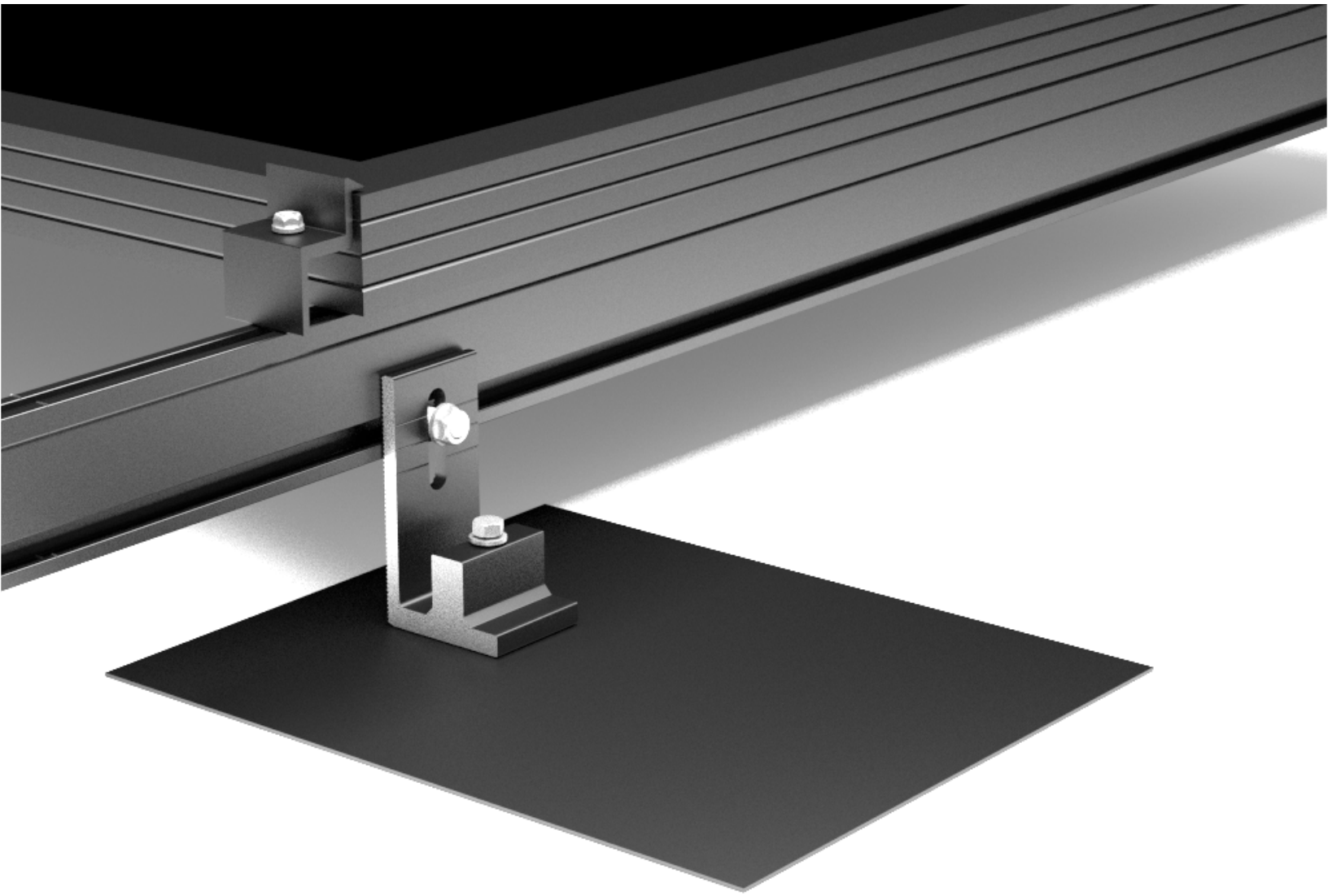
SOLAR WAREHOUSE

SWH Solar Racking
Design & Engineering Guide

Version 16.08.v1



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i. Installer's Responsibilities

Please review this manual thoroughly before installing your SWH solar racking system. This manual provides (1) supporting documentation for building permit applications relating to SWH solar racking system, and (2) planning and assembly instructions for SWH products. When installed in accordance with this manual, SWH PV Mounting system will be structurally adequate and will meet the structural requirements of the IBC 2012, ASCE 7-10 and California Building Code 2013 (collectively refered to as "the Code"). Solar Warehouse also provides a limited warranty on SWH products as attached to the end of this manual.



The installer is solely responsible for:

- Complying with all applicable local or national building codes, including any that may supersede this manual;
- Ensuring that SWH and other products are appropriate for the particular installation and the installation environment;
- Ensuring that the roof, its rafters, connections, and other structural support members can support the array under all code level loading conditions (this total building assembly is referred to as the building structure);
- Using only SWH parts and installer-supplied parts as specified by SWH (substitution of parts may void the warranty and invalidate the letters of certification in all SWH publications);
- Ensuring that lag screws have adequate pullout strength and shear capacities as installed;
- Verifying the strength of any alternate mounting used in lieu of the lag screws;
- Maintaining the waterproof integrity of the roof, including selection of appropriate flashing;
- Ensuring safe installation of all electrical aspects of the PV array;
- Ensuring correct and appropriate design parameters are used in determining the design loading used for design of the specific installation. Parameters, such as snow loading, wind speed, exposure and topographic factor should be confirmed with the local building official or a licensed professional engineer.
- Ensuring all warning labels requirements are met per latest National Electrical code (NEC), International Fire Code (IFC), and/or Cal Fire Code.
- PV system should be inspected periodically. Any loose components or fasteners found shall be tightened immediately. If corrosion is found replace affected components immediately.
- Provide an appropriate method of direct-to-earth grounding according to the latest edition of the National Electrical code including NEC 250: Grounding and Bonding, and NEC 690: Solar Photovoltaic Systems.
- This racking system may be used to ground and/or mount a PV module complying with UL 1703 only when the specific module has been evaluated for grounding and/or mounting in compliance with the included instructions.

TABLE OF CONTENTS

i. Installer's Responsibilities .....

Part I. Procedure to Determine the Design Wind Load.....

[1.1] Using the Low Rise Buildings (Simplified) Method - ASCE 7-10.....1

[1.2] Procedure to Calculate Total Design Wind Load per ASCE 7-10..... 2

Part II. Procedure to Select Rail Span and Foot Spacing .....

[2.1] Using Standard Beam Calculations, Structural Engineering Methodology 17

Part 1: Procedure to Calculate Total Design Wind Load

[1.1.] Using the Low Rise Buildings (Simplified) Method - ASCE 7-10

The procedure to determine Design Wind Load is specified by the American Society of Civil Engineers and referenced in the International Building Code 2012 and California Building Code 2013. For purposes of this document, the values, equations and procedures used in this document reference ASCE 7-10, Minimum Design Loads for Buildings and Other Structures. Please refer to ASCE 7-10 if you have any questions about the definitions or procedures presented in this manual. SWH solar racking system uses Part 2, The Simplified Method, for low rise buildings to calculate the Design Wind Load for pressures on components and cladding in this document. The method described in this document is valid for flush, no tilt, SWH applications on either roofs or walls. Flush is defined as panels parallel to the surface (or with no more than 3" difference between ends of assembly) with no more than 10" space between the roof surface, and the bottom of the PV panels.

This method is not approved for open structure calculations. Applications of these procedures is subject to the following ASCE 7-10 limitations:

1. The building height must be less than 60 feet, h < 60. See note for determining h in the next section. For installations on structures greater than 60 feet, contact your local design professional.

2. The building must be enclosed, not an open or partially enclosed structure, for example a carport.

3. The building is regular shaped with no unusual geometrical irregularity in spatial form, for example a geodesic dome.

4. The building is not in an extreme geographic location such as a narrow canyon or steep cliff.

5. The building has a flat or gable roof with a pitch less than 45 degrees or a hip roof with a pitch less than 27 degrees.

6. If your installation does not conform to these requirements please contact your local professional engineer.

If your installation is outside the United States or does not meet all of these limitations, consult a local professional engineer or your local building authority. Consult ASCE 7-10 for more clarification on the use of Part 2.

The equation for determining the Design Wind Load for components and cladding is:

$$p_{net}\,(psf) = \lambda K_{zt}\, p_{net30}$$

p_{net} (psf) = Design Wind Load

λ = adjustment factor for building height and exposure category

K_{zt} = Topographic Factor = 1

p_{net30} (psf) = net design wind pressure for Exposure B, at height = 30 feet

You will also need to know the following information:

Basic Wind Speed = V (mph), the largest 3 second gust of wind in the last 50 years.

h (ft) = total roof height for flat roof buildings or mean roof height for pitched roof buildings

Roof Pitch (degrees)

This manual will help you determine:

Effective Wind Area (sf) = minimum total continuous area of modules being installed (Step 4)

Roof Zone = the area of the roof you are installing the pv system according to Step 5.

Roof Zone Dimension = a (ft) (Step 5)

Exposure Category (Step 3)

1.2 Procedure to Calculate Total Design Wind Load per ASCE 7-10

Step 1. Determine risk category

Buildings and other structures shall be classified, based on the risk to human life, health and welfare associated with their damage or failure by nature of their occupancy or use. For the purpose of applying flood, wind, snow, ice, and earthquake provisions. See Table 1 below.

