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Wind Load Comparison for the ASCE Standard 7 and the Hanford Site Design Criteria.

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Abstract: This document provides calculations and discussions to compare Hanford Site wind load criteria with the current national standard for wind loads (ASCE 7, 1995). Site criteria uses the 1988 edition ASCE 7.

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**WIND LOAD COMPARISON
FOR THE ASCE STANDARD 7
AND THE HANFORD SITE DESIGN CRITERIA**

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1.0 INTRODUCTION

The American Society of Civil Engineers standard 7 (ASCE-7) is the nationally recognized standard for wind loads. This standard also contains guidance for snow, rain and seismic loads. This standard was first issued in 1988 and revised in 1993 and 1995. Current site design criteria reference the 1988 edition of ASCE-7 for the design of wind loads. The abstract to the 1995 revision states that "The major revision of this standard involves the section on wind." An evaluation is needed to determine the impact and extent of the wind load and other load changes made in the 1995 edition.

1.1 Purpose

The purpose of this evaluation is to investigate the changes made in the 1995 revision of ASCE-7. Wind, snow and rain loads shall specifically be investigated, seismic loads are not to be a part of this investigation. A determination is needed for the impact these changes will make to site design criteria and if changes to the site design criteria are necessary.

1.2 Background

Wind speed data is recorded and archived at National Weather Stations (NWS) around the country. The National Weather Service has phased out the measurement of fastest mile wind speeds in favor of peak gust wind speeds. Along with the change from fastest-mile to peak-gust wind speed, is an adjustment in gust factors such that most regions of the country will not see significantly different wind pressures. Only hurricane susceptible regions of the country have reported larger calculated wind pressures.

Changes to ASCE 7 also include new wind load considerations for structures. Wind produced torsion and biaxial loading on buildings and wind speed increase on buildings located on isolated hills require additional investigation. These additional considerations can be significant.

2.0 SITE DESIGN CRITERIA

The following list provides the current site design criteria documents that have sections dealing with wind loads.

GC-LOAD-01,	<i>Design Loads for Facilities.</i> March, 1996.
UCRL-15910,	<i>Design and Evaluation Guidelines for DOE Facilities Subjected to Natural Phenomena Hazards.</i> June, 1990.
UBC-1994,	<i>Uniform Building Code.</i> May, 1994.
ASCE-7, 1988,	<i>Minimum Design Loads for Buildings and Other Structures.</i> December, 1988.
WHC-CM-1-12,	<i>Structural Design and Evaluation Criteria.</i> Draft May, 1996.
DOE-STD-1020,	<i>Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities.</i> April, 1994.

3.0 ASCE STANDARD-7 WIND LOAD COMPARISON

The 1995 edition of ASCE-7 has major wind load changes and additions from the 1988 edition. These changes and additions in some cases increase and in other cases, decrease the wind loading on a structure. The following sections describe the changes in the 1995 edition of ASCE-7.

3.1 Wind Velocity Difference

The annual probability of maximum wind speed remains unchanged at 0.02 in the 1995 edition of ASCE-7. However, the method of reporting that wind speed has changed from a fastest-mile to a three-second-gust wind designation. The basic wind speed map provided in ASCE-7 has also changed. The 1988 map had three different wind speeds (exclusive of the gulf coast and Alaska), the 1995 map has one wind speed for the west coast and one for the rest of the country (exclusive of the gulf coast and Alaska).

3.2 Basic Velocity Pressure Differences

The basic formula for calculating velocity pressure is unchanged in the 1995 edition of ASCE-7 (see below). However, some of the values of the terms in the formula have changed. The wind velocity (V) has changed from fastest-mile to three-second-gust, the exposure coefficient (K) has been replaced by two exposure coefficients, and the importance factor (I) is no longer squared with the velocity term as it was in the 1988 edition.

$$(ASCE\ 7,\ 1988) \quad q_z = 0.00256K_z(V)^2$$

$$(ASCE\ 7,\ 1995) \quad q_z = 0.00256K_zK_{ex}V^2I$$

3.3 Design Wind Pressure Differences

The design wind pressure used in the evaluation of structures for wind loads is calculated from the basic velocity pressure. Wind pressure coefficients that vary by the building component under consideration are used to modify this pressure. Because of the many factors, coefficients, and variables that go into the calculation of the design wind pressure, it is impossible to determine the differences unless case studies are performed.

