RWDI

PHASE II TECHNICAL MEMORANDUM
FOR THE
ANCHORAGE AREA-WIDE
WIND SPEED STUDY
ANCHORAGE, ALASKA

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Submitted to: The Municipality of Anchorage

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EXECUTIVE SUMMARY

This Technical Memorandum deals with Phase 2 of the Anchorage Area-Wide Wind Speed Study. Phase 1, which was completed in July 1998, consisted of gathering available historical wind data for the study area and assessing its reliability for the purpose of predicting 50-year wind speeds and developing a wind zone map. Four weather stations were identified as having suitable long-term wind records: Anchorage International Airport; Elmendorf AFB; Merrill Field; and the Portman Residence on Upper DeArmoun (see Figure 1).

Phase 2 involved statistical analyses of historical wind data to determine wind speeds for various recurrence intervals. It also involved the use of a numerical interpolation model to estimate the spatial distribution of wind speed for several representative extreme wind speed events, selected during Phase 1. A trial wind zone map for the 50-year return period was produced.

Anchorage International Airport had reliable historical data for hourly 1-minute wind speeds, daily peak gusts and daily fastest mile speeds. Each of these data sets was subjected to two or more statistical methods to estimate extreme wind speeds for the 50-year, 100-year, 250-year and 1000-year return periods. A total of seven estimates of the 50-year fastest mile wind speed at 33 feet above grade in open terrain ranged between 69 and 74 mph.

Elmendorft AFB and Merrill Field had reliable historical data on the hourly 1-minute readings only. Three estimates of the 50-year wind speed ranged between 64 and 68 mph at Elmendorf AFB, and between 75 and 79 mph at Merrill Field. The Portman Residence had historical data on the daily peak gust speeds only. Two estimates of the 50-year wind speed ranged from 105 to 111 mph.

No long-term wind data were available for the large area that lies between the Portman Residence and the other three sites. Consequently, it was difficult to assess the spatial distribution of extreme wind speeds with great precision. Other information that shed some light on the spatial distribution included spot wind readings from a few other locations, anecdotal information from

experienced meteorologists in the Anchorage area, and published information on typical wind damage patterns. The following approach was taken to develop a trial wind zone map:

- Meteorological observations for 10 historical wind storms were extrapolated to predict the approximate spatial distribution of wind speed during these events. A sophisticated meteorological interpolation model known as CALMET was used for this purpose.

- The CALMET results for one of the 10 events was selected as a representative case for use in developing design wind speed zones (see Figure 2).

- Contours of 50-year fastest mile wind speed were then approximated by examining the CALMET results in combination with a published wind damage map, and the predicted 50-year wind speeds shown previously in Table 2.

- The resulting contours of 50-year wind speed were adjusted to produce trial wind speed zones with boundaries conforming to city streets.

The resulting trial wind zone map (Figure 3), includes design wind speed zones of 80 mph, 90 mph, 100 mph and 105 mph, aligned roughly parallel to the base of the Chugach Mountains. The highest zone, 105 mph, covers areas of higher elevation in the eastern and southeastern parts of Anchorage, east of Boniface Parkway and Bragaw & Abbot Loop Roads.

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1. INTRODUCTION AND BACKGROUND

The Municipality of Anchorage retained the team of BBFM Engineers of Anchorage and Rowan Williams Davies & Irwin (RWDI) of Guelph, Ontario, Canada to undertake a multi-phased study that involves the collection and analysis of available historic wind records for Anchorage. Phase 1, entitled "Data Collection and Reliability Analysis," was completed in July, 1998. The current report presents the results of Phase 2, which is entitled "Data Analysis and Development of Preliminary Wind Zones."

The overall goal of the complete study program is to develop a wind zone map for the Anchorage Building Service Area that is based on data collected from a variety of sources and which has a scientific and probabilistic basis. Up to this point, the wind design loads in Anchorage have been based on empirical data and the expertise of the local code review committees. The design wind speeds have not been based on a rigorous analysis.

Phase 1 was described in a Technical Memorandum dated July 29, 1998. It involved the collection of available historical wind data for the Anchorage area, and a review of the data to determine their reliability. Any identified bad readings were filtered from the data.