TABLE 1: Risk Category of Buildings and Other Structrues for Flood, Wind, Snow, Earthquake, and Ice Loads

Use or Occupancy of Buldings and Structures	Risk Category
Buildings and other structures that represent a low risk to human life in the event of failure.	I
All buildings and other structures except those listed in Risk Categories I,III, and IV	II
• Buildings and other structures, the failure of which could pose a substantial risk to human life. • Buildings and other structures, not included in Risk Category IV, with potential to cause a substantial economic impact and/or mass disruption of day-to-day civilian life in the event of failure. • Buildings and other structures, not included in Risk Category IV (including, but not limited to, facilities that manufacture, process, handle, store, use, or dispose of such substances as hazardous fuels, hazardous chemicals, hazardous waste, or explosives) containing toxic or explosive substances where their quantity exceeds a threshold quantity established by authority having jurisdiction and is sufficient to pose a threat ot the public if released.	III
• Buildings and other structures designated as essential facilities. • Buildings and other structures, the failure of which could pose a substantial hazard to the community. • Buildings and other structures (including, but not limited to, facilities that manufacture, process, handle, store, use, or dispose of such substances as hazardous fuels, or hazardous chemicals, or hazardous waste) containing sufficient quantities of highly toxic substances where the quantity exceeds a threshod quantity established by the authority having jurisdiction to be dangerous to the public if released and is sufficient to the pose a threat to the public if released. • Builings andother structures requried to maintain the functtionality of other Risk Category IV structures.	IV

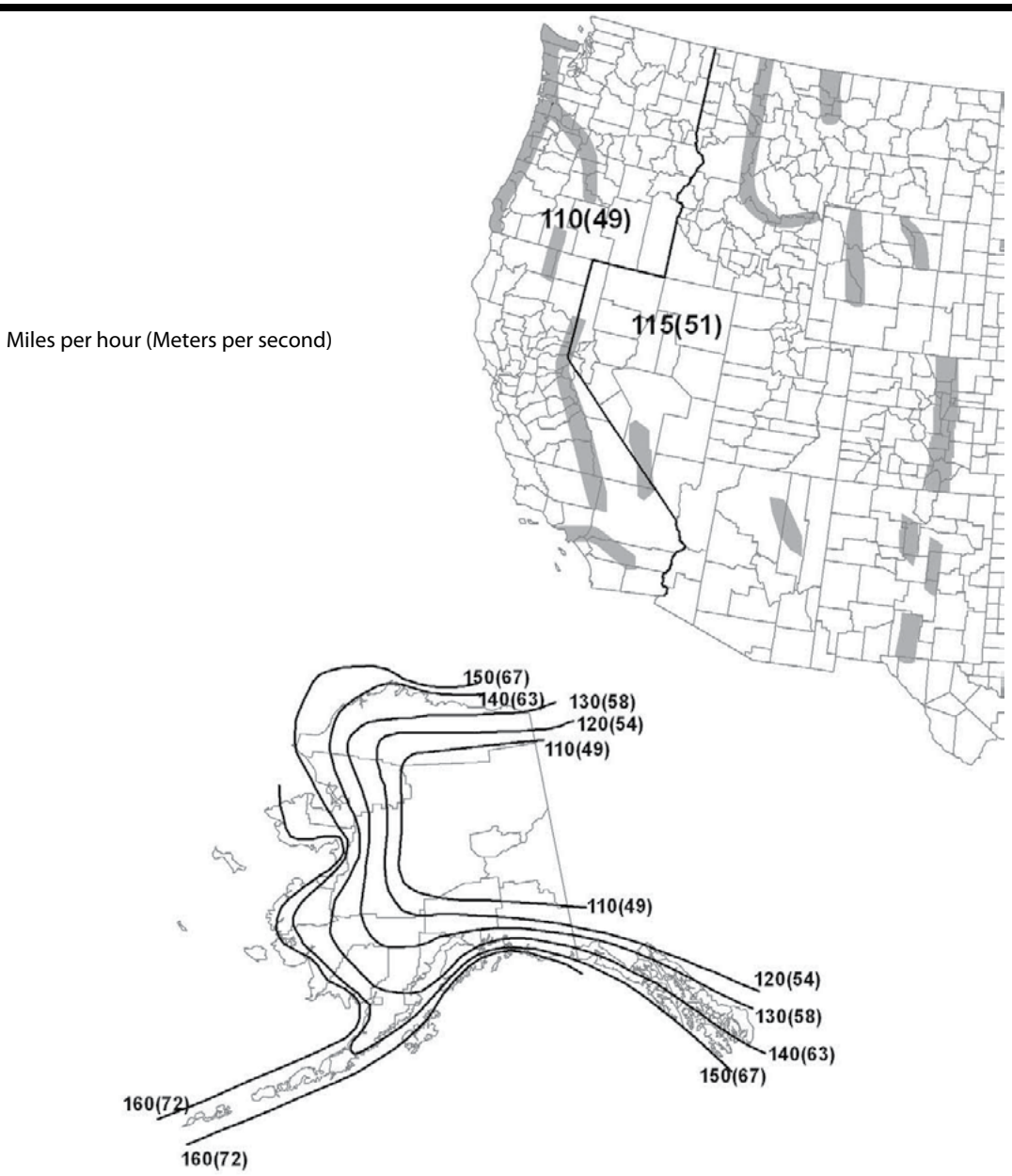
[a]Buildings and other structures containing toxic, highly toxic, or explosive substances shall be eligible for classification to a lower Risk Category if it can be demonstrated to the satisfaction of the authority having jurisdiction by a hazard assessment as described in Section 1.5.2 of ASCE 7-10 that a release of the substances is commensurate with the risk associated with that Risk Category.

Step 2. Determine the Basic Wind Speed, V (mph)

Determine the basic wind speed, V (mph) by consulting your local department or by locating your installation on the maps in Figures 26.5-1A through 1C, pages 6 -11. Please note that the wind speeds are dependent on the Risk (Occupancy) category determined in Step 1.

1.2 Procedure to Calculate Total Design Wind Load per ASCE 7-10

FIGURE 26.5-1A Basic Wind Speeds for Risk Category II Buildings and Other Structures

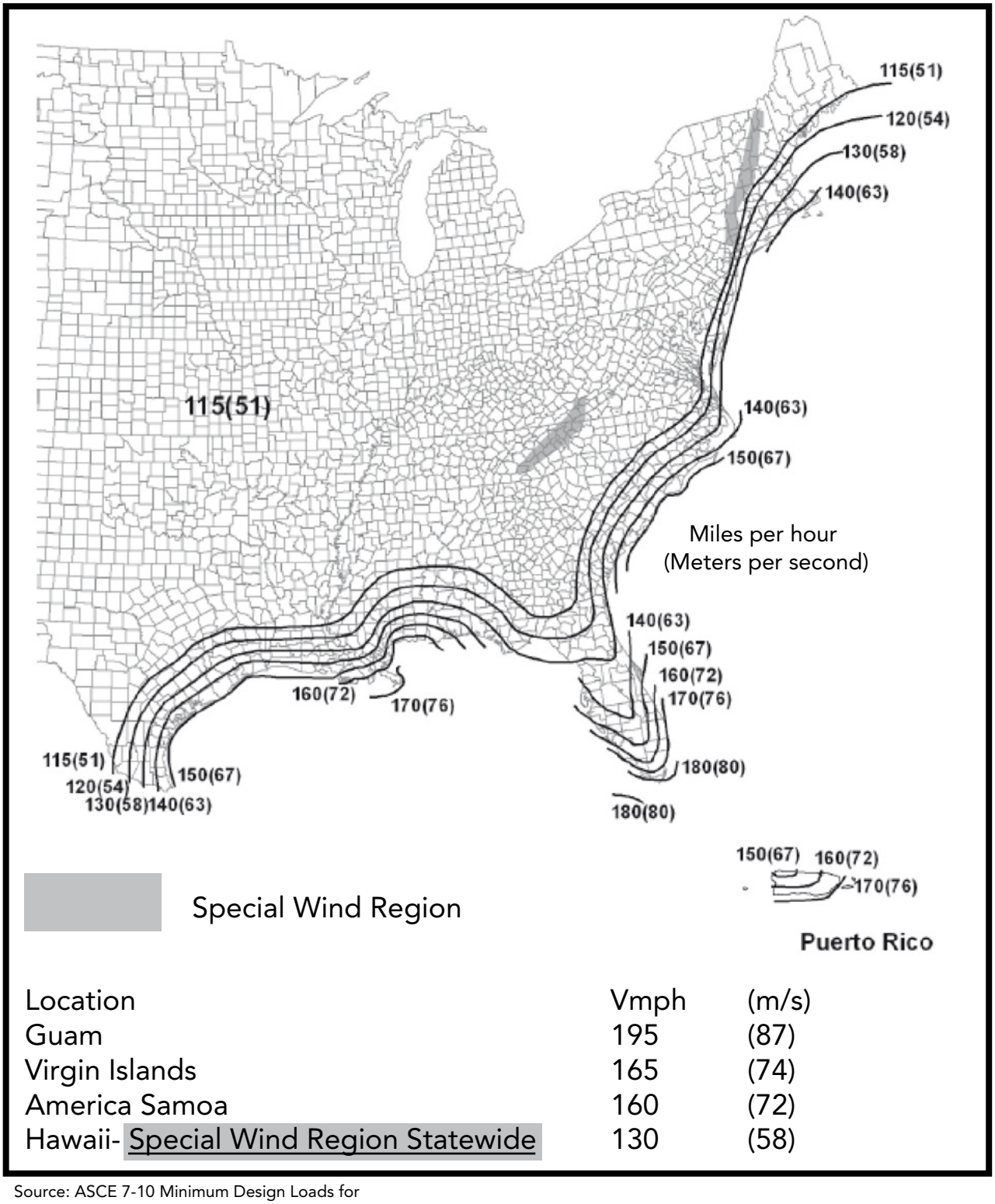


Notes:
1. Values are design 3-second gust wind speeds in miles per hour (m/s) at 33 ft (10m) above ground for Exposure C category.
2. Linear interpolation between contours is permitted.
3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.
4. Mountainous terrain, gorges, ocean promontories, and special wind regions shall be examined for unusual wind conditions.
5. Wind speeds correspond to approximately a 7% probability of exceedance in 50 years (annual exceedance probability = 0.00143, MRI = 700 years).

