Technical Evaluation Report
on
Design Basis Tornadoes for the Grand Gulf ESP Site

JCN J-3067: Early Site Permit Application Reviews

Task 03: Confirmatory Analyses of Site Specific Design Basis Tornadoes

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Tornado data in the National Climatic Data Center storm events database have been analyzed to estimate design basis tornado parameters for the Grand Gulf ESP site. The data cover the period from January 1, 1950 through August 31, 2003. Using the procedure outlined below, the best estimate tornado strike probability and 10^{-7} probability design wind speed for the ESP site are 7.4×10^{-4} yr^{-1} and 294 mph, respectively. The 95% confidence level estimates of the tornado strike probability and 10^{-7} probability design wind speed for the ESP site are 9.4×10^{-4} yr^{-1} and 302 mph, respectively.

Introduction

The National Climatic Data Center (NCDC) maintains a storm events database that lists statistics for tornadoes striking the contiguous United States. In February, 2004, a copy of the database was obtained from NCDC for use in updating NUREG/CR-4461 (Ramsdell and Andrews 1986). The database covered the period from January 1, 1950 through August 31, 2003, and contained entries for more than 49,000 tornado events. More than 47,000 of the entries contained sufficient information to be useful. A tornado event may be all or just a portion of a tornado because the tornado data are listed by state.

Among the statistics included in the database for tornadoes are date, time, location, length, width, and maximum intensity (wind speed). Of these statistics, the most useful are the location, length, width, and maximum intensity. If these four elements are present, data for the event will be used in all aspects of the analysis. If only the location and intensity are listed, the tornado will not be used in estimating tornado dimensions, but the tornado will be counted and used in estimating strike probabilities.

The general approach used to evaluate tornado strike probabilities and design wind speed follows the approach taken in NUREG-4461. However, three significant modifications have been made to that approach. The first modification is addition of the "lifeline" term included in the tornado risk model developed by Garson et al. (1975). Their model includes four terms, two of which are relevant to this analysis. The first term describes the risk to a structure when the structure is small compared to tornado dimensions. This term is called the "point structure" term. It was evaluated in NUREG/CR-4461 and is evaluated here. The second term describes risks to structures that have characteristic dimensions larger than the width of a tornado. This term, which is called the lifeline term, was not evaluated in NUREG/CR-4461. It is included in this analysis. The second modification to the approach is to account for the variation of tornado intensity along and across the tornado path. The analysis in NUREG/CR-4461 assumed that the entire tornado footprint experienced wind speeds equaling or exceeding the minimum wind speed for the reported tornado intensity (Fujita F-Scale). This analysis accounts for the variation of wind speed along and across the path. The third modification to the analysis in NUREG/CR-4461 is the estimation of the total pressure drop and rate of decrease in pressure associated with the tornado.

Analytical Method

The specification of a design basis wind speed has two parts. The first part is specification of an exceedence probability, and the second is specification of the appropriate wind speed for the exceedence probability. The approach followed in the past (Markee et al. 1974; AEC 1974; Shreck and Sandusky 1982; Ramsdell and Andrews 1986) has been to define the exceedence probability, to estimate the probability of a tornado striking a site, and to determine the conditional probability of exceeding specified wind speeds assuming that a tornado strike occurs. The design exceedence probability and the strike probability are used to establish a conditional probability which is converted to the design wind speed. This same general procedure is used in this analysis.

Point Structures

Consider first, the point structure probability, P_p. The probability of the wind speed, u, exceeding some value u_o at a site is defined as the product of the probability that a tornado will strike the point structure and the conditional probability that the wind speed u will exceed u_o assuming that a tornado strike occurs

$$P_p(u \geq u_o) = P_p \times P_p(u \geq u_o|s) \quad (1)$$

The strike probability can now be defined without regard to the tornado intensity. It is

$$P_p = \frac{A_t}{NA_r} \quad (2)$$

where A_t is the total area (mi^2) impacted by tornadoes in the region of interest, which has an area denoted by A_r, (mi^2), and N is the number of years of record. For this analysis, A_r the area of a two-degree box centered on the Grand Gulf ESP site (~16,194 mi^2), and the N is 53.67 years. The total tornado area is the product of the expected area for a tornado event and the total number of tornado events that impacted the region of interest in N years.

