0**
86						0		**0**
87						0		**0**
88						0		**0**
89						0		**0**
90						0		**0**
91						0		**0**
92						0		**0**
93						0		**0**
95						0		**0**
96						0		**0**
		n =	120	**3,104 ft**	5,227 ft	84,931 ft		**54,363 sf**

$z_H = H_{avg}$ = 16.25 ft = $\Sigma S / \Sigma W_{ob}$ = Width Weighted Average Height

H_{ob} = 25.87 ft = $\Sigma H_0 / n$ = Average Obstruction Height

S_{ob} = 453 sf = $\Sigma S_0 / n$ = Average Obstruction Surface Area

A_{ob} = 7,363 sf = A_{uc} / n = Average Site Fetch Area per Obstruction (A_{uc} from pg B2)

Terrain Roughness Length

z_0 = 0.796 ft = $0.5H_{ob}(S_{ob}/A_{ob})$ [ASCE 7-16, Eqn C26.7, Lettau 1969]

Notes: 1) Single Tree So = 0.75·(Ho - 6 ft)·Wo, where tree foliage is assumed to start at 6 ft. above the ground and the 0.75 factor adjusts for the rectangular dimensions assumed for irregular tree shapes.

2) Eff. Area Factor adjusts for reduced wind resistance of non-solid objects likes trees, see Appendix A.

3) Surface areas shown are for a single object, Item No's with multiple objects are summed at the bottom.

Wind Sector SW Fetch Area

Figure B5: Google Maps Aerial Photo of B332 Wind Sector SW Fetch

Obstructions in SW Wind Sector Fetch

Item No.	Sub-sector	Description	Qty of Similar Objects	Frontal Height [H_o] (ft)	Frontal Width [W_o] (ft)	Frontal Surface Area [1][3] [S] (sf)	Effective Area Factor[2]	Effective Frontal Surface Area[3] [S_o] (sf)
1	**160**	Removed 326	0	**0**	0	0	1.00	**0**
2	**161**	Removed 3226	0	**0**	0	0	1.00	**0**
3	**184**	Tree - Deciduous	2	**20**	15	158	0.15	**24**
4	**184**	Tree - Deciduous	1	**10**	5	15	0.15	**2**
5	**184**	Tree - Deciduous	1	**25**	20	285	0.15	**43**
6	**158B**	B336	1	**11**	42	462	1.00	**462**
7	**159**	2nd St South Fence (3/16in, 1.125in)	1	**8**	230	1,840	0.17	**313**
8	**162**	B327	1	**20**	102	2,040	1.00	**2,040**
9	**163**	B321	1	**30**	490	14,700	1.00	**14,700**
10	**164**	Tree Removed	0	**0**	0	0	0.15	**0**
11	**165**	Tree - Deciduous	1	**35**	20	435	0.15	**65**
12	**165**	Tree - Deciduous	1	**25**	20	285	0.15	**43**
13	**166**	T3180	1	**15**	83	1,245	1.00	**1,245**
14	**167**	B313	1	**15**	92	1,380	1.00	**1,380**
15	**168**	B311	1	**30**	133	3,990	1.00	**3,990**
16	**169**	Tree - Evergreen	1	**50**	15	495	0.50	**248**
17	**169**	Tree - Evergreen	1	**40**	15	383	0.50	**191**
18	**169**	Tree - Evergreen	1	**40**	10	255	0.50	**128**
19	**160A**	B317	1	**12**	69	828	1.00	**828**
20	**186**	Tree - Evergreen	2	**20**	15	158	0.50	**79**
21	**185**	Tree - Evergreen	5	**20**	20	210	0.50	**105**
22	**170**	B217	1	**30**	200	6,000	1.00	**6,000**
23	**171**	B218	1	**30**	200	6,000	1.00	**6,000**
24	**174**	B319	1	**30**	200	6,000	1.00	**6,000**
25	**175**	B219	1	**30**	200	6,000	1.00	**6,000**
26	**172**	B318	1	**15**	118	1,770	1.00	**1,770**
27	**183**	B211	1	**25**	80	2,000	1.00	**2,000**
28	**182**	B212	1	**20**	68	1,360	1.00	**1,360**
29	**173**	Tree - Deciduous	1	**35**	35	761	0.15	**114**
30	**173**	Tree - Deciduous	1	**30**	25	450	0.15	**68**
31	**173**	Tree - Deciduous	1	**25**	15	214	0.15	**32**
32	**173**	Tree - Deciduous	1	**25**	25	356	0.15	**53**
33	**158A**	Security Fence	2	**11**	190	2,090	0.17	**355**
34	**157**	Perimeter Security Poles	5	**50**	2	100	1.00	**100**
35	**176**	Tree - Deciduous	2	**20**	20	210	0.15	**32**
36	**176**	Tree - Deciduous	1	**25**	25	356	0.15	**53**
37	**176**	Tree - Evergreen	1	**20**	15	158	0.50	**79**
38	**177**	10' Brush	1	**10**	75	750	0.15	**113**
39	**178**	Tree - Evergreen	1	**25**	20	285	0.50	**143**
40	**178**	Tree - Evergreen	1	**45**	20	585	0.50	**293**
41	**178**	Tree - Evergreen	1	**40**	25	638	0.50	**319**
42	**178**	Tree - Evergreen	1	**35**	20	435	0.50	**218**
43	**180**	Tree - Evergreen	5	**60**	20	810	0.50	**405**
44	**180**	Tree - Evergreen	1	**50**	15	495	0.50	**248**
45	**179**	Tree - Evergreen	3	**35**	20	435	0.50	**218**
46	**179**	Tree - Evergreen	2	**35**	20	435	0.50	**218**
47	**181**	Tree - Evergreen	1	**75**	25	1,294	0.50	**647**
48						0		**0**
49						0		**0**
50						0		**0**

51						0		**0**
52						0		**0**
53						0		**0**
54						0		**0**
55						0		**0**
56						0		**0**
57						0		**0**
58						0		**0**
59						0		**0**
60						0		**0**
61						0		**0**
62						0		**0**
63						0		**0**
64						0		**0**
65						0		**0**
66						0		**0**
67						0		**0**
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69						0		**0**
70						0		**0**
71						0		**0**
72						0		**0**
73						0		**0**
74						0		**0**
75						0		**0**
76						0		**0**
77						0		**0**
78						0		**0**
79						0		**0**
80						0		**0**
81						0		**0**
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84						0		**0**
85						0		**0**
86						0		**0**
87						0		**0**
88						0		**0**
89						0		**0**
90						0		**0**
91						0		**0**
92						0		**0**
93						0		**0**
95						0		**0**
96						0		**0**
			n =	63	**1,953 ft**	3,542 ft	77,549 ft	**62,300 sf**

$z_H = H_{avg}$ = 21.89 ft = $\Sigma S / \Sigma W_{ob}$ = Width Weighted Average Height

H_{ob} = 31.00 ft = $\Sigma H_0 / n$ = Average Obstruction Height

S_{ob} = 989 sf = $\Sigma S_0 / n$ = Average Obstruction Surface Area

A_{ob} = 14,025 sf = A_{uc} / n = Average Site Fetch Area per Obstruction (A_{uc} from pg B2)

Terrain Roughness Length

z_0 = 1.093 ft = $0.5H_{ob}(S_{ob}/A_{ob})$ [ASCE 7-16, Eqn C26.7, Lettau 1969]

Notes: 1) Single Tree So = 0.75·(Ho - 6 ft)·Wo, where tree foliage is assumed to start at 6 ft. above the ground and the 0.75 factor adjusts for the rectangular dimensions assumed for irregular tree shapes.