Source: ASCE 7-10 Minimum Design Loads for Buildings and Other Structures, Chapter 26

1.2 Procedure to Calculate Total Design Wind Load per ASCE 7-10

FIGURE 26.5-1A (Continued) Basic Wind Speeds for Risk Category II Buildings and Other Structures

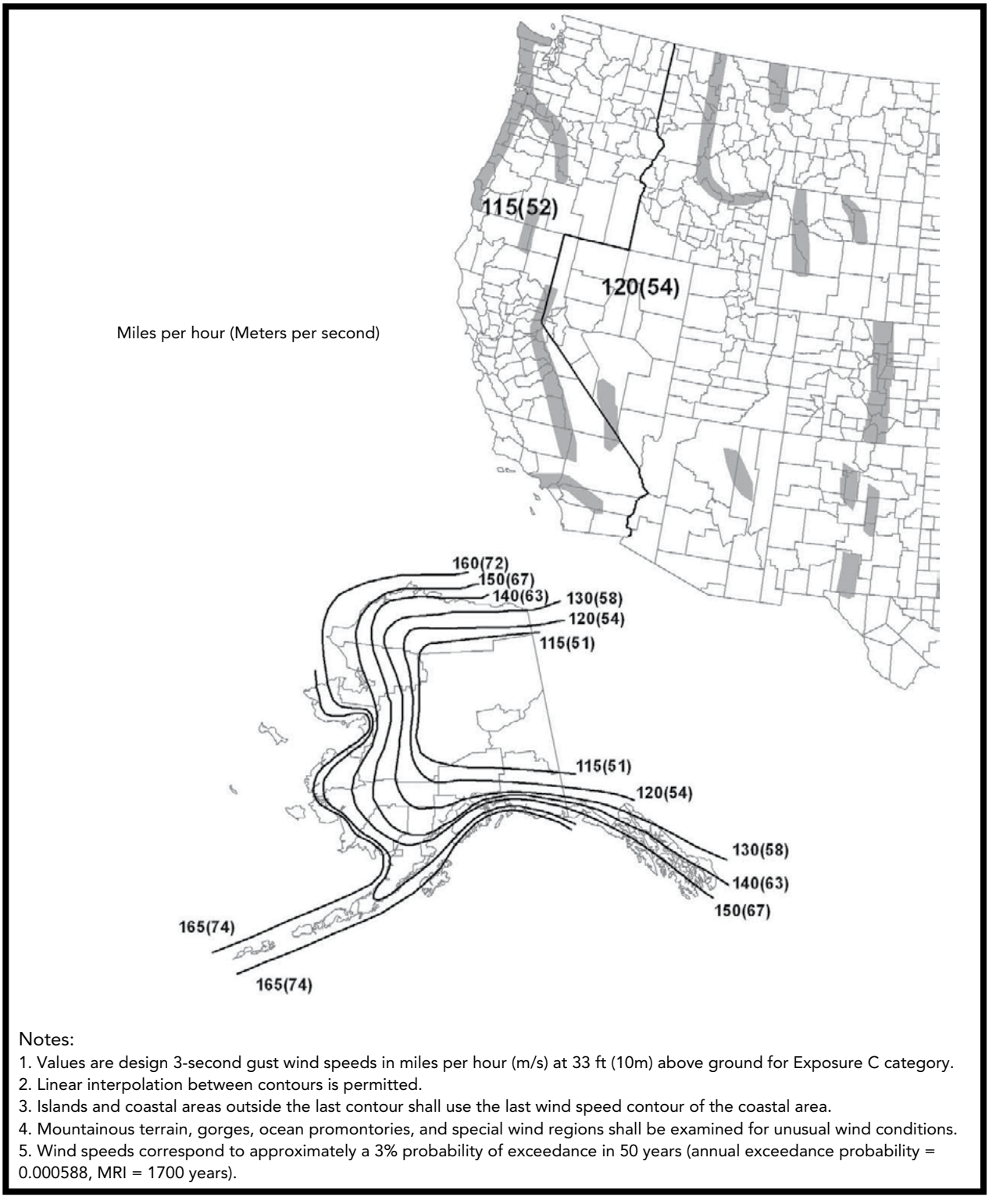


Location	Vmph	(m/s)
Guam	195	(87)
Virgin Islands	165	(74)
America Samoa	160	(72)
Hawaii- Special Wind Region Statewide	130	(58)

Source: ASCE 7-10 Minimum Design Loads for Buildings and Other Structures, Chapter 26

1.2 Procedure to Calculate Total Design Wind Load per ASCE 7-10

FIGURE 26.5-1B Basic Wind Speeds for Risk Category III and IV Buildings and Other Structures

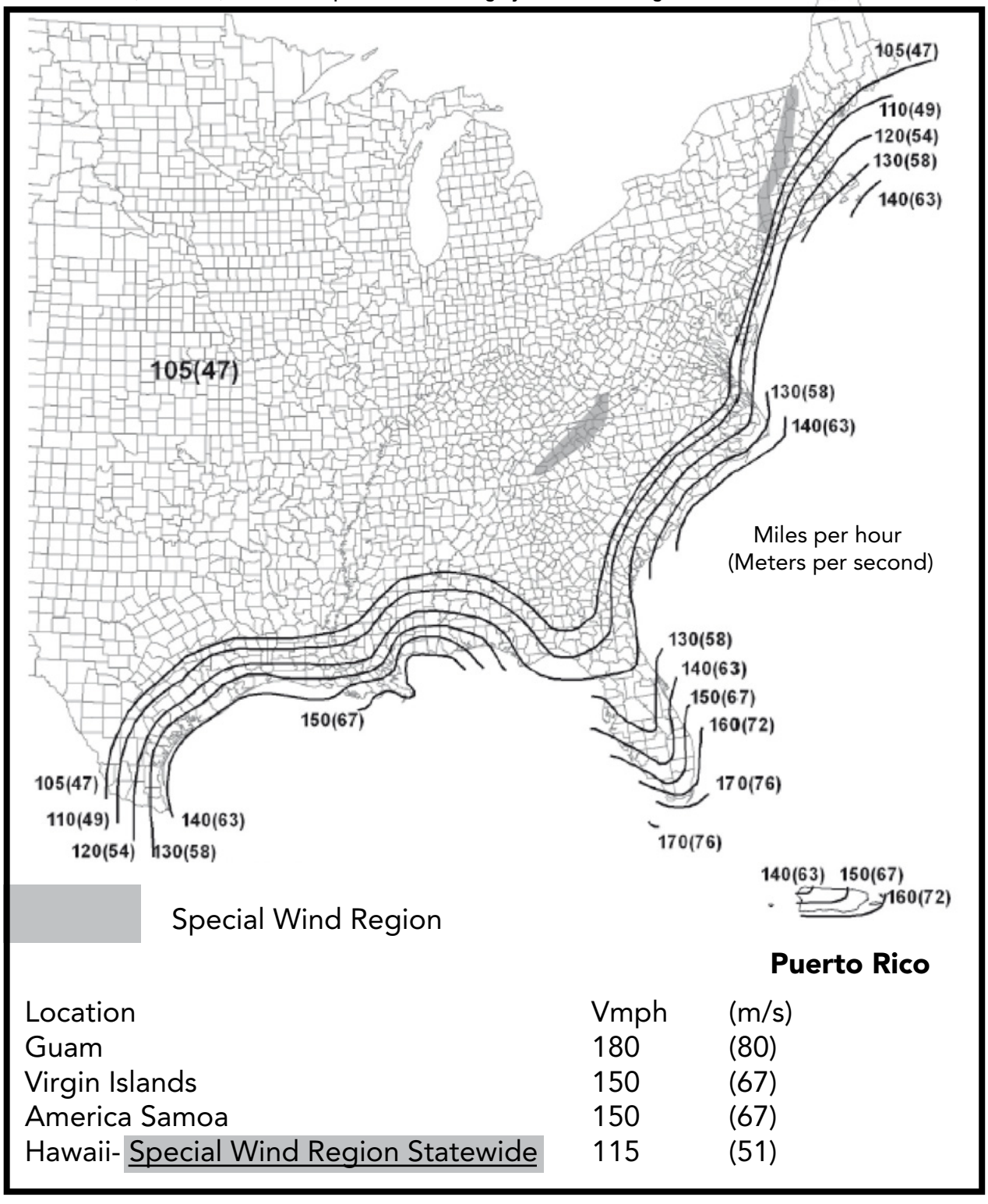


Notes:
1. Values are design 3-second gust wind speeds in miles per hour (m/s) at 33 ft (10m) above ground for Exposure C category.
2. Linear interpolation between contours is permitted.
3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.
4. Mountainous terrain, gorges, ocean promontories, and special wind regions shall be examined for unusual wind conditions.
5. Wind speeds correspond to approximately a 3% probability of exceedance in 50 years (annual exceedance probability = 0.000588, MRI = 1700 years).