The total area impacted by tornadoes is estimated from the tornado data base. The expected area of tornado events is determined assuming that the areas of individual events have a log-normal distribution. This assumption was made in the analysis leading to NUREG/CR-4461, and is supported by cursory examination of the distribution of the event areas in a companion study (JCN J-3067). The calculation of expected values for the log-normal distribution is described in NUREG/CR4461. NUREG/CR-4461 also describes estimation of the upper and lower bounds of the 90% confidence interval (5% and 95% points) for the expected value. The total impacted area is the product of the number of events and the expected value for an individual event. The number of events in this calculation includes events that were considered in calculation of the expected value of the area because of missing information.

The 95% bound on the strike probability is calculated the same as the strike probability except that the 95% upper bound for the expected area is used in place of the expected area.

In NUREG/CR-4461, it was assumed that

$$A_{u \geq u_o} = A_{f \geq f_o} \tag{3}$$

where $A_{f \geq f o}$ is the total area impacted by tornado with Fujita F-Scales greater than or equal to a reference F-Scale, f_o. That assumption significantly overestimated the area impacted by the highest wind speeds. For this analysis,

$$A_{u \geq u_o} = \sum_{f=0}^{5} A_f F_A(u \geq u_o | f) \tag{4}$$

where A_f is the area impacted by tornadoes of F-Scale f and $F_A(u \geq u_o|f)$ is the fraction of the area impacted by tornadoes of F-Scale f that has wind speeds equaling or exceeding u_o. Reinhold and Ellingwood (1982) include several tables that contain values for $F_A(u \geq u_o|f)$. Table 1 (Reinhold and Ellingwood Table 15d) lists the values of F used in this analysis. Based on this table, 48.4% of the area impacted by an F2 tornado is assumed to have wind speeds in the 40 to 72 mph range, 41.4% is assumed to have wind speeds in the 73 to 112 mph range, and the remaining 10.2% of the area is assumed to be impacted by wind speeds in the 113 to 157 mph wind speed range.

Application of the adjustment of areas based on tornado event dimensions to areas associated with intensity (wind speed) is illustrated in Table 2. The first column in the table lists the reported F-Scale and the last column lists the range of maximum wind speeds associated with the F-Scale. The total area impacted for tornadoes in each category is listed in the second column. The third column lists the area by wind speed classes after adjustment to account for variation in wind speed within the impact area. For example, the total area impacted by winds from 40 through 72 mph is all of the area of F0 tornadoes plus 75.1% of the area impacted by F1 tornadoes plus 48.4% of the area impacted by F2 tornadoes, etc. Note that the areas in column 3 decrease monotonically with increasing wind speed, while the areas in column 2 do not. Note also, that the total impact area for all tornadoes before and after the adjustment remains constant within limits of roundoff error. As a result, the adjustment does not affect the strike probability. The fourth column lists cumulative area based on wind speed. The F0 entry list the total area for tornadoes of all classes. This is the area to be used in calculating the strike probability. The F1 entry lists the total area with wind speeds of 73 mph or greater, etc.

Table 1 Tornado area intensity distribution for the point structure design wind speed estimates.

Intensity F-Scale	Wind Speed Range (mph)	Recorded Tornado F-Scale					
		F0	F1	F2	F3	F4	F5
F0	40 - 72	1.000	0.751	0.484	0.316	0.315	0.293
F1	73 - 112		0.249	0.414	0.423	0.371	0.330
F2	113 - 157			0.102	0.205	0.199	0.201
F3	158 - 206				0.056	0.089	0.112
F4	207 - 260					0.026	0.050
F5	261 -318						0.014

Table 2. Area Impacted by Tornadoes in the Central United States.

F-Scale	Total Area (mi^2) by F-Scale	Total Area (mi^2) by Wind Speed	Cumulative Area (mi^2)	Probability of Wind Speed Exceeding Threshold	Wind Speed Range (mph)
F0	412.43	12,172.16	27,336.40	1.00	40 - 72
F1	4090.05	10,263.32	15,164.24	5.55×10^{-1}	73 - 112
F2	8920.88	3,729.87	4,900.92	1.79×10^{-1}	113 - 156
F3	8230.74	988.01	1,171.05	4.28×10^{-2}	157 - 205
F4	4753.35	170.03	183.04	6.70×10^{-3}	206 -259
F5	928.95	13.01	13.01	4.76×10^{-4}	≥ 260