Five case studies were performed to calculate design wind pressures on buildings, cladding, and components for the 1988 and 1995 editions of ASCE-7. These case studies are provided in Appendix B. Table 1 shows the design wind pressure results for three of these studies, the two remaining case studies showed no changes. Table 1 shows some design wind pressure differences for low-rise building main load-resisting frame.

Table 1.
Case Study
Design Pressure Results

Load Case		Main Load-Resisting Frame	Maximum Roof Component or Cladding Pressure	Maximum Wall Component or Cladding Pressure
CASE 1 Flat Roof, Low Rise Bldg h=50'	ASCE-1988	22.3 psf	60.4 psf	32.0 psf
	ASCE-1995	13.9 psf	60.2 psf	31.9 psf
CASE 2 Sloped Roof Low Rise Bldg h=50'	ASCE-1988	22.3 psf	46.1 psf	32.0 psf
	ASCE-1995	19.4 psf	46.1 psf	31.9 psf
CASE 3 High Rise h=80'	ASCE-1988	24.9 psf	85.0 psf	44.6 psf
	ASCE-1995	24.8 psf	75.7 psf	44.4 psf

Table 2.
Classification and Importance factors
for Buildings and Other Structures

Classification of Buildings	Category 1988	I 1988	Category 1995	I 1995
Buildings and other structures that represent a low hazard to human life in the event of failure.	IV	0.95	I	0.87
All buildings and other structures except those listed in the other categories.	I	1.0	II	1.0
Buildings and other structures that represent a substantial hazard to human life in the event of failure.	II	1.07	III	1.15
Buildings and other structures designated as essential facilities.	III	1.07	IV	1.15

3.4 Importance Factor

Building classification definitions and category numbers have been revised to make them more logical. The importance factors (I) have been changed to reflect this logic and have been adjusted and included in the wind velocity formula (Page 2) to the first power. Table 2 provides a comparison for the building classification definitions, category and the corresponding I values. With the exception of Category IV (1988) buildings, the net result of the importance factor revisions is no effect. In the above exception the 1988 Category IV calculation would be conservative.

3.5 Additional Wind Load Considerations

The 1995 edition of ASCE-7 includes three new wind load design considerations. These new considerations consist of wind speed-up and pressure increase at the crest of hills or escarpments, building torsion produced by wind at building corners, and biaxial wind loading. Specific methods have been included in ASCE-7 1995 to calculate these additional wind pressures and loads, and to apply them to building structures.

4.0 ASCE STD-7 OTHER LOADS COMPARISON

4.1 Seismic Load Comparison

The section on seismic loads had major revisions in the 1993 edition of ASCE-7. However, the Hanford Site does not use the ASCE-7 seismic load provisions and further discussion is not needed here.

4.2 Snow Load Comparison

The basic equation for calculating snow loads on roofs has not been changed from 1988 to 1995. However, the values of one coefficient in the equation have changed. The roof exposure coefficient C_e has been changed to add more choices and definitions. Previously there were 5 choices ranging from 0.8 to 1.2, now there are 15 choices ranging from 0.7 to 1.3.

One other change in the snow load criteria is the ground snow load map. The new map has better definition because county lines are shown for each state. The ground snow load magnitudes are slightly changed throughout the country but are unchanged for the Hanford site.

4.3 Rain Load Comparison

The 1995 edition of ASCE-7 provides an equation to calculate rain loads on roofs that have drain systems. The 1995 edition also requires a rain load structural analysis for roofs with slopes less than 1/4 in./ft. Both of these requirements are new in the 1995 edition of ASCE-7.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Wind Load Results

The most visible revision in the ASCE-7 1995 document is the change of wind speed reporting designation from fastest-mile to three-second-gust winds. However, this change in wind speed reporting designation has minor overall wind load effects. Some revisions in the ASCE-7 1995 document do have significant effects, for example the wind load effects on the main load-resisting frames of low rise buildings is reduced from the 1988 document. Additionally, the revised ASCE-7 1995 document provides increased wind load effects for torsion, biaxial loading and pressure at hill crests.