Source: ASCE 7-10 Minimum Design Loads for Buildings and Other Structures, Chapter 26

1.2 Procedure to Calculate Total Design Wind Load per ASCE 7-10

FIGURE 26.5-1B (Continued) Basic Wind Speeds for Risk Category III and IV Buildings and Other Structures

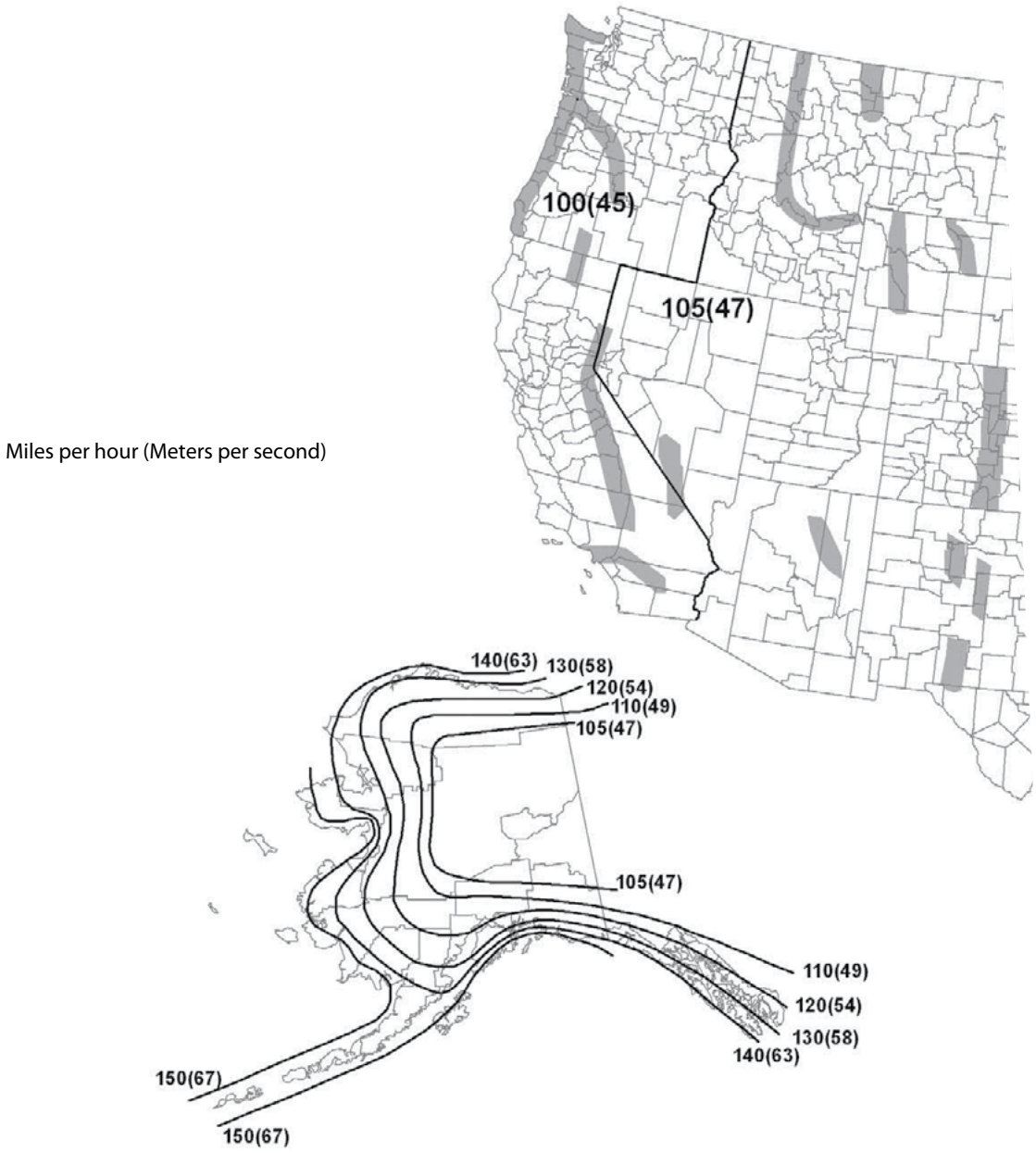


Location	Vmph	(m/s)
Guam	180	(80)
Virgin Islands	150	(67)
America Samoa	150	(67)
Hawaii- Special Wind Region Statewide	115	(51)

Source: ASCE 7-10 Minimum Design Loads for Buildings and Other Structures, Chapter 26

1.2 Procedure to Calculate Total Design Wind Load per ASCE 7-10

FIGURE 26.5-1C Basic Wind Speeds for Risk Category I Buildings and Other Structures

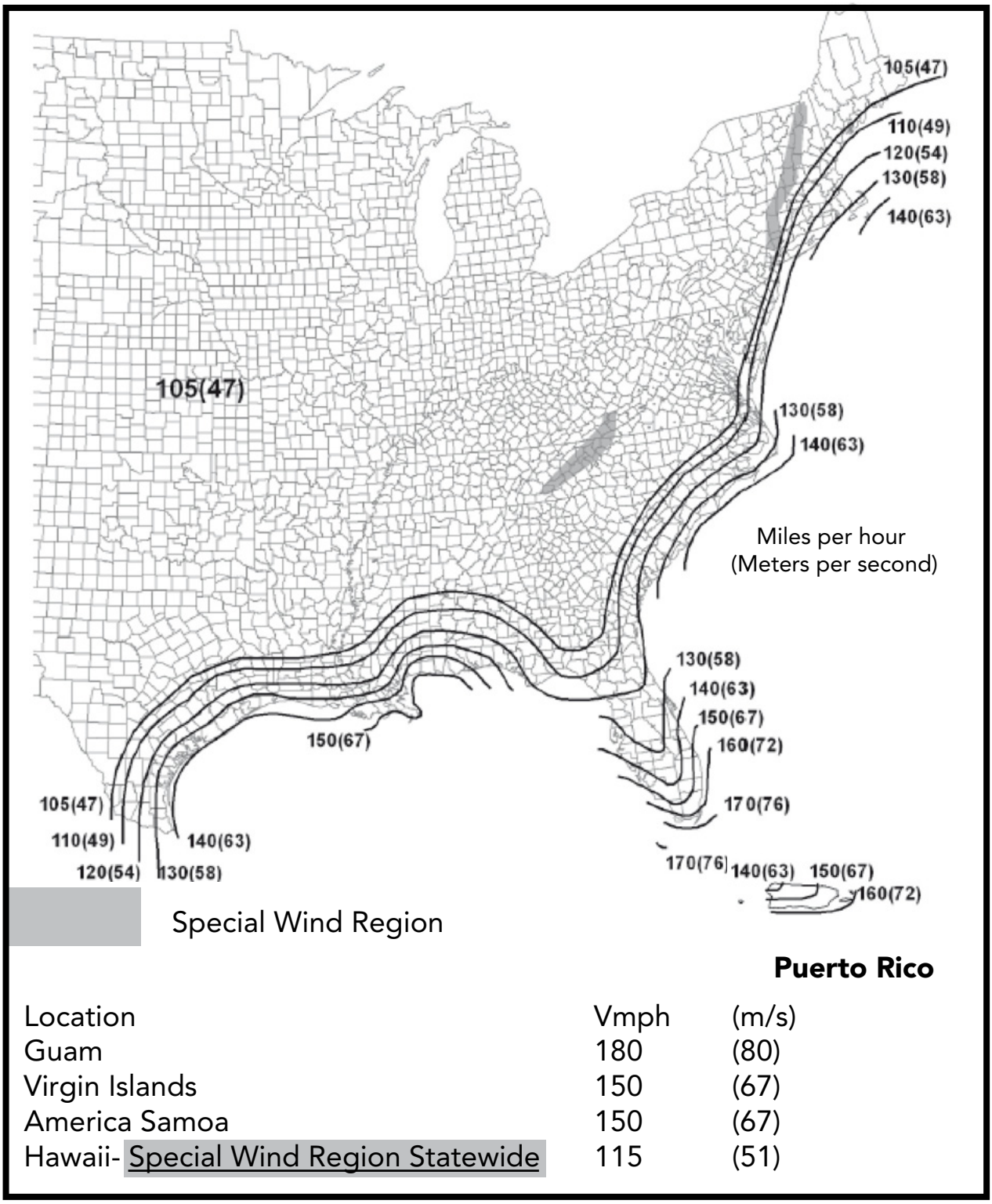


Notes:
1. Values are design 3-second gust wind speeds in miles per hour (m/s) at 33 ft (10m) above ground for Exposure C category.
2. Linear interpolation between contours is permitted.
3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.
4. Mountainous terrain, gorges, ocean promontories, and special wind regions shall be examined for unusual wind conditions.
5. Wind speeds correspond to approximately a 15% probability of exceedance in 50 years (annual exceedance probability = 0.00333, MRI = 300 years).

Source: ASCE 7-10 Minimum Design Loads for Buildings and Other Structures, Chapter 26

1.2 Procedure to Calculate Total Design Wind Load per ASCE 7-10

FIGURE 26.5-1C (Continued) Basic Wind Speeds for Risk Category I Buildings and Other Structures



Location	Vmph	(m/s)
Guam	180	(80)
Virgin Islands	150	(67)
America Samoa	150	(67)
Hawaii- Special Wind Region Statewide	115	(51)

Source: ASCE 7-10 Minimum Design Loads for Buildings and Other Structures, Chapter 26

1.2 Procedure to Calculate Total Design Wind Load per ASCE 7-10

Step 3. Determine Wind Load Parameters

Step 3a: Determine the proper Exposure Category (B, C, or D) for the project by using the following definitions for Surface Roughness Categories.
ASCE 7-10 defines wind surface roughness categories as follows:
Surface Roughness B: Urban and suburban areas, wooded areas, or other terrain with numerous closely spaced obstructions having the size of single-family dwellings or larger.

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

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

Step 3b: Determine the Topographic Factor, K_{zt}
For the purposes of this code compliance document, the Topographic Factor, K_{zt}, is taken as equal to one (1) as per Section 26.8-2 or as determined by Figure 26.8-1 in ASCE 7-10. Also shown in pages 13-14`.