2) Eff. Area Factor adjusts for reduced wind resistance of non-solid objects likes trees, see Appendix A.

3) Surface areas shown are for a single object, Item No's with multiple objects are summed at the bottom.

Wind Sector WS Fetch Area

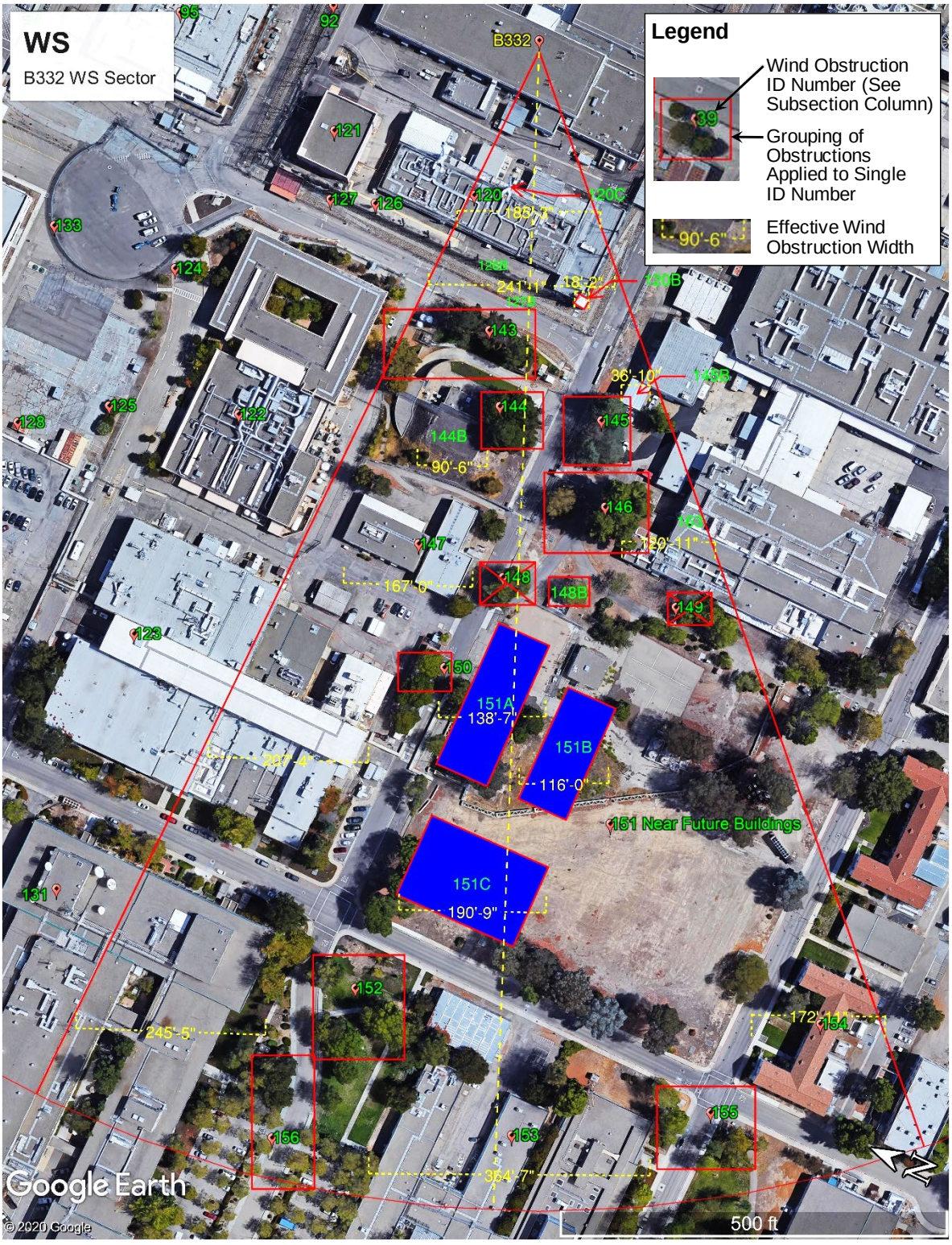

Figure B5: Google Maps Aerial Photo of B332 Wind Sector WS Fetch

Rev	Prepared	Date	Reviewed
0	Y. Lucille	03/03/20	M. Sampson

Title: Determination of Wind Exposure Category and Basic Wind Speed for Facilities Located within Superblock