Equation (1) shows the probability of exceeding a given wind speed at point as the product of two components. The first component is the probability of a tornado striking a point, and the second component is a conditional probability of exceeding a given wind speed assuming that a tornado strike occurs. As indicated above, the strike probability can be estimated from the total area impacted by tornadoes without regard to F-Scale. The conditional probability of exceeding u_o given that a tornado has occurred is estimated as

$$P_p(u \geq u_o | s) = \frac{A_{u \geq u_o}}{A_t} \tag{5}$$

where $A_{u \geq u_o}$ is the total area impacted by wind speeds greater than u_o. The next to last column in Table 3 lists the results of applying Eq. (5) to the areas in column 4. These values, with the lower bound wind speed in each range in the last column, provide up to six points on a curve that can be used to represent the conditional probability.

The contiguous United States has been divided into three regions for the purpose of determining the conditional probability to ensure that there are sufficient tornadoes to adequately define the frequency of low probability events. Figure 1 shows the regions, and Table 3 presents the results of analyses for three regions of the country. The numbers in the figure are the number of events in each one-degree box. The approximate location of the Grand Gulf ESP site is indicated by the dot in Region II. Note that Table 3 contains results based on both expected values for area and the 95^{th} percentile bound for the expected values.

The probability of exceeding u_o may be represented by a Weibull distribution. In that distribution

$$P_p(u \geq u_o | s) = Exp\left[-\left(\frac{u_o - 40}{a_p}\right)^{b_p}\right] \tag{6}$$

where 40 is the minimum tornado wind speed, and a and b are parameters of the Weibull distribution. Estimation of these parameters requires good estimates of $A_{u \geq u_o}$, which can only be obtained from considering a large number of tornadoes. The Weibull distribution parameters have been estimated for three regions of the contiguous United States from the tornado intensity distributions presented in Table3 using an optimization procedure, for example the Nelder-Mead Simplex algorithm (Nelder and Mead 1965), to determine the parameter values that minimize the sum of squares of the errors between the probabilities estimated using the Weibull distribution and the observed probabilities. The parameter values are listed in Table 4.