Step 4. Determine Effective Wind Area
Determine the smallest area of continuous modules you will be installing. This is the smallest area tributary (contributing load) to a support or to a simple-span of rail. That area is the Effective Wind Area, the total area of the fewest number of modules on a run of rails. If the smallest area of continuous modules exceeds 100 sq ft, use 100 sq ft, if less round down to values available in Table 3, page 17.

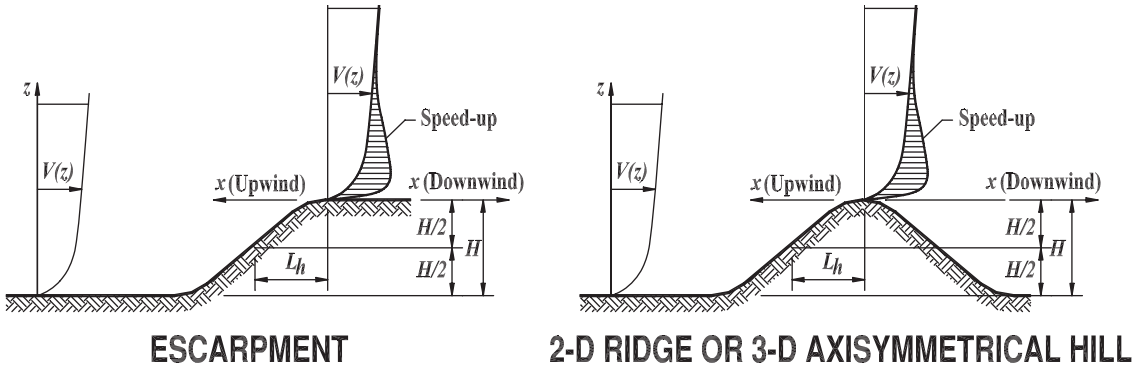
Step 5. Determine the appropriate roof zone for the installation.
The Design Wind Load will vary based on where the installation is located on a roof. Arrays may be located in more than one roof zone.

Using Table 2, page 15, determine the Roof Zone Dimension Length, a (ft) , according to the width and height of the building on which you are installing the pv system.

1.2 Procedure to Calculate Total Design Wind Load per ASCE 7-10

Figure 26.8-1 WIND LOADS: GENERAL REQUIREMENTS

Topographic Factor, K_{zt}



ESCARPMENT

2-D RIDGE OR 3-D AXISYMMETRICAL HILL

Topographic Multipliers for Exposure C

H/L_h	K_1 Multiplier			x/L_h	K_2 Multiplier		z/L_h	K_3 Multiplier		
	2-D Ridge	2-D Escarp.	3-D Axisym. Hill		2-D Escarp.	All Other Cases		2-D Ridge	2-D Escarp.	3-D Axisym. Hill
0.20	0.29	0.17	0.21	0.00	1.00	1.00	0.00	1.00	1.00	1.00
0.25	0.36	0.21	0.26	0.50	0.88	0.67	0.10	0.74	0.78	0.67
0.30	0.43	0.26	0.32	1.00	0.75	0.33	0.20	0.55	0.61	0.45
0.35	0.51	0.30	0.37	1.50	0.63	0.00	0.30	0.41	0.47	0.30
0.40	0.58	0.34	0.42	2.00	0.50	0.00	0.40	0.30	0.37	0.20
0.45	0.65	0.38	0.47	2.50	0.38	0.00	0.50	0.22	0.29	0.14
0.50	0.72	0.43	0.53	3.00	0.25	0.00	0.60	0.17	0.22	0.09
				3.50	0.13	0.00	0.70	0.12	0.17	0.06
				4.00	0.00	0.00	0.80	0.09	0.14	0.04
							0.90	0.07	0.11	0.03
							1.00	0.05	0.08	0.02
							1.50	0.01	0.02	0.00
							2.00	0.00	0.00	0.00

Notes:

1. For values of H/L_h, x/L_h and z/L_h other than those shown, linear interpolation is permitted.
2. For $H/L_h > 0.5$, assume $H/L_h = 0.5$ for evaluating K_1 and substitute $2H$ for L_h for evaluating K_2 and K_3.
3. Multipliers are based on the assumption that wind approaches the hill or escarpment along the direction of maximum slope.
4. Notation:
   - H: Height of hill or escarpment relative to the upwind terrain, in feet (meters).
   - L_h: Distance upwind of crest to where the difference in ground elevation is half the height of hill or escarpment, in feet (meters).
   - K_1: Factor to account for shape of topographic feature and maximum speed-up effect.
   - K_2: Factor to account for reduction in speed-up with distance upwind or downwind of crest.
   - K_3: Factor to account for reduction in speed-up with height above local terrain.
   - x: Distance (upwind or downwind) from the crest to the building site, in feet (meters).
   - z: Height above ground surface at building site, in feet (meters).
   - μ: Horizontal attenuation factor.
   - γ: Height attenuation factor.

Source: ASCE-7-10 Chapter 26, page 26

1.2 Procedure to Calculate Total Design Wind Load per ASCE 7-10

Figure 26.8-1 (cont'd) WIND LOADS: GENERAL REQUIREMENTS

Topographic Factor, K_{zt}

Equations:

$$K_{zt} = (1 + K_1 K_2 K_3)^2$$

K_1 determined from table below

$$K_2 = (1 - \frac{|x|}{\mu L_h})$$

$$K_3 = e^{-\gamma z / L_h}$$

Parameters for Speed-Up Over Hills and Escarpments

Hill Shape	$K_1/(H/L_h)$ Exposure			g	m	
	B	C	D		Upwind of Crest	Downwind of Crest
2-dimensional ridges (or valleys with negative H in $K_1/(H/L_h)$)	1.30	1.45	1.55	3	1.5	1.5
2-dimensional escarpments	0.75	0.85	0.95	2.5	1.5	4
3-dimensional axisym. hill	0.95	1.05	1.15	4	1.5	1.5

Source: ASCE-7-10 Chapter 26, page 253

1.2 Procedure to Calculate Total Design Wind Load per ASCE 7-10

Table 2. Determine Roof/Wall Zone dimension (a) according to building width and height

a = 10 percent of the least horizontal dimension or 0.4h whichever is smaller, but not less than either 4% of the least horizontal dimension or 3 ft of the building.

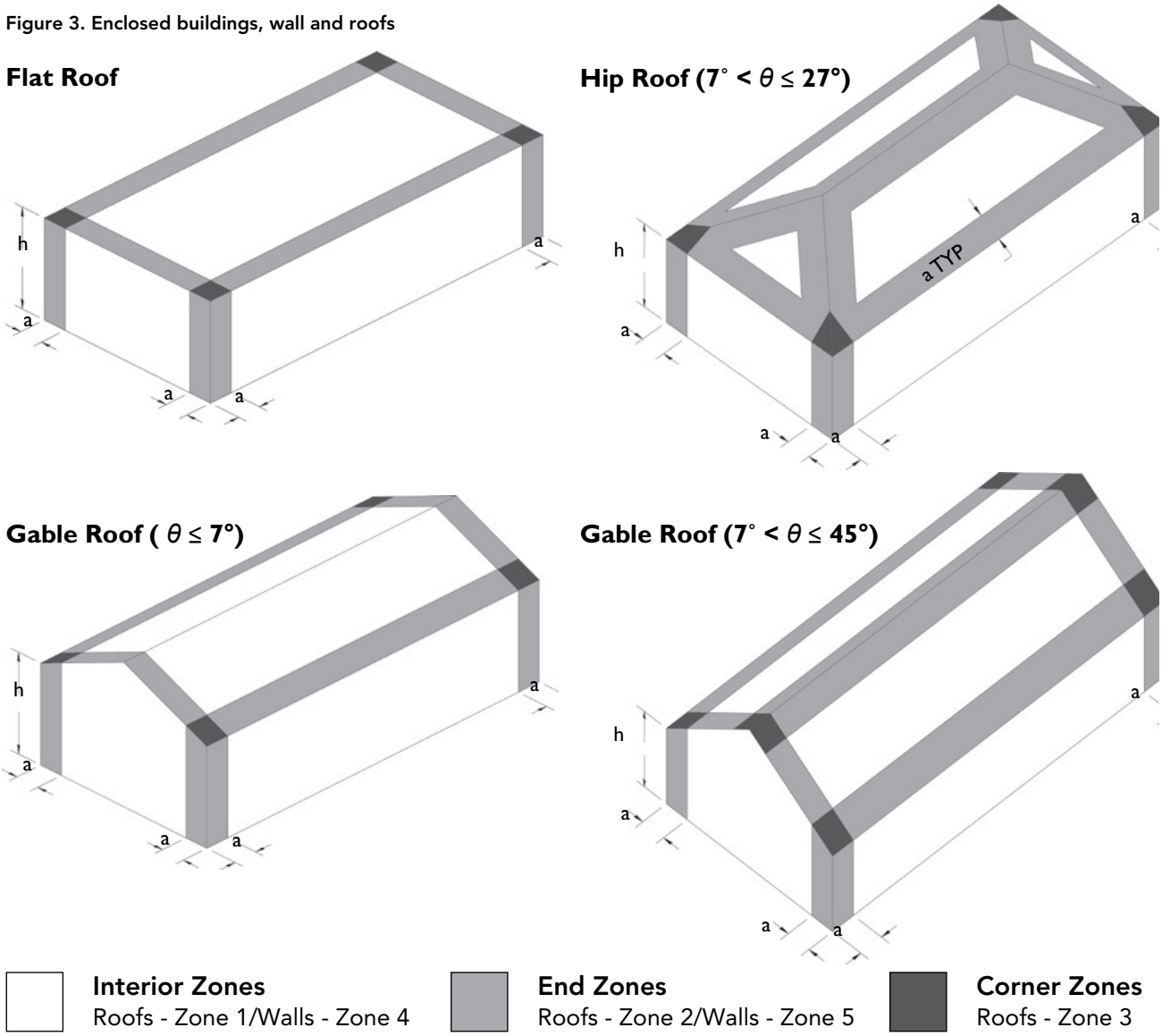
Roof Height (ft)	Least Horizontal Dimensions (ft)																		
	10	15	20	25	30	40	50	60	70	80	90	100	125	150	175	200	300	400	500
10	3	3	3	3	3	4	4	4	4	4	4	4	5	6	7	8	12	16	20
15	3	3	3	3	3	4	5	6	6	6	6	6	6	6	7	8	12	16	20
20	3	3	3	3	3	4	5	6	7	8	8	8	8	8	8	8	12	16	20
25	3	3	3	3	3	4	5	6	7	8	9	10	10	10	10	10	12	16	20
30	3	3	3	3	3	4	5	6	7	8	9	10	12	12	12	12	12	16	20
35	3	3	3	3	3	4	5	6	7	8	9	10	12.5	14	14	14	14	16	20
40	3	3	3	3	3	4	5	6	7	8	9	10	12.5	15	16	16	16	16	20
45	3	3	3	3	3	4	5	6	7	8	9	10	12.5	15	17.5	18	18	18	20
50	3	3	3	3	3	4	5	6	7	8	9	10	12.5	15	17.5	20	20	20	20
60	3	3	3	3	3	4	5	6	7	8	9	10	12.5	15	17.5	20	24	24	24