Table 1 summarizes the results from three case studies for the calculation design wind pressures. Following is an itemization of the wind load changes from 1988 to 1995.

- Main Frame design wind pressures have been reduced for low rise buildings, and flat roofed low rise buildings have been reduced more than sloped roofed low rise buildings.
- Increased design wind pressures are required for buildings at the crest of hills or escarpments where wind can speed up.
- Wind hitting a building corner causes torsion in buildings, and a method is provided in the 1995 edition to calculated this effect.
- The effects of biaxial wind loading is a new requirement in the 1995 edition.
- Three new roof types and one new building type has been added to ASCE-7. Monoslope, stepped, and sawtooth roof types, and a partially-open building type are now available for use by design professionals.

The site design criteria listed in Section 2.0 of this document all have wind load design information that will require changing when the 1995 edition of ASCE-7 is adopted. This includes a wind reporting designation change from fastest-mile wind to three-second-gust and an importance factor change. Appendix A provides a recommended wind load criteria table for use in these existing criteria documents.

5.2 Snow Load Results

The 1995 edition of ASCE-7 has new values for the snow load coefficients and a new ground snow load map. The change to the Hanford Site is minor and no change is required to the site design criteria.

5.3 Rain Load Results

The 1995 edition of ASCE-7 has new requirements for rain loads. Roofs with drainage systems and roofs with slopes less than 1/4 in./ft require analysis. The Hanford Site design criteria will need to include this when ASCE-7 1995 is adopted.

APPENDIX A

Table 1A.
Wind Load and Missile Criteria

		PC-4	PC-3	PC-2	PC-1
"Fastest Mile" Wind Velocity (5)		40 m/s (90 mi/h)	36 m/s (80 mi/h)	31 m/s (70 mi/h)	31 m/s (70 mi/h)
"3 Second Gust" Wind Velocity (6)		49 m/s (110 mi/h)	44 m/s (100 mi/h)	38 m/s (85 mi/h)	38 m/s (85 mi/h)
Importance Factor (3)	I	1.0	1.0	1.07	1.0
	I ²	1.0	1.0	1.15	1.0
Exposure Category		(4)	(4)	(4)	(4)
Missile (horizontal)		(1)	(2)	na	na

- (1) 50 X 100 mm (2X4) timber plank weighing 7 kg (15 lb) @ 22 m/s (50 mi/h). maximum trajectory height = 15 m (50 ft.)
- (2) 50 X 100 mm (2X4) timber plank weighing 7 kg (15 lb) @ 22 m/s (50 mi/h). maximum trajectory height = 9 m (30 ft.)
- (3) Wind pressures calculated in accordance with ASCE 7, 1988 vary according to the square of the "I" term (I²). The UBC and ASCE 7, 1995 Importance Factors for wind corresponds to I² from ASCE 7, 1988.
- (4) Exposure "C", flat and generally open terrain, should be used for all construction unless it can be shown that the necessary permanent shielding will be provided by natural terrain (not including shielding from trees or adjacent buildings).
- (5) See WHC-SD-GN-ER-501.
- (6) ASCE 7, 1995 uses a Three Second Gust wind velocity in place of the Fastest Mile wind velocity.

The wind pressure increase due to nearby terrain features, building torsion produced by wind and biaxial wind loading of buildings are effects that must be structurally investigated as described in ASCE 7, 1995.

Client	WHC	WO/Job No.	
Subject	ASCE-7 1988-1995	Date	6-14-96 By RA Giller
	Comparison	Checked	6-14-96 By Nd Ita
Location		Revised	By

Wind Load Comparison for the ASCE Standard &
and the Hanford Site Design Criteria

Purpose:

Compare the ASCE-7 1988 and 1995 editions of this standard. Evaluate the effects and impact that these changes will have to the Hanford Site Design Criteria.