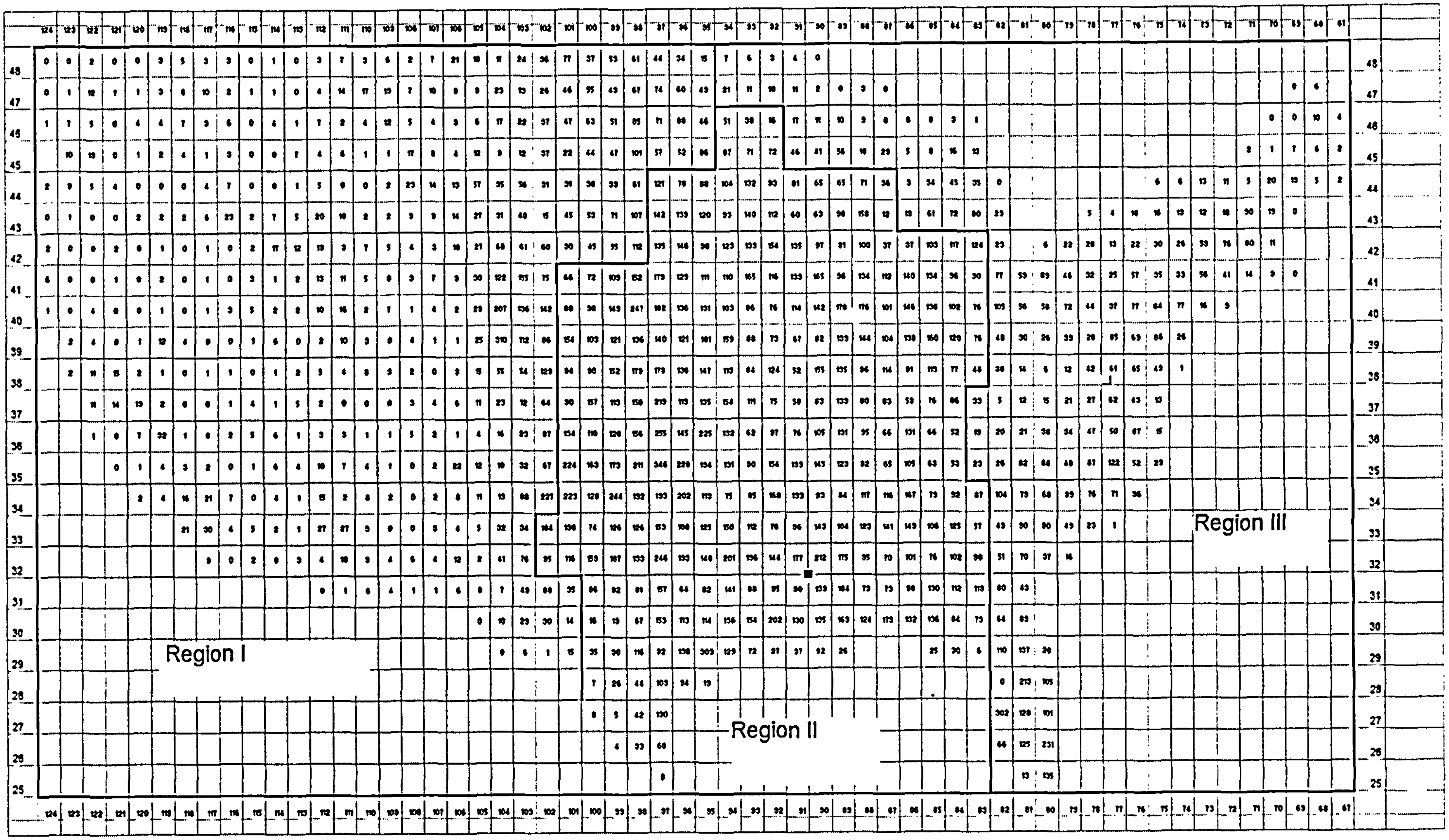

Figure 1. Tornado Regions in the Contiguous United States Showing the Approximate Location of the Grand Gulf ESP Site.

Table 3. Conditional Probability of Equaling or Exceeding Specified Wind Speeds Given a Tornado Strike.

Wind Speed (mph)	Region I		Region II		Region III	
	Expected. Value	95% Bound	Expected. Value	95% Bound	Expected. Value	95% Bound
≥ 40	1.0	1.0	1.0	1.0	1.0	1.0
≥ 73	5.27×10^{-1}	5.65×10^{-1}	5.51×10^{-1}	5.55×10^{-1}	5.39×10^{-1}	5.54×10^{-1}
≥ 113	1.63×10^{-1}	1.94×10^{-1}	1.75×10^{-1}	1.79×10^{-1}	1.66×10^{-1}	1.81×10^{-1}
≥ 157	3.77×10^{-2}	5.08×10^{-2}	4.08×10^{-2}	4.28×10^{-2}	3.93×10^{-2}	4.40×10^{-2}
≥ 206	6.23×10^{-3}	9.25×10^{-3}	6.08×10^{-3}	6.70×10^{-3}	5.55×10^{-3}	6.47×10^{-3}
≥ 260	5.97×10^{-4}	8.77×10^{-4}	3.83×10^{-4}	4.76×10^{-4}	1.40×10^{-4}	1.91×10^{-4}

Table 4 Weibull distribution parameters for the point structure conditional probability term.

Weibull Parameter	Region I		Region II		Region III	
	Best Estimate	95 %	Best Estimate	95%	Best Estimate	95%
a_p	46.74	52.00	51.14	51.14	55.72	56.85
b_p	1.291	1.348	1.407	1.389	1.574	1.572

Large Structures

Consider now, the probability represented by the lifeline term. If a structure is large, the probability of being struck by a tornado is greater than that determined based only on tornado dimensions. The additional probability is determined by a characteristic dimension of the structure and the expected length for tornadoes. This additional probability is estimated by the lifeline term.

The process for estimating the lifeline term is nearly identical to the process for estimating the point structure term. The initial step is to separate the desired probability into a strike probability that is independent of intensity and a conditional probability that considers intensity

$$P_l(u \geq u_o) = P_l \times P(u \geq u_o | s) \qquad (7)$$

The initial definition of the strike probability is also the same.

$$P_l = \frac{A_t}{NA_r} = \frac{w_s L_t}{NA_r} \qquad (8)$$

However, in this case, the impacted area is estimated as the product of a characteristic building dimension, w_s, (mi), and the total length of tornado paths, L_t (mi). A characteristic dimension of 200 ft (0.0379 mi) has been assumed for this analysis. With this change, the conditional probability statement becomes

$$P_l(u \geq u_o | s) = \frac{L_{u \geq u_o}}{L_t} \qquad (9)$$

where $L_{u \geq u_o}$ is the total tornado path length with wind speeds equaling or exceeding u_o.