Step 5. Determine the appropriate roof zone for the installation (continued)

Using the Roof Zone Dimension Length, a, determine the roof zone locations according to your roof type, gable, hip or monoslope. Determine in which roof zone your pv system is located, Zone 1, 2, or 3 according to Figure 3, page 16.

1.2 Procedure to Calculate Total Design Wind Load per ASCE 7-10

Figure 3. Enclosed buildings, wall and roofs



Source: ASCE/SEI 7-10, Minimum Design Loads for Buildings and Other Structures, Chapter 30, p. 345.

Step 6. Determine Net Design Wind Pressure, p_{net30} (psf)

Using the Effective Wind Area (Step 4), Roof Zone Location (Step 5), and Basic Wind Speed (Step 2), look up the appropriate Net Design Wind Pressure in Table 3, page 17. Use the Effective Wind Area value in the table which is smaller than the value calculated in Step 2. If the installation is located on a roof overhang, use Table 4, page 18. Both downforce and uplift pressures must be considered in overall design. Refer to Section II, Step 1 for applying downforce and uplift pressures. Positive values are acting toward the surface. Negative values are acting away from the surface.

1.2 Procedure to Calculate Total Design Wind Load per ASCE 7-10

Components and Cladding – Method 1		h ≤ 60 ft.
Figure 30.5-1 (cont'd)	Design Wind Pressures	Walls & Roofs
Enclosed Buildings		

Net Design Wind Pressure, p_{net30} (psf) *(Exposure B at h = 30 ft.)*

	Zone	Effective wind area (sf)	Basic Wind Speed V (mph)																	
			110		115		120		130		140		150		160		180		200	
Roof 0 to 7 degrees	1	10	8.9	-21.8	9.7	-23.8	10.5	-25.9	12.4	-30.4	14.3	-35.3	16.5	-40.5	18.7	-46.1	23.7	-58.3	29.3	-72.0
	1	20	8.3	-21.2	9.1	-23.2	9.9	-25.2	11.6	-29.6	13.4	-34.4	15.4	-39.4	17.6	-44.9	22.2	-56.8	27.4	-70.1
	1	50	7.6	-20.5	8.3	-22.4	9.0	-24.4	10.6	-28.6	12.3	-33.2	14.1	-38.1	16.0	-43.3	20.3	-54.8	25.0	-67.7
	1	100	7.0	-19.9	7.7	-21.8	8.3	-23.7	9.8	-27.8	11.4	-32.3	13.0	-37.0	14.8	-42.1	18.8	-53.3	23.2	-65.9
	2	10	8.9	-36.5	9.7	-39.9	10.5	-43.5	12.4	-51.0	14.3	-59.2	16.5	-67.9	18.7	-77.3	23.7	-97.8	29.3	-120.7
	2	20	8.3	-32.6	9.1	-35.7	9.9	-38.8	11.6	-45.6	13.4	-52.9	15.4	-60.7	17.6	-69.0	22.2	-87.4	27.4	-107.9
	2	50	7.6	-27.5	8.3	-30.1	9.0	-32.7	10.6	-38.4	12.3	-44.5	14.1	-51.1	16.0	-58.2	20.3	-73.6	25.0	-90.9
	2	100	7.0	-23.6	7.7	-25.8	8.3	-28.1	9.8	-33.0	11.4	-38.2	13.0	-43.9	14.8	-50.0	18.8	-63.2	23.2	-78.1
	3	10	8.9	-55.0	9.7	-60.1	10.5	-65.4	12.4	-76.8	14.3	-89.0	16.5	-102.2	18.7	-116.3	23.7	-147.2	29.3	-181.7
	3	20	8.3	-45.5	9.1	-49.8	9.9	-54.2	11.6	-63.6	13.4	-73.8	15.4	-84.7	17.6	-96.3	22.2	-121.9	27.4	-150.5
	3	50	7.6	-33.1	8.3	-36.1	9.0	-39.3	10.6	-46.2	12.3	-53.5	14.1	-61.5	16.0	-69.9	20.3	-88.5	25.0	-109.3
	3	100	7.0	-23.6	7.7	-25.8	8.3	-28.1	9.8	-33.0	11.4	-38.2	13.0	-43.9	14.8	-50.0	18.8	-63.2	23.2	-78.1
Roof > 7 to 27 degrees	1	10	12.5	-19.9	13.7	-21.8	14.9	-23.7	17.5	-27.8	20.3	-32.3	23.3	-37.0	26.5	-42.1	33.6	-53.3	41.5	-65.9
	1	20	11.4	-19.4	12.5	-21.2	13.6	-23.0	16.0	-27.0	18.5	-31.4	21.3	-36.0	24.2	-41.0	30.6	-51.9	37.8	-64.0
	1	50	10.0	-18.6	10.9	-20.4	11.9	-22.2	13.9	-26.0	16.1	-30.2	18.5	-34.6	21.1	-39.4	26.7	-49.9	32.9	-61.6
	1	100	8.9	-18.1	9.7	-19.8	10.5	-21.5	12.4	-25.2	14.3	-29.3	16.5	-33.6	18.7	-38.2	23.7	-48.4	29.3	-59.8
	2	10	12.5	-34.7	13.7	-37.9	14.9	-41.3	17.5	-48.4	20.3	-56.2	23.3	-64.5	26.5	-73.4	33.6	-92.9	41.5	-114.6
	2	20	11.4	-31.9	12.5	-34.9	13.6	-38.0	16.0	-44.6	18.5	-51.7	21.3	-59.3	24.2	-67.5	30.6	-85.4	37.8	-105.5
	2	50	10.0	-28.2	10.9	-30.9	11.9	-33.6	13.9	-39.4	16.1	-45.7	18.5	-52.5	21.1	-59.7	26.7	-75.6	32.9	-93.3
	2	100	8.9	-25.5	9.7	-27.8	10.5	-30.3	12.4	-35.6	14.3	-41.2	16.5	-47.3	18.7	-53.9	23.7	-68.2	29.3	-84.2
	3	10	12.5	-51.3	13.7	-56.0	14.9	-61.0	17.5	-71.6	20.3	-83.1	23.3	-95.4	26.5	-108.5	33.6	-137.3	41.5	-169.5
	3	20	11.4	-47.9	12.5	-52.4	13.6	-57.1	16.0	-67.0	18.5	-77.7	21.3	-89.2	24.2	-101.4	30.6	-128.4	37.8	-158.5
	3	50	10.0	-43.5	10.9	-47.6	11.9	-51.8	13.9	-60.8	16.1	-70.5	18.5	-81.0	21.1	-92.1	26.7	-116.6	32.9	-143.9
	3	100	8.9	-40.2	9.7	-44.0	10.5	-47.9	12.4	-56.2	14.3	-65.1	16.5	-74.8	18.7	-85.1	23.7	-107.7	29.3	-132.9
Roof > 27 to 45 degrees	1	10	19.9	-21.8	21.8	-23.8	23.7	-25.9	27.8	-30.4	32.3	-35.3	37.0	-40.5	42.1	-46.1	53.3	-58.3	65.9	-72.0
	1	20	19.4	-20.7	21.2	-22.6	23.0	-24.6	27.0	-28.9	31.4	-33.5	36.0	-38.4	41.0	-43.7	51.9	-55.3	64.0	-68.3
	1	50	18.6	-19.2	20.4	-21.0	22.2	-22.8	26.0	-26.8	30.2	-31.1	34.6	-35.7	39.4	-40.6	49.9	-51.4	61.6	-63.4
	1	100	18.1	-18.1	19.8	-19.8	21.5	-21.5	25.2	-25.2	29.3	-29.3	33.6	-33.6	38.2	-38.2	48.4	-48.4	59.8	-59.8
	2	10	19.9	-25.5	21.8	-27.8	23.7	-30.3	27.8	-35.6	32.3	-41.2	37.0	-47.3	42.1	-53.9	53.3	-68.2	65.9	-84.2
	2	20	19.4	-24.3	21.2	-26.6	23.0	-29.0	27.0	-34.0	31.4	-39.4	36.0	-45.3	41.0	-51.5	51.9	-65.2	64.0	-80.5
	2	50	18.6	-22.9	20.4	-25.0	22.2	-27.2	26.0	-32.0	30.2	-37.1	34.6	-42.5	39.4	-48.4	49.9	-61.3	61.6	-75.6
	2	100	18.1	-21.8	19.8	-23.8	21.5	-25.9	25.2	-30.4	29.3	-35.3	33.6	-40.5	38.2	-46.1	48.4	-58.3	59.8	-72.0
	3	10	19.9	-25.5	21.8	-27.8	23.7	-30.3	27.8	-35.6	32.3	-41.2	37.0	-47.3	42.1	-53.9	53.3	-68.2	65.9	-84.2
	3	20	19.4	-24.3	21.2	-26.6	23.0	-29.0	27.0	-34.0	31.4	-39.4	36.0	-45.3	41.0	-51.5	51.9	-65.2	64.0	-80.5
	3	50	18.6	-22.9	20.4	-25.0	22.2	-27.2	26.0	-32.0	30.2	-37.1	34.6	-42.5	39.4	-48.4	49.9	-61.3	61.6	-75.6
	3	100	18.1	-21.8	19.8	-23.8	21.5	-25.9	25.2	-30.4	29.3	-35.3	33.6	-40.5	38.2	-46.1	48.4	-58.3	59.8	-72.0
Wall	4	10	21.8	-23.6	23.8	-25.8	25.9	-28.1	30.4	-33.0	35.3	-38.2	40.5	-43.9	46.1	-50.0	58.3	-63.2	72.0	-78.1
	4	20	20.8	-22.6	22.7	-24.7	24.7	-26.9	29.0	-31.6	33.7	-36.7	38.7	-42.1	44.0	-47.9	55.7	-60.6	68.7	-74.8
	4	50	19.5	-21.3	21.3	-23.3	23.2	-25.4	27.2	-29.8	31.6	-34.6	36.2	-39.7	41.2	-45.1	52.2	-57.1	64.4	-70.5
	4	100	18.5	-20.4	20.2	-22.2	22.0	-24.2	25.9	-28.4	30.0	-33.0	34.4	-37.8	39.2	-43.1	49.6	-54.5	61.2	-67.3
	4	500	16.2	-18.1	17.7	-19.8	19.3	-21.5	22.7	-25.2	26.3	-29.3	30.2	-33.6	34.3	-38.2	43.5	-48.4	53.7	-59.8
	5	10	21.8	-29.1	23.8	-31.9	25.9	-34.7	30.4	-40.7	35.3	-47.2	40.5	-54.2	46.1	-61.7	58.3	-78.0	72.0	-96.3
	5	20	20.8	-27.2	22.7	-29.7	24.7	-32.4	29.0	-38.0	33.7	-44.0	38.7	-50.5	44.0	-57.5	55.7	-72.8	68.7	-89.9
	5	50	19.5	-24.6	21.3	-26.9	23.2	-29.3	27.2	-34.3	31.6	-39.8	36.2	-45.7	41.2	-52.0	52.2	-65.8	64.4	-81.3
	5	100	18.5	-22.6	20.2	-24.7	22.0	-26.9	25.9	-31.6	30.0	-36.7	34.4	-42.1	39.2	-47.9	49.6	-60.6	61.2	-74.8
	5	500	16.2	-18.1	17.7	-19.8	19.3	-21.5	22.7	-25.2	26.3	-29.3	30.2	-33.6	34.3	-38.2	43.5	-48.4	53.7	-59.8