Scope:

This evaluation and comparison will investigate the changes in ASCE-7 for wind, snow, and other loads except seismic. The results shall be reported in an SD document.

Site Design Criteria:

GC-LOAD-01, *Design Loads for Facilities.*
UCRL-15910, *Design and Evaluation Guidelines for DOE Facilities*
Subjected to Natural Phenomena Hazards.
UBC-1994, *Uniform Building Code.*
ASCE-7, 1988, *Minimum Design Loads for Buildings and Other structures.*
~~WHC SP 1174, *Structural Design and Evaluation Criteria.*~~
WHC-CM-1-12, *Structural Design and Evaluation Criteria.*
DOE-STD-1020, *Natural Phenomena Hazards Design and Evaluation Criteria for*
DOE Facilities.

Conclusions:

The wind designation change from fastest mile to 3 second gust winds does not change the wind loads at the Hanford Site. The wind speed contours map change also does not change the wind loads at Hanford. There are three significant changes in ASCE-7 1995 that do change wind loads at Hanford and they are listed as follows.

1. Low rise buildings have lower wind loading in ASCE-7, 1995.
2. All buildings must now be evaluated for torsion wind effects.
3. Wind loads in biaxial directions must now be combined.

Snow, and Rain loads have some small changes as discussed in the report. Most of the above site design criteria documents give wind load information based on the ASCE-7, 1988 which will require changing to match the 1995 edition.

DESIGN ANALYSIS

Calc. No. _____
Revision _____
Page No. B2 of _____

Client	WHC	WO/Job No.	
Subject	ASCE-7 1988 - 1995	Date	6-5-96 By RA Giller
	Comparison	Checked	6/14/96 By ND Ha
Location		Revised	By

CASE 1:

Low Rise, $h = 50'$
Roof Slope $\theta < 10^\circ$

CASE 2:

Low Rise, $h = 50'$
 $\theta = 20^\circ$

CASE 3:

High Rise, $h = 80'$

High Rise $h > 60'$
ASCE-7 1988

CASE 4:

High Rise, $h = 80'$
Flexible Bldg

CASE 5:

Open Sided, $h = 80'$

High Rise $h > 60'$
ASCE-7 1995

DESIGN ANALYSIS

Client	WHC	WO/Job No.	
Subject	ASCE-7 1988-1995	Date	6-5-96 By R A Giller
	Comparison	Checked	6/14/96 By N D Ita
Location		Revised	By

CASE 1 : $h=50'$, $\theta < 10^\circ$

ASCE-7 1988	ASCE-7 1995
<p><u>Velocity Pressure</u> : q</p> $q = .00256 K_z (VI)^2$ $K_z = 1.13 \quad V = 70 \quad I = 1.0$ $q = 14.2 \text{ psf}$ <p><u>Design Wind Pressures</u> : P</p> <p><u>Main Frame</u></p> $P = q G_h C_p - q G_h C_{pi} \quad \begin{matrix} \text{windward} \\ \uparrow \\ \text{leeward} \end{matrix}$ $= q (1.21)(.8) - q (.25) \quad \begin{matrix} \text{windward} \\ \text{wall} \end{matrix}$ $+ q (1.21)(.5) + q (.25) \quad \begin{matrix} \text{lee ward} \\ \text{wall} \end{matrix}$ $P = q (1.21)(.8 + .5) = \boxed{22.3 \text{ psf}}$ <p><u>Cladding & Components</u></p> $P = q [G C_p \pm G C_{pi}]$	$q = .00256 K_z K_{zt} V^2 I$ $K_z = 1.09 \quad K_{zt} = 1.0$ $V = 85 \quad I = 1.0$ $q = 20.2 \text{ psf}$ <p><u>Main Frame</u></p> $p = q [G C_{pf} - G C_{pi}]$ $= q [.4 - .18] \quad \text{windward}$ $+ q [.29 + .18] \quad \text{leeward}$ $p = q (.4 + .29) = \boxed{13.9 \text{ psf}}$ <p><u>Cladding & Components</u></p> $P = q [G C_p - G C_{pi}]$