Continuing the analogy with the "point structure" term, $L_{u \geq u_o}$ is estimated as

$$L_{u \geq u_o} = \sum_{f=0}^{5} L_f F_L(u \geq u_o | f) \qquad (10)$$

where L_f is the total path length of tornadoes of F-Scale f and F_L is the fraction of the length having wind speed equaling or exceeding u_o. Table 5 from Reinhold and Ellingwood (1982) lists appropriate values for $F_L(u \geq u_o|f)$.

Table 5. Tornado length intensity distribution for the lifeline term estimates.

Intensity F-Scale	Wind Speed Range (mph)	Recorded Tornado F-Scale					
		F0	F1	F2	F3	F4	F5
F0	40 - 72	1.000	0..572	0.280	0.116	0.142	0.133
F1	73 - 112		0.428	0.352	0.245	0.158	0.102
F2	113 - 157			0.368	0.318	0.278	0.189
F3	158 - 206				0.321	0.210	0.242
F4	207 - 260					0.212	0.185
F5	261 -318						0.149

As before, the conditional distribution can be represented by a Weibull distribution.

$$P_l(u \geq u_o|s) = Exp\left[-\left(\frac{u_o - 40}{a_l}\right)^{b_l}\right] \tag{11}$$

Parameters for the distribution for the three regions of the contiguous United States are listed in Table 6.

Table 6. Weibull distribution parameters for the lifeline conditional probability term.

	Region I		Region II		Region III	
Weibull Parameter	Best Estimate	95 %	Best Estimate	95%	Best Estimate	95%
a_l	51.59	55.19	70.03	70.02	65.28	65.47
b_l	1.284	1.298	1.613	1.601	1.621	1.581

Thus, the total probability of a structure being struck by a tornado with winds exceeding some value u is the sum of the point structure and lifeline probabilities

Equation (12) provides the means to estimate the probability of a tornado strike with wind speeds exceeding u_o, but it can not be inverted to estimate the wind speed, u_o, associated with a given probability. Estimation of the wind speed associated with a given probability involves two steps. In the first step, strike probabilities are estimated for a range of wind speeds that is sufficiently large that the strike probability of interest is included within the range of calculated strike probabilities. Then, in the second step the wind speed of interest, u_o, associated with the given probability is determined by interpolation.

$$\begin{aligned} P(u \geq u_o) &= P_p(u \geq u_o) + P_l(u \geq u_o) \\ &= \frac{A_t}{NA_r} Exp\left[-\left(\frac{u_o - 40}{a_p}\right)^{b_p}\right] + \frac{w_s L_t}{NA_r} Exp\left[-\left(\frac{u_o - 40}{a_l}\right)^{b_l}\right] \end{aligned} \tag{12}$$

The cyclostrophic wind equation and Rankine vortex wind profile can be used to estimate the total pressure drop and rate of decrease in pressure as the core of the tornado passes over a point. The cyclostrophic wind equation represents a balance between pressure gradient and centifugal forces. It is

$$-\frac{1}{\rho}\frac{\partial p}{\partial r} = \frac{u_r^2}{r_{max}} \tag{13}$$

where ρ is the air density, p is the pressure, r is the radial direction, u_r is the rotational component of the wind, and r_{max} is the radius of maximum wind speed. For this analysis, dry air at a pressure of 1000 mb and 68 °F is assumed giving an air density of 0.07414 lb/ft³ (1.188 kg m³).

Assuming a translational speed, u_t, for the tornado, Eq. (13) becomes

$$-\frac{\partial p}{\partial t} = \frac{u_t}{r_{max}} \rho u_r^2 \qquad (14)$$

Multiplying both sides of Eq. (14) by the time required for the tornado to move a distance equal to r_{max} yields the maximum pressure drop

$$-\Delta p = -\frac{\partial p}{\partial t}\frac{r_{max}}{u_t} = \rho u_r^2 \qquad (15)$$

The maximum wind speed in the tornado is the sum of the translational speed and the rotational speed. For this analysis, the translational speed has been assumed to be

$$u_t = 0.20 u_o \qquad (16)$$

where u_o is the design wind speed. The fraction 0.20 is consistent with current NRC guidance (AEC 1974). However, actual tornadoes may move faster or slower than estimated by Eq. (16). Both Regulatory Guide 1.76 and the ANS standard for estimating tornado characteristics (ANS 1983) states that the minimum value for u_t is 5 mph. Pressure drop estimates have been calculated for a translational speed of 5 mph in addition to the speeds calculated by Eq. (16). Increasing the fraction increases the translational speed, but it decreases the maximum pressure drop because the pressure drop is proportional to the square of the rotational speed, which decreases.