Note: For effective areas between the those given above the load may be interpolated, otherwise use the load associated with the lower effective area.

Table 3. p_{net30} (psf) Roof and Wall

1.2 Procedure to Calculate Total Design Wind Load per ASCE 7-10

Roof Overhang Net Design Wind Pressure, P_{net30} (psf)
(Exposure B at h=30 ft.)

	Zone	Effective wind area (sf)	Basic Wind Speed V (mph)							
			110	115	130	140	150	160	180	200
Roof 0 to 7 degrees	2	10	-31.4	-34.3	-43.8	-50.8	-58.3	-66.3	-84.0	-103.7
	2	20	-30.8	-33.7	-43.0	-49.9	-57.3	-65.2	-82.5	-101.8
	2	50	-30.1	-32.9	-42.0	-48.7	-55.9	-63.6	-80.5	-99.4
	2	100	-29.5	-32.3	-41.2	-47.8	-54.9	-62.4	-79.0	-97.6
	3	10	-51.6	-56.5	-72.1	-83.7	-96.0	-109.3	-138.3	-170.7
	3	20	-40.5	-44.3	-56.6	-65.7	-75.4	-85.8	-108.6	-134.0
	3	50	-25.9	-28.3	-36.1	-41.9	-48.1	-54.7	-69.3	-85.5
	3	100	-14.8	-16.1	-20.6	-23.9	-27.4	-31.2	-39.5	-48.8
Roof 7 to 27 degrees	2	10	-40.6	-44.4	-56.7	-65.7	-75.5	-85.9	-108.7	-134.2
	2	20	-40.6	-44.4	-56.7	-65.7	-75.5	-85.9	-108.7	-134.2
	2	50	-40.6	-44.4	-56.7	-65.7	-75.5	-85.9	-108.7	-134.2
	2	100	-40.6	-44.4	-56.7	-65.7	-75.5	-85.9	-108.7	-134.2
	3	10	-68.3	-74.6	-95.3	-110.6	-126.9	-144.4	-182.8	-225.6
	3	20	-61.6	-67.3	-86.0	-99.8	-114.5	-130.3	-164.9	-203.6
	3	50	-52.8	-57.7	-7.7	-85.5	-98.1	-111.7	-141.3	-174.5
	3	100	-46.1	-50.4	-64.4	-74.7	-85.8	-97.6	-123.5	-152.4
Roof > 27 to 45 degrees	2	10	-36.9	-40.3	-51.5	-59.8	-68.6	-78.1	-98.8	-122.0
	2	20	-35.8	-39.1	-50.0	-58.0	-66.5	-75.7	-95.8	-118.3
	2	50	-34.3	-37.5	-47.9	-55.6	-63.8	-72.6	-91.9	-113.4
	2	100	-33.2	-36.3	-46.4	-53.8	-61.7	-70.2	-88.9	-109.8
	3	10	-36.9	-40.3	-51.5	-59.8	-68.6	-78.1	-98.8	-122.0
	3	20	-35.8	-39.1	-50.0	-58.0	-66.5	-75.7	-95.8	-118.3
	3	50	-34.3	-37.5	-47.9	-55.6	-63.8	-72.6	-91.9	-113.4
	3	100	-33.2	-36.3	-46.4	-53.8	-61.7	-70.2	-88.9	-109.8

Table 4. p_{net30} (psf) Roof Overhang

Step 7. Determine adjustment factor for height and exposure category, l

Using the Exposure Category (Step 3) and the roof height, h (ft), look up the adjustment factor for height and exposure (λ) in Table 5, page 19.

1.2 Procedure to Calculate Total Design Wind Load per ASCE 7-10

Table 5. Adjustment Factor( ) for Roof Height & Exposure Category

Mean roof height (ft)	Exposure		
	B	C	D
15	1.00	1.21	1.47
20	1.00	1.29	1.55
25	1.00	1.35	1.61
30	1.00	1.40	1.66
35	1.05	1.45	1.70
40	1.09	1.49	1.74
45	1.12	1.53	1.78
50	1.16	1.56	1.81
55	1.19	1.59	1.84
60	1.22	1.62	1.87

Step 8. Calculate the adjusted wind pressures, p_{net}, (psf)

Multiply the Net Design Wind Pressure, p_{net30} by the adjustment factor for height and exposure, l, the Topographic Factor, K_{zt}.

Where
l = adjustment factor for building height and exposure (Step 7)
K_{zt} = For the purposes of this code compliance document, the Topographic Factor, K_{zt}, is taken as equal to one (1) as per Section 26.8-2 or as determined by Figure 26.8-1 in ASCE 7-10.
P_{net30} = net design wind pressure for Exposure B, at h = 30 ft (Step 6)

The adjusted wind pressures will be used to select the appropriate SWH rail, rail span and attachment spacing.

Use both the positive (downforce) and the negative (uplift) results from this calculation.

Part 2: *Procedure to Select Rail Span and Foot Spacing*

[2.1.] Using Standard Beam Calculations, Structural Engineering Methodology ASCE 7-10

The procedure to determine the SWH rail span uses standard beam calculations and structural engineering methodology. The beam calculations are based on a simply supported beam conservatively, ignoring the reductions allowed for supports of continuous beams over multiple supports. Please refer to **Part I** for more information on beam calculations, equations and assumptions. If beams are installed perpendicular to the eaves on a roof steeper than a 4/12 pitch in an area with a ground snow load greater than 30 psf, then additional analysis is required for side loading on the roof attachment and beam.

In using this document, obtaining correct results is dependent upon the following:

1. Obtain the *Snow Load* for your area from your local building official.

2. Obtain the Design Wind Load, p_{net}. See **Part I** (Procedure to Determine the Design Wind Load) for more information on calculating the *Design Wind Load*.

3. ***Please Note:*** The terms rail span and footing spacing are interchangeable in this document. See **Figure 4** for illustrations.

4. To use **Table 7** the *Dead Load* for your specific installation must be less than 5 psf, including modules and SWH racking systems. If the Dead Load is greater than 5 psf, see your SWH distributor, a local structural engineer or contact SWH. The following procedure will guide you in selecting a SWH rail for a flush mount installation. It will also help determine the design loading imposed by the SWH PV Mounting Assembly that the building structure must be capable of supporting.

Step 1. Determine the Total Design Load

The Total Design Load, P (psf) is determined using ASCE 7-10 2.4.1 (ASD Method equations 3, 5, 6a and 7) by adding the Snow Load, S (psf), Design Wind Load, Pnet (Psf) Step 8 page 19 and the Dead Load (psf). Both Uplift and Downforce Wind Loads calculated in Step 8, Page 19 of section 1.2. must be investigated. Use Table 6 to calculate the Total Design Load for the load cases. Use the maximum absolute value of the three downforce cases and the uplift case for sizing the rail. Use the uplift case only for sizing lag bolts pull out capacities. Use the following equations or Table 6, below.