DESIGN ANALYSIS

Client WHC

WO/Job No. _____

Subject _____

Date 6-5-96 By RA Giller

Location _____

Checked 6/14/96 By N & H

Revised _____ By _____

CASE 1: Continued

ASCE - 7 1988

Roof C & C

$$P_1 = q(1.4 \pm .25) = 23.4 \text{ psf}$$

$$P_2 = q(2.6 \pm .25) = 40.5 \text{ psf}$$

$$P_3 = q(4 \pm .25) = 60.4 \text{ psf}$$

Wall C & C

$$P_4 = q(1.5 \pm .25) = 24.9$$

$$P_5 = q(2 \pm .25) = 32.0$$

ASCE - 7 1995

Roof C & C

$$P_1 = q(1 \pm .18) = 23.8$$

$$P_2 = q(1.9 \pm .18) = 42.0$$

$$P_3 = q(2.8 \pm .18) = 60.2$$

Wall C & C

$$P_4 = q(1.1 \pm .18) = 25.8$$

$$P_5 = q(1.4 \pm .18) = 31.9$$

DESIGN ANALYSIS

 Client WHC

WO/Job No. _____

Subject _____

 Date 6-9-96 By RA Giller

Location _____

 Checked 6/14/96 By N D Itz
 Revised _____ By _____

CASE 2: $h = 50'$ $\theta = 20^\circ$
ASCE-7 1988
Velocity Pressure:

$$q = 14.2 \text{ psf}$$

Design Pressure:
Main Frame

$$P = 22.3 \text{ psf}$$

Roof C & C

$$P_1 = q(1.3 + .25) = 22.0$$

$$P_2 = q(3 + .25) = 46.1$$

$$P_3 = q(3 + .25) = 46.1$$

Wall C & C

$$P_4 = q(1.5 \pm .25) = 24.9$$

$$P_5 = q(2 \pm .25) = 32.0$$

ASCE-7 1995

$$q = 20.2 \text{ psf}$$

Main Frame

$$P = q(.53 + .43) = 19.4 \text{ psf}$$

Roof C & C

$$P_1 = q(.9 + .18) = 21.8$$

$$P_2 = q(2.1 + .18) = 46.1$$

$$P_3 = q(2.1 + .18) = 46.1$$

Wall C & C

$$P_4 = q(1.1 + .18) = 25.8$$

$$P_5 = q(1.4 + .18) = 31.9$$

DESIGN ANALYSIS

Client WHC

WO/Job No. _____

Subject _____

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Location _____

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CASE 3: $h = 80'$

ASCE-7 1988

Velocity Pressure:

$$q = .00256 K_z (VI)^2$$

$$K_z = 1.29$$

$$q = 16.2 \text{ psf}$$

Design Wind Pressure:Main Frame

$$P = q(1.18)(.8 + .5) = 24.9$$

Roof C & C

$$P_1 = q(2 \pm .25) = 36.4$$

$$P_2 = q(2.5 \pm .25) = 44.6$$

$$P_3 = q(4 \pm .25) = 68.8$$

$$P_4 = q(5 \pm .25) = 85.0$$

Wall C & C

$$P_5 = q(1.1 \pm .25) = 21.9$$

$$P_6 = q(1.8 \pm .25) = 33.2$$

$$P_7 = q(2.5 \pm .25) = 44.6$$

ASCE-7 1995

$$q = .00256 K_z K_{zt} V^2 I$$

$$K_z = 1.21$$

$$q = 22.4 \text{ psf}$$

Main Frame

$$P = q(.85)(.8 + .5) = 24.8$$

Roof C & C

$$P_1 = q(1.4 \pm .18) = 35.4$$

$$P_2 = q(2.3 \pm 1.8) = 55.6$$

$$P_3 = q(3.2 \pm 1.8) = 75.7$$

Wall C & C

$$P_4 = q(.9 \pm .18) = 24.2$$

$$P_5 = q(1.8 \pm .18) = 44.4$$

DESIGN ANALYSIS

Client	WHC	WO/Job No.	
Subject		Date	6-5-96 By RA Giller
Location		Checked	6/14/96 By N D Iw
		Revised	By