The Rankine vortex model provides the wind profile across the tornado. It is

$$u_r r = k(f) \qquad (17)$$

for $r \geq r_{max}$ where *k(f)* is a constant that is a function of the tornado F-Scale, and

$$\frac{u_r}{r} = k(f) \qquad (18)$$

for $r \leq r_{max}$. The constant in these equations is estimated as

$$k(f) = \frac{w(f)}{2} u_d \qquad (19)$$

where w(f) is the expected width of tornadoes of the given F-Scale, and u_d is a threshold wind speed for damage to occur. One set of values for the expected width for tornadoes is used for the entire contiguous United States. The expected tornado widths assumed for this analysis are listed in Table 7. There is some evidence that there are regional differences in tornado widths. However, the differences do not appear to be sufficient to warrant use of local expected values that may be based on relatively few tornadoes.

Following the lead of Reinhold and Ellingwood (1982), a damage threshold of 59 mph has been used in this analysis. Use of a damage threshold of 75 mph, as is suggested in the ANS standard (ANS 1983) and the IAEA safety guide (IAEA 1981), disregards F0 tornadoes in their entirety.

Table 7. Expected tornado widths for the contiguous United States.

	F-Scale					
	0	1	2	3	4	5
Expected width (ft)	115	220	415	920	1650	2050

Given the tornado width and the damage threshold, the radius of maximum wind speed is determined from Eqs. (17) and (19) as

$$r_{\max} = \frac{w(f)u_d}{2u_r} \tag{20}$$

Analytical Results.

This section describes the results of evaluation of a design basis tornado for the Grand Gulf ESP site. The analysis considers tornado events occurring within a two-degree latitude and longitude box, centered on the site from January 1, 1950 through August 31, 2003. The area of the box is 15,037 mi^2.

During the period of record there were 213 tornado events within the area. The characteristics of these tornadoes are summarized in Table 8. Log-normal distributions were assumed for the lengths and areas of the tornado events.

Table 8. Characteristics of Tornadoes Within a Two Degree Box Centered on the Grand Gulf ESP Site.

Event Intensity	Number of Events	Number with Length	Expected Length (mi)	Number with Area	Expected Area (mi^2)
≥F0	587	529	6.74	529	0.84
≥F1	470	421	8.15	421	1.00
≥F2	231	217	11.12	217	1,50
≥F3	84	82	12.51	82	2,23
≥F4	30	29	13.93	29	2.74
≥F5	7	7	14.18	7	2.39

Table 9 lists tornado strike probabilities for the Grand Gulf ESP site as a function of maximum wind speed. Both expected (best estimate) and upper 95% confidence limit strike probabilities are listed in the table. All probabilities are based on the assumption that the tornado event lengths and areas have log-normal distributions. The 95% confidence limit values are the sum of the 95% confidence limit values for the point structure and lifeline terms.

Table 9. Tornado Strike Probabilities as a Function of Maximum Wind Speed for the Grand Gulf ESP Site.