$P\ (psf) = 1.0D + 1.0S$ [1] (downforce case 1)

$P\ (psf) = 1.0D + 0.6\ p_{net}$ (downforce case 2)

$P\ (psf) = 1.0D + 0.75S$ [1] $+ 0.75(0.6p_{net})$ (downforce case 3)

$P\ (psf) = 0.6D + 0.6\ p_{net}$ (uplift)

D = Dead Load (psf)

S = Snow Load (psf)

p_{net} = Design Wind Load (psf) (Positive for downforce, negative for uplift)

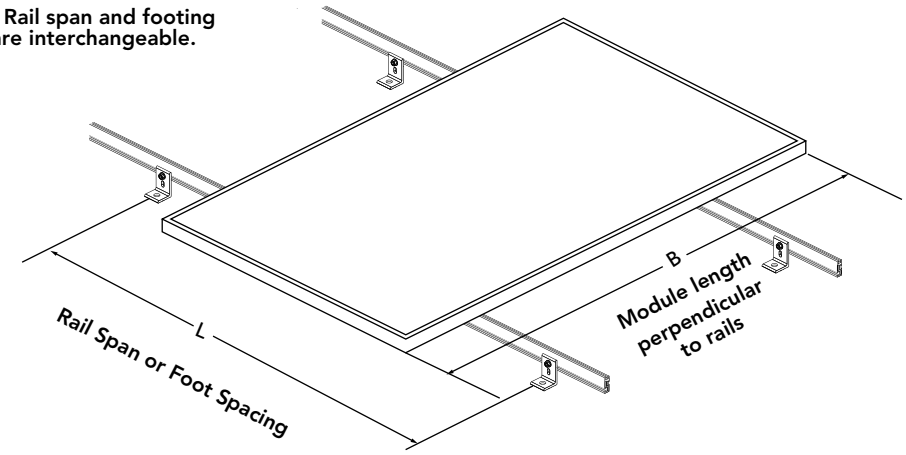
Table 6. ASCE 7-10 Load Combinations

Description	*Variable*	*Downforce Case 1*	*Downforce Case 2*	*Downforce Case 3*	*Uplift*	*units*
Dead Load	D	1.0 x	1.0 x	1.0 x	0.6 x	psf
Snow Load	S	1.0 x + _____		0.75 x + _____		psf
Design Wind Load	Pnet		0.6 x + _____	0.75 x + _____	0.6 x -	psf
Total Design Load	P					psf

Note: Table to be filled out or attached for evaluation.

2.1 Using Standard Beam Calculations, Structural Engineering

Figure 4. Rail span and footing spacing are interchangeable.



Note: Modules must be centered symmetrically on the rails (+/- 2°), as shown.

Step 2: Determine the Distributed Load on the rail, w (plf)

Determine the Distributed Load, w (plf), by multiplying the module length, B (ft), by the *Total Design Load, P (psf)* and dividing by two. Use the maximum absolute value of the three downforce cases and the Uplift Case. We assume each module is supported by two rails.

$$w = PB/2$$

w = Distributed Load (pounds per linear foot, plf)

B = Module Length Perpendicular to Rails (ft)

P = Total Design Pressure (pounds per square foot, psf)

Step 3: Determine Rail Span/ L-bracket Spacing

Using the *distributed load, w*, from Part II, Step 2, look up the *allowable spans, L* in Table 7.
The L-bracket SWH Series Rail Span Table uses a single L-bracket connection to the roof, wall or stand-off.

Table 7 . L-Foot SWH Rail Span

ST- SWH STANDARD RAIL EC- SWH ECOLITE RAIL

Span (ft)	Distributed Load (pounds/linear foot)															
	20	25	30	40	50	60	80	100	120	140	160	180	200	220	240	260
2	ST/EC	ST/EC	ST/EC	ST/EC	ST/EC	ST/EC	ST/EC	ST/EC	ST/EC	ST/EC	ST/EC	ST	ST	ST	ST	ST
2.5	ST/EC	ST/EC	ST/EC	ST/EC	ST/EC	ST/EC	ST/EC	ST/EC	ST/EC	ST/EC	ST	ST	ST	ST	ST	
3	ST/EC	ST/EC	ST/EC	ST/EC	ST/EC	ST/EC	ST/EC	ST/EC	ST/EC	ST	ST	ST	ST			
3.5	ST/EC	ST/EC	ST/EC	ST/EC	ST/EC	ST/EC	ST/EC	ST/EC	ST	ST	ST					
4	ST/EC	ST/EC	ST/EC	ST/EC	ST/EC	ST/EC	ST/EC	ST	ST							
4.5	ST/EC	ST/EC	ST/EC	ST/EC	ST/EC	ST/EC	ST	ST	ST							
5	ST/EC	ST/EC	ST/EC	ST/EC	ST/EC	ST/EC	ST	ST								
5.5	ST/EC	ST/EC	ST/EC	ST/EC	ST/EC	ST	ST									
6	ST/EC	ST/EC	ST/EC	ST/EC	ST	ST										
6.5	ST/EC	ST/EC	ST/EC	ST	ST	ST										
7	ST/EC	ST/EC	ST/EC	ST	ST											
7.5	ST/EC	ST/EC	ST/EC	ST												
8	ST/EC	ST/EC	ST	ST												
8.5	ST/EC	ST	ST													
9	ST	ST	ST													
9.5	ST	ST	ST													
10	ST	ST														
10.5	ST	ST														
11	ST															
11.5	ST															

Rail cantilever/overhang span shall NOT exceed 25% of footing attachment spacing

2.1 Using Standard Beam Calculations, Structural Engineering

METHODOLOGY ASCE 7-10

Step 4: Select Rail Type

Selecting a span and rail type affects the price of your installation. Longer spans produce fewer wall or roof penetrations. However, longer spans create higher point load forces on the building structure. A point load force is the amount of force transferred to the building structure at each connection.



It is the installer's responsibility to verify that the building structure is strong enough to support the point load forces.

Step 5: Determine the Downforce Point Load, R (lbs), at each connection based on rail span

When designing the SWH Flush Mount Installation, you must consider the downforce Point Load, R (lbs) on the roof structure.

The Downforce, Point Load, R (lbs), is determined by multiplying the Total Design Load, P (psf), ***(Step 1)*** by the Rail Span, L (ft) ***(Step 3)*** and the Module Length Perpendicular to the Rails, B (ft) divided by two.

$$R\ (lbs) = PLB/2$$

R = Point Load (lbs)

P = Total Design Load (psf)

L = Rail Span (ft)

B = Module Length Perpendicular to Rails (ft)

It is the installer's responsibility to verify that the building structure is strong enough to support the maximum point loads calculated according to Step 5.

Table 8. Downforce Point Load Calculation

Total Design Load (downforce) (max of case 1, 2 or 3):	P	t	psf	Step 1
Module length perpendicular to rails:	B	x	ft	
Rail Span:	L	x	ft	Step 3
		/2		
Downforce Point Load:	R		lbs	

2.1 Using Standard Beam Calculations, Structural Engineering

METHODOLOGY ASCE 7-10

Step 6: Determine the Uplift Point Load, R (lbs), at each connection based on rail span

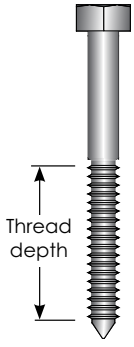
You must also consider the Uplift Point Load, R (lbs), to determine the required lag bolt attachment to the roof (building) structure.

Table 9. Uplift Point Load Calculation

Total Design Load (uplift):	P			psf	Step 1
Module length perpendicular to rails:	B	x		ft	
Rail Span:	L	x		ft	Step 3
			/2		
Uplift Point Load:	R			lbs	

Table 10. Lag pull-out (withdrawal) capacities (lbs) in typical roof lumber (ASD)

	Specific gravity	*Lag screw specifications* 5/16" *shaft,* per inch thread depth*
Douglas Fir, Larch	**0.50**	**266**
Douglas Fir, South	**0.46**	**235**
Engelmann Spruce, Lodgepole Pine (MSR 1650 f & higher)	**0.46**	**235**
Hem, Fir, Redwood (close grain)	**0.43**	**212**
Hem, Fir (North)	**0.46**	**235**
Southern Pine	**0.55**	**307**
Spruce, Pine, Fir	**0.42**	**205**
Spruce, Pine, Fir (E of 2 million psi and higher grades of MSR and MEL)	**0.50**	**266**



Use Table 10 to select a lag bolt size and embedment depth to satisfy your Uplift Point Load Force, R (lbs), requirements. Divide the uplift pointload by the withdrawal capacity, this results in inches of 5/16 lagbolt embedded thread depth needed to counteract the bolt is used (as with a concrete or steel), consult fastener mfr documentation.

It is the installer's responsibility to verify that the substructure and attachment method is strong enough to support the maximum point loads calculated according to Step 5 and Step 6.

Sources: American Wood Council, NDS 2005, Table 11.2A, 11.3.2A.

Notes: (1) Thread must be embedded in the side grain of a rafter or other structural member integral with the building structure.
(2) Lag bolts must be located in the middle third of the structural member.
(3) These values are not valid for wet service.
(4) This table does not include shear capacities. If necessary, contact a local engineer to specifiy lag bolt size with regard to shear forces.
(5) Install lag bolts with head and washer flush to surface (no gap). Do not over-torque.
(6) Withdrawal design values for lag screw connections shall be multiplied by applicable adjustment factors if necessary. See Table 10.3.1 in the American Wood Council NDS for Wood Construction.

**Use flat washers with lag screws.*