Obstructions in WS Wind Sector Fetch

Item No.	Sub-sector	Description	Qty of Similar Objects	Frontal Height [H_o] (ft)	Frontal Width [W_o] (ft)	Frontal Surface Area [1][3] [S] (sf)	Effective Area Factor[2]	Effective Frontal Surface Area[3] [S_o] (sf)
1	**145**	Tree - Evergreen	1	**45**	25	731	0.50	**366**
2	**145**	Tree - Evergreen	1	**40**	15	383	0.50	**191**
3	**145**	Tree - Evergreen	4	**35**	15	326	0.50	**163**
4	**144**	Tree - Evergreen	1	**50**	30	990	0.50	**495**
5	**144**	Tree - Evergreen	1	**50**	20	660	0.50	**330**
6	**127B**	Security Fence	2	**11**	241	2,651	0.17	**451**
7	**143**	Tree - Evergreen	1	**45**	20	585	0.50	**293**
8	**150**	Tree - Deciduous	3	**25**	20	285	0.15	**43**
9	**146**	Tree - Evergreen	3	**55**	25	919	0.50	**459**
10	**146**	Tree - Evergreen	1	**45**	20	585	0.50	**293**
11	**148B**	Tree - Deciduous	1	**30**	20	360	0.15	**54**
12	**120**	Building	1	**16**	185	2,960	1.00	**2,960**
13	**120C**	B331 South Stack	1	**100**	3.92	392	1.00	**392**
14	**120B**	SW Tower	1	**30**	18	540	1.00	**540**
15	**145B**	B327	1	**15**	36	540	1.00	**540**
16	**144B**	B239	1	**15**	90	1,350	1.00	**1,350**
17	**163**	B321	1	**20**	120	2,400	1.00	**2,400**
18	**147**	B233/B234	1	**15**	167	2,505	1.00	**2,505**
19	**123**	B231	1	**35**	207	7,245	1.00	**7,245**
20	**151A**	B223	1	**23.5**	138	3,243	1.00	**3,243**
21	**151B**	B225	1	**24.3**	116	2,819	1.00	**2,819**
22	**151C**	B224	1	**20**	190	3,800	1.00	**3,800**
23	**131**	B131	1	**32.5**	245	7,963	1.00	**7,963**
24	**154**	B216	1	**30**	172	5,160	1.00	**5,160**
25	**153**	B121	1	**15**	364	5,460	1.00	**5,460**
26	**126B**	Perimeter Security Poles	8	**50**	2	100	1.00	**100**
27	**152**	Tree - Evergreen	2	**25**	15	214	0.50	**107**
28	**155**	Tree - Deciduous	2	**20**	10	200	0.15	**30**
29	**156**	Tree - Evergreen	1	**20**	10	200	0.50	**100**
30	**156**	Tree - Deciduous	6	**15**	10	150	0.15	**23**
31						0		**0**
32						0		**0**
33						0		**0**
34						0		**0**
35						0		**0**
36						0		**0**
37						0		**0**
38						0		**0**
39						0		**0**
40						0		**0**
41						0		**0**
42						0		**0**
43						0		**0**
44						0		**0**
45						0		**0**
46						0		**0**
47						0		**0**
48						0		**0**
49						0		**0**
50						0		**0**

51						0		**0**
52						0		**0**
53						0		**0**
54						0		**0**
55						0		**0**
56						0		**0**
57						0		**0**
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61						0		**0**
62						0		**0**
63						0		**0**
64						0		**0**
65						0		**0**
66						0		**0**
67						0		**0**
68						0		**0**
69						0		**0**
70						0		**0**
71						0		**0**
72						0		**0**
73						0		**0**
74						0		**0**
75						0		**0**
76						0		**0**
77						0		**0**
78						0		**0**
79						0		**0**
80						0		**0**
81						0		**0**
82						0		**0**
83						0		**0**
84						0		**0**
85						0		**0**
86						0		**0**
87						0		**0**
88						0		**0**
89						0		**0**
90						0		**0**
91						0		**0**
92						0		**0**
93						0		**0**
95						0		**0**
96						0		**0**
			n =	52	**1,698 ft**	3,015 ft	63,616 ft	**52,766 sf**

$z_H = H_{avg}$ = 21.10 ft = $\Sigma S / \Sigma W_{ob}$ = Width Weighted Average Height

H_{ob} = 32.66 ft = $\Sigma H_0 / n$ = Average Obstruction Height

S_{ob} = 1,015 sf = $\Sigma S_0 / n$ = Average Obstruction Surface Area

A_{ob} = 16,992 sf = A_{uc} / n = Average Site Fetch Area per Obstruction (A_{uc} from pg B2)

Terrain Roughness Length

z_0 = 0.975 ft = $0.5H_{ob}(S_{ob}/A_{ob})$ [ASCE 7-16, Eqn C26.7, Lettau 1969]

Notes: 1) Single Tree So = 0.75·(Ho - 6 ft)·Wo, where tree foliage is assumed to start at 6 ft. above the ground and the 0.75 factor adjusts for the rectangular dimensions assumed for irregular tree shapes.

2) Eff. Area Factor adjusts for reduced wind resistance of non-solid objects likes trees, see Appendix A.

3) Surface areas shown are for a single object, Item No's with multiple objects are summed at the bottom.