CASE 4: flexible Bldg, $h = 80'$

ASCE-7 1988	ASCE-7 1995
<p><u>Velocity Pressure:</u></p> <p>$q = 16.2 \text{ psf}$ same as Case 3</p> <p><u>Design Wind Pressure:</u></p> <p><u>Main Frame</u></p> <p>$p = q \bar{G} C_p$</p> <p>$p = q \bar{G} (.8 + .5) = 1.3 q \bar{G}$</p> <p>$\bar{G} = G_f =$ responses obtained by rational analysis</p> <p><u>Roof & Wall C & C</u></p> <p>same as case 3</p>	<p>$q = 22.4 \text{ psf}$ same as case 3</p> <p><u>Main Frame</u></p> <p>$p = q G_f C_p$</p> <p>$p = q G_f (.8 + .5) = 1.3 q G_f$</p> <p>$G_f = \bar{G} =$ response obtained by rational analysis</p> <p><u>Roof & Wall C & C</u></p> <p>same as case 3</p>

DESIGN ANALYSIS

 Client WHC

WO/Job No. _____

Subject _____

 Date 6-5-96 By RA Giller

Location _____

 Checked 6/14/96 By N D Itt

Revised _____ By _____

CASE 5: $h = 80'$ Open sided building

ASCE-7 1988
ASCE-7 1995
Velocity Pressure:

$$q = 16.2 \text{ psf}$$

$$q = 22.4 \text{ psf}$$

Design Wind Force:
Main Frame

$$F = q G_h C_f A_f$$

$$F = q (1.18)(.8+.5) A_f$$

$$F = \boxed{24.8 A_f}$$

Roof & Wall C & C

$$F = \boxed{24.8 A_f}$$

Main Frame

$$F = q G C_f A_f$$

$$F = q (.85)(.8+.5) A_f$$

$$F = \boxed{24.7 A_f}$$

Roof & Wall C & C

$$F = \boxed{24.7 A_f}$$

DESIGN ANALYSIS

Client WHC

WO/Job No. _____

Subject _____

Date 6-5-96 By RA Giller

Location _____

Checked 6/14/96 By N D Itt

Revised _____ By _____

Torsion Effects :

Low Rise Building

Assume :

Shear wall structure

lateral wind force

$$F = 100^K$$

50^K each wall

Wind
Torsion
Force

T

Example

Torsion force

$$T = 100 \left(\frac{1}{10} \right) \left(\frac{.61 - .4}{.4} \right)$$

$$= 5.25^K$$

Find Wind Force

$$50 + 5.25 = 55.25^K/\text{wall}$$

$$\frac{5.25}{50} = 10\% \text{ increase}$$

DESIGN ANALYSIS

Client WHC

WO/Job No. _____

Subject _____

Date 6-5-96 By RA Giller

Location _____

Checked 6/19/96 By N J H

Revised _____ By _____

Combined Wind Effects :

ASCE-7 1995

Figure 6.9

[Find load in each column for
a wind force in one direction only.]

$$\text{Col. 1, 2, 3, 4} = \pm (F_w) \left(\frac{h}{2} \right) \div L (2 \text{ columns}) = \frac{F_w h}{4L}$$

[Find load in columns for 75%
wind force in each direction]

$$\frac{.25 F_w h}{L}$$

$$\text{Col. 1-4} = \pm \left(\frac{3}{4} F_w \right) \left(\frac{h}{2} \right) \div 2L \pm \left(\frac{3}{4} F_w \right) \left(\frac{h}{2} \right) \div 2L$$

$$= \pm \frac{3 F_w h}{16L} \pm \frac{3 F_w h}{16L}$$

$$= \pm \frac{6 F_w h}{16L} \text{ or } 0$$

$$= \pm .375 F_w h / L$$

$\Rightarrow$

Columns 1 & 4
are 50% higher
loaded

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Project Title/Work Order Wind Load Comparison for the ASCE Standard 7 and the Hanford Site Design Criteria.		EDT No. 615763 <hr/> ECN No.

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