Maximum Wind Speed (mph)	Expected Strike Probability (yr^{-1})			Upper 95% Confidence Limit (yr^{-1})		
	Point	Lifeline	Total	Point	Lifeline	Total
40	$5.6x10^{-4}$	$1.7x10^{-4}$	$7.4x10^{-4}$	$7.3x10^{-4}$	$2.0x10^{-4}$	$9.3x10^{-4}$
75	$3.2x10^{-4}$	$1.2x10^{-4}$	$4.4x10^{-4}$	$4.1x10^{-4}$	$1.4x10^{-4}$	$5.5x10^{-4}$
100	$1.6x10^{-4}$	$7.9x10^{-5}$	$2.4x10^{-4}$	$2.1x10^{-4}$	$9.2x10^{-5}$	$3.0x10^{-4}$
125	$7.3x10^{-5}$	$4.4x10^{-5}$	$1.2x10^{-4}$	$9.7x10^{-5}$	$5.1x10^{-5}$	$1.5x10^{-4}$
150	$3.0x10^{-5}$	$2.2x10^{-5}$	$5.2x10^{-5}$	$4.1x10^{-5}$	$2.6x10^{-5}$	$6.6x10^{-5}$
175	$1.1x10^{-5}$	$9.7x10^{-6}$	$2.1x10^{-5}$	$1.6x10^{-5}$	$1.1x10^{-5}$	$2.7x10^{-5}$
200	$3.9x10^{-6}$	$3.9x10^{-6}$	$7.8x10^{-6}$	$5.6x10^{-6}$	$4.7x10^{-6}$	$1.0x10^{-5}$
225	$1.3x10^{-6}$	$1.4x10^{-6}$	$2.7x10^{-6}$	$1.9x10^{-6}$	$1.8x10^{-6}$	$3.6x10^{-6}$
250	$3.8x10^{-7}$	$4.8x10^{-7}$	$8.7x10^{-7}$	$6.0x10^{-7}$	$6.1x10^{-7}$	$1.2x10^{-6}$
275	$1.1x10^{-7}$	$1.5x10^{-7}$	$2.6x10^{-7}$	$1.8x10^{-7}$	$1.9x10^{-7}$	$3.7x10^{-7}$
300	$3.0x10^{-8}$	$4.3x10^{-8}$	$7.3x10^{-8}$	$5.1x10^{-8}$	$5.7x10^{-8}$	$1.1x10^{-7}$
325	$7.6x10^{-9}$	$1.1x10^{-8}$	$1.9x10^{-8}$	$1.4x10^{-8}$	$1.6x10^{-8}$	$3.0x10^{-8}$

Characteristics of design-basis tornadoes for the Grand Gulf ESP site are listed in Tables 10 through 13. Tables 10 and 11 list characteristics for fast moving tornadoes, while the Tables 12 and 13 list characteristics for slow moving tornadoes. Fast moving tornado characteristics should be used when limiting factors in the design are sensitive to the rate of change in pressure, and the slow moving characteristics should be used when the limiting design factors are sensitive to total pressure drop or time of passage of the tornado.

Table 10. Best Estimate Grand Gulf Design Basis Tornado Characteristics for Fast Moving Tornadoes

	Probability Level		
Tornado Characteristic	1.0×10^{-5}	1.0×10^{-6}	1.0×10^{-7}
Maximum Wind Speed (mph)	194	247	294
Translational Speed (mph)	39	49	59
Rotational Wind Speed (mph)	155	197	235
Radius of Maximum Speed (ft)	175	246	257
Rate of Pressure Drop (psi/s)	0.27	0.39	0.64
Maximum Pressure Drop (psi)	0.83	1.34	1.90

Table 11. 95% Confidence Grand Gulf Design Basis Tornado Characteristics for Fast Moving Tornadoes

	Probability Level		
Tornado Characteristic	1.0×10^{-5}	1.0×10^{-6}	1.0×10^{-7}
Maximum Wind Speed (mph)	201	254	302
Translational Speed (mph)	40	51	60
Rotational Wind Speed (mph)	161	203	241
Radius of Maximum Speed (ft)	169	240	251
Rate of Pressure Drop (psi/s)	0.31	0.44	0.71
Maximum Pressure Drop (psi)	0.89	1.42	2.00

Table 12. Best Estimate Grand Gulf Design Basis Tornado Characteristics for Slow Moving Tornadoes

	Probability Level		
Tornado Characteristic	$1.0x10^{-5}$	$1.0x10^{-6}$	$1.0x10^{-7}$
Maximum Wind Speed (mph)	194	247	294
Translational Speed (mph)	5	5	5
Rotational Wind Speed (mph)	189	242	289
Radius of Maximum Speed (ft)	144	201	209
Rate of Pressure Drop (psi/s)	0.06	0.07	0.10
Maximum Pressure Drop (psi)	1.22	2.01	2.87

Table 13. 95% Confidence Grand Gulf Design Basis Tornado Characteristics for Slow Moving Tornadoes

	Probability Level		
Tornado Characteristic	$1.0x10^{-5}$	$1.0x10^{-6}$	$1.0x10^{-7}$
Maximum Wind Speed (mph)	201	254	302
Translational Speed (mph)	5	5	5
Rotational Wind Speed (mph)	196	249	297
Radius of Maximum Speed (ft)	139	195	204
Rate of Pressure Drop (psi/s)	0.07	0.08	0.11
Maximum Pressure Drop (psi)	1.32	2.13	3.02

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