Wind Sector WN Fetch Area

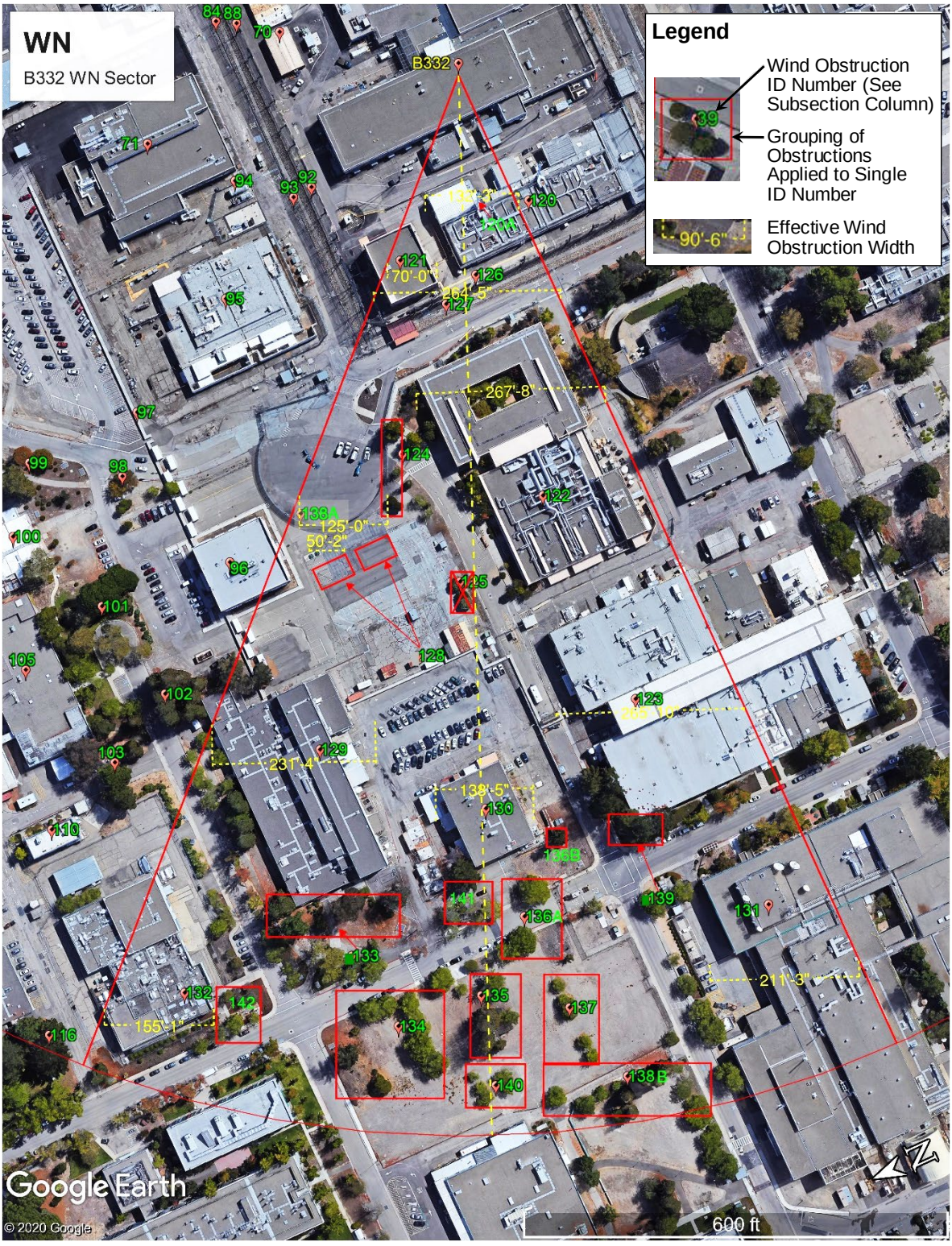

Figure B5: Google Maps Aerial Photo of B332 Wind Sector WN Fetch

Rev	Prepared	Date	Reviewed
0	Y. Lucille	03/03/20	M. Sampson

Title: Determination of Wind Exposure Category and Basic Wind Speed for Facilities Located within Superblock

Obstructions in WN Wind Sector Fetch

Item No.	Sub-sector	Description	Qty of Similar Objects	Frontal Height [H_o] (ft)	Frontal Width [W_o] (ft)	Frontal Surface Area [1][3] [S] (sf)	Effective Area Factor[2]	Effective Frontal Surface Area[3] [S_o] (sf)
1	**138A**	NW Fence (1/8", 1.25")	1	**8**	125	1,000	0.20	**200**
2	**124**	Tree - Evergreen	2	**30**	10	180	0.50	**90**
3	**124**	Tree - Deciduous	1	**15**	10	68	0.15	**10**
4	**124**	Tree - Deciduous	1	**15**	15	101	0.15	**15**
5	**136B**	Tree - Evergreen	1	**40**	15	383	0.50	**191**
6	**136A**	Tree - Deciduous	1	**35**	25	544	0.15	**82**
7	**136A**	Tree - Deciduous	1	**30**	20	360	0.15	**54**
8	**136A**	Tree - Deciduous	2	**25**	15	214	0.15	**32**
9	**141**	Tree - Deciduous	3	**35**	20	435	0.15	**65**
10	**139**	Tree - Evergreen	2	**50**	25	825	0.50	**413**
11	**137**	Tree - Deciduous	5	**15**	10	68	0.15	**10**
12	**138B**	Tree - Evergreen	4	**50**	15	495	0.50	**248**
13	**138B**	Tree - Deciduous	3	**15**	10	68	0.15	**10**
14	**138B**	Tree - Evergreen	1	**12**	12	54	0.50	**27**
15	**138B**	Tree - Deciduous	1	**15**	15	101	0.15	**15**
16	**138B**	Tree - Deciduous	3	**15**	10	68	0.15	**10**
17	**140**	Tree - Deciduous	5	**12**	10	45	0.15	**7**
18	**135**	Tree - Evergreen	4	**55**	15	551	0.50	**276**
19	**135**	Tree - Deciduous	3	**20**	15	158	0.15	**24**
20	**135**	Tree - Deciduous	2	**15**	10	68	0.15	**10**
21	**134**	Tree - Deciduous	1	**30**	25	450	0.15	**68**
22	**134**	Tree - Deciduous	4	**25**	20	285	0.15	**43**
23	**134**	Tree - Evergreen	1	**50**	25	825	0.50	**413**
24	**133**	Tree - Evergreen	4	**55**	15	551	0.50	**276**
25	**142**	Tree - Deciduous	4	**15**	15	101	0.15	**15**
26	**142**	Tree - Deciduous	1	**15**	15	101	0.15	**15**
27	**120**	B331 North Stack	1	**16**	132	2,112	1.00	**2,112**
28	**121**	B334	1	**35**	70	2,450	1.00	**2,450**
29	**122**	B235	1	**20**	267	5,340	1.00	**5,340**
30	**128**	New Trailers	2	**15**	50	750	1.00	**750**
31	**123**	B231	1	**35**	235	8,225	1.00	**8,225**
32	**129**	B241	1	**35**	231	8,085	1.00	**8,085**
33	**130**	B243	1	**30**	138	4,140	1.00	**4,140**
34	**127**	Security Fence	2	**11**	264	2,904	0.17	**494**
35	**126**	Perimeter Security Poles	7	**50**	2	100	1.00	**100**
36	**120A**	B331 North Stack	1	**100**	3.92	392	1.00	**392**
37	**131**	B131	1	**32.5**	211	6,858	1.00	**6,858**
38	**132**	B251	1	**22**	155	3,410	1.00	**3,410**
39						0		**0**
40						0		**0**
41						0		**0**
42						0		**0**
43						0		**0**
44						0		**0**
45						0		**0**
46						0		**0**
47						0		**0**
48						0		**0**
49						0		**0**
50						0		**0**

51						0		**0**
52						0		**0**
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54						0		**0**
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86						0		**0**
87						0		**0**
88						0		**0**
89						0		**0**
90						0		**0**
91						0		**0**
92						0		**0**
93						0		**0**
95						0		**0**
96						0		**0**
			n =	81	**2,423 ft**	3,092 ft	66,259 ft	**50,216 sf**

$z_H = H_{avg}$ = 21.43 ft = $\Sigma S / \Sigma W_{ob}$ = Width Weighted Average Height

H_{ob} = 29.91 ft = $\Sigma H_0 / n$ = Average Obstruction Height

S_{ob} = 620 sf = $\Sigma S_0 / n$ = Average Obstruction Surface Area

A_{ob} = 10,908 sf = A_{uc} / n = Average Site Fetch Area per Obstruction (A_{uc} from pg B2)

Terrain Roughness Length

z_0 = **0.850 ft** = $0.5 H_{ob}(S_{ob}/A_{ob})$ [ASCE 7-16, Eqn C26.7, Lettau 1969]

Notes: 1) Single Tree So = 0.75·(Ho - 6 ft)·Wo, where tree foliage is assumed to start at 6 ft. above the ground and the 0.75 factor adjusts for the rectangular dimensions assumed for irregular tree shapes.

2) Eff. Area Factor adjusts for reduced wind resistance of non-solid objects likes trees, see Appendix A.

3) Surface areas shown are for a single object, Item No's with multiple objects are summed at the bottom.

Wind Sector NW Fetch Area

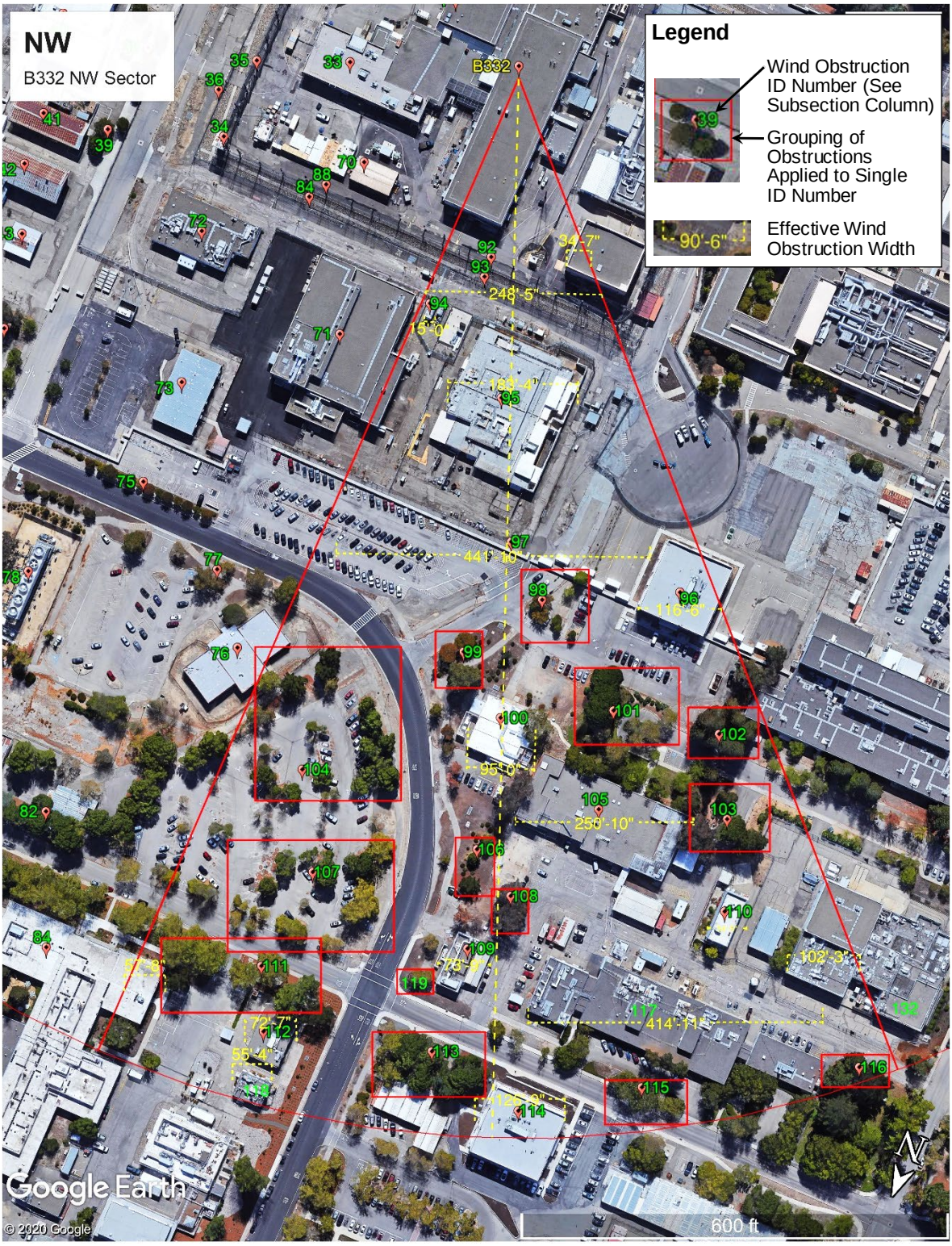

Figure B5: Google Maps Aerial Photo of B332 Wind Sector NW Fetch

Rev	Prepared	Date	Reviewed
0	Y. Lucille	03/03/20	M. Sampson

Title: Determination of Wind Exposure Category and Basic Wind Speed for Facilities Located within Superblock

Obstructions in NW Wind Sector Fetch

Item No.	Sub-sector	Description	Qty of Similar Objects	Frontal Height [H_o] (ft)	Frontal Width [W_o] (ft)	Frontal Surface Area [1][3] [S] (sf)	Effective Area Factor[2]	Effective Frontal Surface Area[3] [S_o] (sf)
1	**98**	Tree - Deciduous	2	**20**	15	158	0.15	**24**
2	**98**	Tree - Deciduous	6	**12**	8	36	0.15	**5**
3	**98**	Tree - Deciduous	1	**15**	10	68	0.15	**10**
4	**98**	Tree - Deciduous	1	**25**	12	171	0.15	**26**
5	**99**	Tree - Deciduous	2	**20**	15	158	0.15	**24**
6	**99**	Tree - Deciduous	1	**15**	10	68	0.15	**10**
7	**99**	Tree - Evergreen	1	**12**	10	45	0.50	**23**
8	**99**	Tree - Deciduous	1	**40**	25	638	0.15	**96**
9	**104**	Tree - Evergreen	5	**45**	20	585	0.50	**293**
10	**104**	Tree - Evergreen	2	**35**	20	435	0.50	**218**
11	**104**	Tree - Evergreen	1	**45**	25	731	0.50	**366**
12	**104**	Tree - Evergreen	1	**25**	20	285	0.50	**143**
13	**104**	Tree - Evergreen	10	**25**	15	214	0.50	**107**
14	**104**	Tree - Evergreen	4	**20**	10	105	0.50	**53**
15	**104**	Tree - Deciduous	4	**30**	15	270	0.15	**41**
16	**104**	Tree - Evergreen	3	**35**	20	435	0.50	**218**
17	**101**	Tree - Deciduous	2	**40**	20	510	0.15	**77**
18	**101**	Tree - Deciduous	1	**30**	15	270	0.15	**41**
19	**101**	Tree - Deciduous	1	**25**	10	143	0.15	**21**
20	**102**	Tree - Evergreen	12	**60**	12	486	0.50	**243**
21	**103**	Tree - Evergreen	1	**60**	15	608	0.50	**304**
22	**103**	Tree - Deciduous	1	**20**	15	158	0.15	**24**
23	**103**	Tree - Evergreen	2	**40**	15	383	0.50	**191**
24	**103**	Tree - Evergreen	2	**45**	25	731	0.50	**366**
25	**116**	Tree - Evergreen	3	**55**	25	919	0.50	**459**
26	**115**	Tree - Deciduous	2	**35**	20	435	0.15	**65**
27	**115**	Tree - Deciduous	1	**20**	20	210	0.15	**32**
28	**115**	Tree - Deciduous	1	**20**	15	158	0.15	**24**
29	**113**	Tree - Evergreen	1	**35**	45	979	0.50	**489**
30	**113**	Tree - Evergreen	1	**35**	20	435	0.50	**218**
31	**113**	Tree - Evergreen	1	**30**	10	180	0.50	**90**
32	**113**	Tree - Evergreen	3	**30**	30	540	0.50	**270**
33	**113**	Tree - Evergreen	4	**30**	20	360	0.50	**180**
34	**113**	Tree - Deciduous	2	**25**	15	214	0.15	**32**
35	**113**	Tree - Deciduous	3	**20**	10	105	0.15	**16**
36	**119**	Tree - Deciduous	3	**20**	15	158	0.15	**24**
37	**108**	Communication Tower	1	**65**	1.5	98	1.00	**98**
38	**106**	Tree - Evergreen	3	**15**	10	68	0.50	**34**
39	**106**	Tree - Deciduous	1	**8**	10	15	0.15	**2**
40	**107**	Tree - Deciduous	2	**15**	10	68	0.15	**10**
41	**107**	Tree - Evergreen	4	**30**	15	270	0.50	**135**
42	**107**	Tree - Deciduous	6	**20**	10	105	0.15	**16**
43	**107**	Tree - Evergreen	4	**30**	20	360	0.50	**180**
44	**107**	Tree - Evergreen	2	**20**	15	158	0.50	**79**
45	**107**	Tree - Deciduous	4	**25**	15	214	0.15	**32**
46	**107**	Tree - Deciduous	3	**20**	5	53	0.15	**8**
47	**111**	Tree - Evergreen	1	**45**	25	731	0.50	**366**
48	**111**	Tree - Evergreen	1	**40**	25	638	0.50	**319**
49	**111**	Tree - Deciduous	3	**30**	20	360	0.15	**54**
50	**93**	Security Fence	2	**11**	248	2,728	0.17	**464**

51	**92**	Perimeter Security Poles	7	**50**	2	100	1.00	**100**
52	**94**	Nitrogen Tank	1	**12**	15	180	1.00	**180**
53	**95**	B343	1	**15**	183	2,745	1.00	**2,745**
54	**97**	Vehicle Barrier	1	**3.8**	441	1,676	1.00	**1,676**
55	**96**	B242	1	**27**	116	3,132	1.00	**3,132**
56	**100**	B256	1	**15**	95	1,425	1.00	**1,425**
57	**105**	B255	1	**15**	250	3,750	1.00	**3,750**
58	**109**	B254	1	**17**	73	1,241	1.00	**1,241**
59	**110**	B2580	1	**25**	102	2,550	1.00	**2,550**
60	**132**	B251	1	**22**	102	2,244	1.00	**2,244**
61	**117**	B253	1	**15**	414	6,210	1.00	**6,210**
62	**114**	B264	1	**30**	126	3,780	1.00	**3,780**
63	**84**	B361	1	**15**	57	855	1.00	**855**
64	**112**	B362	1	**15**	72	1,080	1.00	**1,080**
65	**118**	B363	1	**20**	55	1,100	1.00	**1,100**
66						0		**0**
67						0		**0**
68						0		**0**
69						0		**0**
70						0		**0**
71						0		**0**
72						0		**0**
73						0		**0**
74						0		**0**
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86						0		**0**
87						0		**0**
88						0		**0**
89						0		**0**
90						0		**0**
91						0		**0**
92						0		**0**
93						0		**0**
95						0		**0**
96						0		**0**
			n =	150	**4,541 ft**	4,577 ft	77,208 ft		**49,761 sf**

$z_H = H_{avg}$ = 16.87 ft = $\Sigma S / \Sigma W_{ob}$ = Width Weighted Average Height

H_{ob} = 30.27 ft = $\Sigma H_0 / n$ = Average Obstruction Height

S_{ob} = 332 sf = $\Sigma S_0 / n$ = Average Obstruction Surface Area

A_{ob} = 5,890 sf = A_{uc} / n = Average Site Fetch Area per Obstruction (A_{uc} from pg B2)

Terrain Roughness Length

z_0 = 0.852 ft = $0.5H_{ob}(S_{ob}/A_{ob})$ [ASCE 7-16, Eqn C26.7, Lettau 1969]

Notes: 1) Single Tree So = 0.75·(Ho - 6 ft)·Wo, where tree foliage is assumed to start at 6 ft. above the ground and the 0.75 factor adjusts for the rectangular dimensions assumed for irregular tree shapes.

2) Eff. Area Factor adjusts for reduced wind resistance of non-solid objects likes trees, see Appendix A.

3) Surface areas shown are for a single object, Item No's with multiple objects are summed at the bottom.

Appendix C

Determination of Basic Wind Speed for B332

C-1.0 Summary of Atmospheric Boundary Layer Winds

The wind hazard for LLNL and B332 is dominated by straight-line winds generated by normal atmospheric conditions arising from thunderstorms and large barometric pressure differentials. Located within the western region on the continental US, the hazards from high winds originating from hurricanes and tornadoes are extremely low; therefore, the *Basic Wind Speed* used for the design of structures and categorizing wind-missile hazards are dominated by normal straight-line geostrophic-induced winds.

Geostrophic winds arise from atmospheric air flow caused by the Coriolis force from the earth's rotation and atmospheric pressure gradients. This type of wind generally occurs at heights of a few hundred to a few thousand feet above the ground surface. The region between the ground and geostrophic wind zone is referred to as the *atmospheric boundary layer*. Winds in this layer of the atmosphere are affected by the interaction of the frictional drag forces of the ground surface on the moving air above. The wind velocity at the top of this boundary layer is referred to as the *gradient wind speed*. ASCE 7 [Ref. 2] defines the velocity of the gradient wind V_g as 168 mph (75 m/s) for all locations at a height signified as z_g. A velocity gradient (reduced wind speed) occurs below this level.

The atmospheric boundary layer, defined by z_g, varies in height depending on the surface conditions of the terrain over which it flows. Obstructions along the ground cause turbulence and eddy currents causing resistance that slows the wind as it nears the surface, see Figure C1. The resistance is defined as the *surface shear stress* τ_0 and the *surface drag coefficient* κ.

The mathematical expression that defines the varying wind profile is known as the *Logarithmic Law* and is written as follows:

$$\overline{U}_{(z)} = \frac{u_*}{k} ln\left(\frac{z}{z_0}\right) \text{ [Ref. 7 \& 8]}$$

where,

$\overline{U}_{(z)}$ = Wind velocity at height z = V_z

k ≃ 0.4 (known as *von Karman's constant*)

$u_* = \sqrt{\frac{\tau_0}{\rho_a}}$ (called the *friction velocity*)
where, ρ_a is the air density

z_0 is a measure of surface roughness known as the *roughness length*, see Appendix A for further discussion.

z_d is the theoretical bottom of the wind profile required to account for stagnate air along the ground of rough terrain.

then, the logarithmic law may be rewritten as:

$$V_z = 2.5u_* ln\left(\frac{z-z_d}{z_0}\right) \text{ [Ref. 8]}$$

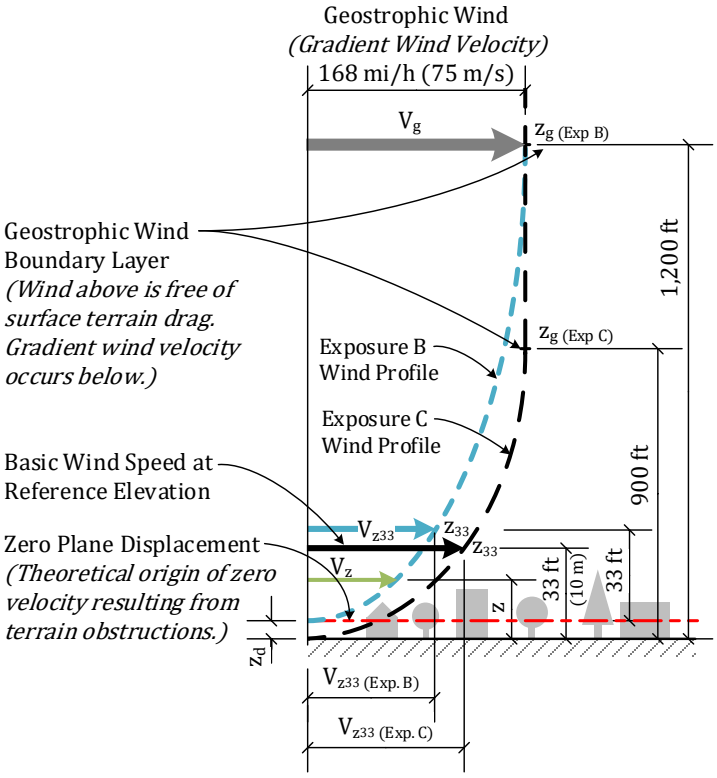

Figure C1: Typical Wind Velocity Profile
(Adapted from Simiu (1996) [Ref. 7])

Whereas the logarithmic law is considered an accurate representation of the wind profile, it has some inherent problems and can be difficult to calculate without knowledge of appropriate coefficients, such as u_*. Therefore, a common simplification that closely matches the shape of the wind profile curve is used by ASCE 7 [Ref. 2] and takes the form of the *Power Law*, which in its simplest form is expressed as:

$$\frac{V_z}{V_g} = \left(\frac{z}{z_g}\right)^n \qquad \text{[Irwin 2006, Ref.6]}$$

Footnote #1 to ASCE 7 [Ref. 2] Table 26.10-1 and Commentary Section C26.10 utilize the power law to define the *Velocity Pressure Coefficient* K_z, used to calculate design wind pressures at various heights and for different Exposures Categories, as follows:

$$K_z = 2.01\left(\frac{z}{z_g}\right)^{2/\alpha} \qquad \text{[ASCE 7, Ref.2]}$$

Where K_z is set to 1.0 for the basic 3-second gust wind speed for Exposure C at a height of 33 ft. Incorporating this relationship into the power law results in the following expression that can be used to calculate the wind speed for various combinations of height (above 15 ft) and Exposure Category.

$$\frac{V_{gust\,(z)}}{V_{gust,basic}} = \sqrt{2.01}\left(\frac{z}{z_g}\right)^{1/\alpha} \qquad \text{[Irwin 2006, Ref.6]}$$

or

$$V_{gust\,(z)} = V_{gust,basic}\sqrt{2.01}\left(\frac{z}{z_g}\right)^{1/\alpha}$$

where,

$\alpha = c_1 z_0{}^{-0.133}$, and c_1= 6.62 ft [ASCE 7, eq C26.10-3, Ref. 2]

$z_g = c_2 z_0{}^{0.125}$, and c_2= 1,273 ft [ASCE 7, eq C26.10-4, Ref. 2]

The factor $\sqrt{2.01}$ is used to adjust fastest-mile wind speeds to 3-second gust wind speeds because the value of α was developed assuming fastest-mile basic wind speeds.

ASCE 7 [Ref. 2] provides the typical values of α and z_g in table form for different Exposure Categories and is reproduced in Table C1 below.

Customary Units										
Exposure	α	z_g (ft)	$\hat{\alpha}$	$\hat{b}$	$\bar{\alpha}$	$\bar{b}$	c	ℓ' (ft)	$\bar{\varepsilon}$	z_{min} (ft)[a]
B	7.0	1,200	1/70	0.84	1/4.0	0.45	0.30	320	1/3.0	30
C	9.5	900	1/9.5	1.00	1/6.5	0.65	0.20	500	1/5.0	15
D	11.5	700	1/11.5	1.07	1/9.0	0.80	0.15	650	1/8.0	7

Table C1: Terrain Exposure Constants

Reproduced from Table 26.11-1 of ASCE 7-16 [Ref. 2]

C-2.0 Calculation of WDC-3 Basic Wind Speed for LLNL Site-Specific Value of z_0

ASCE 7 [Ref. 2] defines *Basic Wind Speed* as the three-second gust speed at 33 ft (10 m) above the ground in Exposure C. The basic wind speed is used as the basis for determining and calculating wind hazards and wind-induced forces on structures for a given location. The Wind Design Category 3 (WDC-3) basic wind speed for LLNL Site 200 nuclear facilities is specified in ANS 2.3 [Ref. 3], which divides the country into three regions based on their common wind characteristics. The three regions are shown in Figure 1 of ANS 2.3 [Ref. 3] and can be generally characterized as follows: *Region I* (US central plain) – high tornado risk, no hurricane risk; *Region II* (Atlantic and Gulf coasts, and eastern Rockies) – high hurricane risk and moderate tornado risk; *Region III* (western US) – low tornado risk, no hurricane risk, and dominated by straight-line storm-type winds. LLNL, being located on the US west coast, is located in Region III.

Wind speeds in Region III are characterized and documented in Table 3 of ANS 2.3 [Ref. 3] and are graphically presented in ANS 2.3 Figure 4, which has been reproduced (with additional annotation) in Figure C2 below. As shown in Figure C2, the wind hazard at LLNL is dominated by extreme straight-line winds, with a maximum WDC-3 basic wind speed of 118 mph.

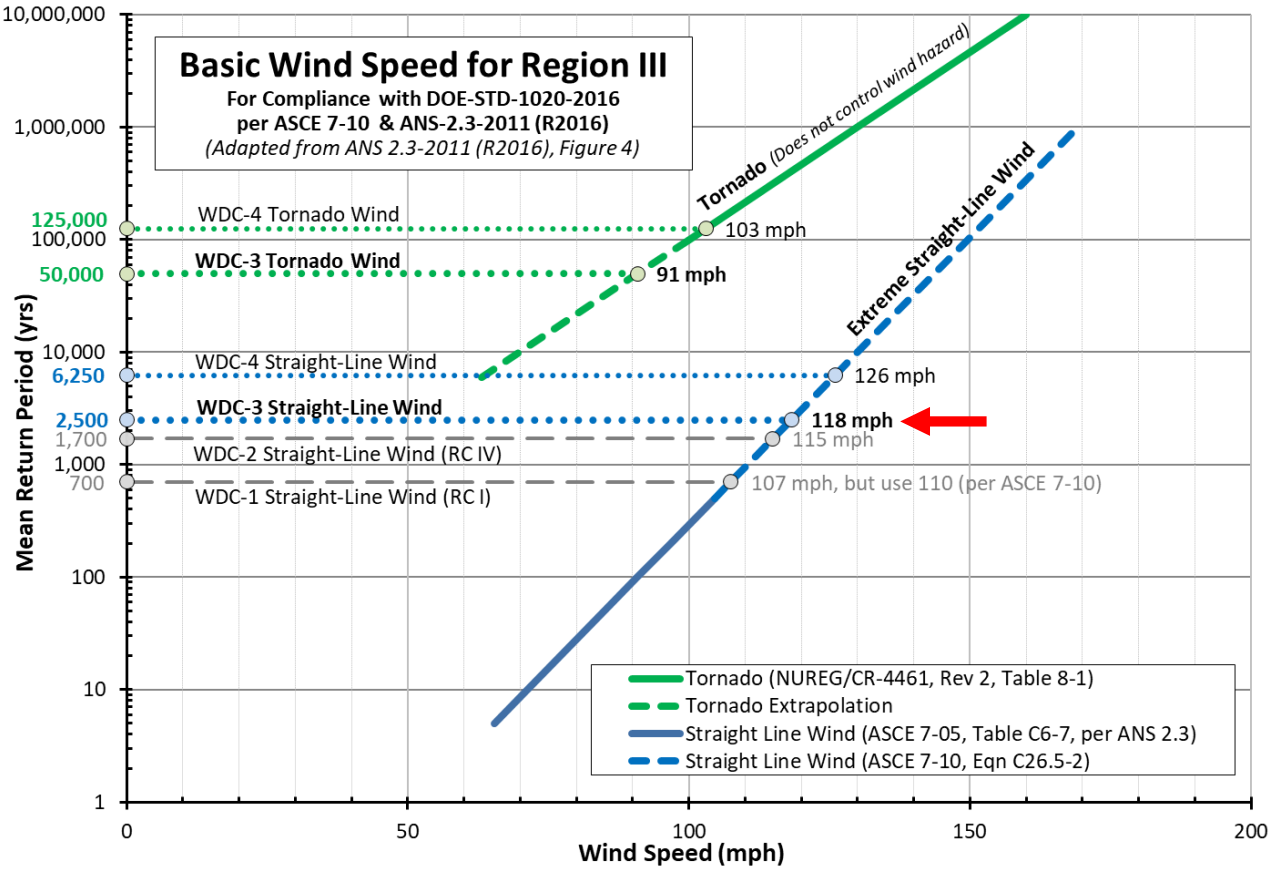

Figure C2: Basic Wind Speed Plot for LLNL Site 200

Adapted from ANS 2.3 Figure 4 [Ref. 3] and ASCE 7-10 [Ref. 10]

ANS 2.3 [Ref. 3], Section 3.4.3 states, "*These wind speeds apply at an elevation of 33 ft (10 m) above ground level for Exposure Category C from ASCE/SEI 7-05*…" which confirms that the wind speeds specified in ANS 2.3 [Ref. 3] conform to the same basis as ASCE 7 [Ref. 2] and therefore are subject to the same adjustments.

Appendix A of this report demonstrates that the minimum surface terrain surrounding Superblock and B332 conforms to the characteristics of Exposure Category B with a *roughness length* z_0 determined to be 0.75 ft. The derived power law equation documented in Section C-1.0 is used to calculate the adjusted WDC-3 basic wind speed for the site-specific terrain having the Exposure Category B roughness length previously determined, as follows where:

$$V_{gust\,(z)} = V_{gust,basic}\sqrt{2.01}\left(\frac{z}{z_g}\right)^{1/\alpha}$$

z_0 = 0.75 ft (Exposure Category B)
$V_{gust,basic}$ = 118 mph [from ANS 2.3 [Ref. 3] for Exposure Category C]
$\alpha = c_1 z_0^{-0.133}$ = (6.62 ft)(0.75 ft)$^{(-0.133)}$ = 6.88
$z_g = c_2 z_0^{0.125}$ = (1,273 ft)(0.75 ft)$^{(0.125)}$ = 1,228 ft

To be conservative, the *zero plane displacement* z_d will be added to the 33 ft reference height. Most references provide rule-of-thumb values for z_d of approximately ⅔ to ¾ the general height of building rooftops in the surrounding area [Ref. 8]. However, the Commentary to ASCE 7 [Ref. 2] includes Table C26.7-2 for reference which summarizes the *Davenport Classification of Effective Terrain Roughness*. The table provides varying values of z_d based on the roughness of the terrain (the higher the obstructions, the larger the value). For terrain with a z_o value of approx. 0.75 ft, the recommended value of z is $0.2z_H$, where z_H is the typical height of obstructions.

for z_H = 17 ft
z_d= (0.2)(17 ft) = 3.4 ft
$\therefore\ z_{eff} = z + z_d$ = 33 ft + 3.4 ft = 36.4 ft

Therefore, the site-specific ANS 2.3 [Ref. 3] WDC-3 basic wind speed for Exposure Category B is calculated as:

$$V_{gust\,(z)-B} = (118\ mph)\sqrt{2.01}\left(\frac{36.4\ ft}{1{,}228\ ft}\right)^{1/6.88} = 100\ mph$$

For reference, the following calculates the non-site-specific ANS-2.3 [Ref. 3] WDC-3 basic wind speed in accordance with the ASCE 7-16 [Ref. 2] definition of Exposure B, where z_0 = 0.66 ft and the values of α and z_g are defined as 7.0 and 1,200 ft, respectively, per ASCE 7 Table 26.11-1 (see Table C1 above):

$$V_{gust\,(z)-B} = (118\ mph)\sqrt{2.01}\left(\frac{33\ ft}{1{,}200\ ft}\right)^{1/7} = 100\ mph$$

Similarly, the corresponding ANS-2.3 [Ref. 3] WDC-2 basic wind speed is calculated as:

$$V_{gust\,(z)-B} = (115\ mph)\sqrt{2.01}\left(\frac{33\ ft}{1{,}200\ ft}\right)^{1/7} = 98\ mph$$

C-3.0 Results

When compensating for the site-specific surface terrain surrounding B332 and Superblock for characteristics conforming to Exposure Category B, the ANS 2.3 [Ref. 3] WDC-3 *Basic Wind Speed* for B332 is adjusted from 118 mph to 100 mph and the WDC-2 *Basic Wind Speed* is adjusted from 115 mph to 98 mph.