Four weather stations were identified as having long-term wind records: Anchorage International Airport; Elmendorf AFB; Merrill Field; and the Carl Portman Residence on Upper DeArmoun Road (see Figure 1 for the locations). Of these sites, Anchorage International Airport had the most reliable data set, having a long period record (over 40 years), few bad readings and good documentation on the siting of the instrument. Merrill Field and the Portman Residence had the least reliable data sets. The Merrill Field data set had a relatively large number of bad readings and some missing information on the siting of the instrument. The Portman Residence had a relatively short period of record (14 years) and some questions with respect to the reliability of the instrument.

Phase 2, which is the subject of the present report, involved statistical analyses of the long-term wind records to determine wind speeds for various recurrence intervals. It also involved the use of a numerical interpolation model to estimate the spatial distribution of wind speed for several representative extreme wind events selected during Phase 1. A trial wind zone map for the 50-year return period winds has been produced. Consideration for additional phases of this study is being given and may include a field monitoring program with new wind instrumentation sites (Phase 3). An analysis of updated wind data and a further refinement to a wind zone map are also being considered (Phase 4).

2. STATISTICAL ANALYSIS METHODS

2.1 Accounting for Instrument Exposure

It is important to correct for differences in instrument height and terrain roughness among the wind measurement sites, so that these effects are removed before any statistical comparisons are made. This section describes the process that was undertaken to correct the historical wind data sets for Anchorage.

The term "atmospheric boundary layer" is used to refer to the lowest layer of the atmosphere, where the wind is slowed down by the drag effect of numerous features on the surface such as vegetation, ground roughness and man-made structures. The mean wind speed (mean implying an averaging time of about one hour) generally increases with height until the top of the boundary layer is reached, at which point surface drag no longer plays a role. The height of the boundary layer is variable. Some authors have suggested that the best estimate in moderate to strong winds is approximately 2000ft, or 600m (Counihan, 1971[1]; Snyder, 1981[2]). Others, such as ESDU (1990)[3], give values that can exceed 6500ft (2000m) in very strong winds. A value of 2000ft has been adopted for the present study. Fortunately, the resulting correction factors are not very sensitive to the assumed boundary layer height. Had 6500ft been used instead of 2000ft, the difference in the correction factors would have been only about 5 percent.

Throughout the full depth of the boundary layer, the vertical profile of horizontal mean wind speed has been found to be well represented by a power law (Snyder, 1981), i.e.,

$$U = U_g \left(\frac{z}{z_g} \right)^{\alpha} \qquad (1)$$

where U is horizontal mean wind speed (mph) at height z (ft), U_g is the gradient wind speed (value of U at the top of the boundary layer, mph), z_g is depth of boundary layer, and α is the power law exponent.

The exponent of the power law, α, is a function of terrain roughness and takes on the following approximate values in a neutrally stable atmospheric boundary layer:

open water	-	0.10	(Exposure D in ASCE 7 - 95)
open country	-	0.14	(Exposure C)
suburban area	-	0.24	(Exposure B)
urban area	-	0.33	(Exposure A)

Equation 1 provides a relatively simple means of correcting hourly mean wind speed data recorded in homogeneous terrain. The applicable power law exponent is estimated for each wind direction sector and the measured speeds are scaled from anemometer height to the top of the boundary layer. The wind speeds are then scaled back down to a height of 33ft (10m) in standard open terrain. In order to correct fastest mile and peak gust wind speeds, the following additional expressions relating these speeds to the hourly mean are needed (based on Simiu et al., 1979)[4]:

$$U_{pk} = U + 3\,\sigma \qquad (2)$$

and,

$$U_{fm} = 0.5\,(U + U_{pk}) \qquad (3)$$

where U_{pk}, U_{fm} and σ are the peak gust speed, fastest mile speed and standard deviation of wind speed at height z above grade, respectively. The standard deviation of wind speed, σ, is a function of the mean wind speed, U, which leads to the concept of turbulence intensity, defined here as 100 σ/U. Turbulence intensity takes on the following approximate values at a height of 10m above grade:

open water	-	11%	(Exposure D)
open country	-	17%	(Exposure C)
suburban area	-	35%	(Exposure B)
urban area	-	> 40%	(Exposure A)

Equations 1, 2 and 3 are applicable only in relatively homogeneous terrain. When one looks upwind from a wind instrument at an airport, however, one often finds that the character of the terrain goes through many changes. In the immediate vicinity of the instrument, the terrain will consist of open runways and areas of short grass. Further away, extensive built-up areas may be encountered, punctuated by open areas or wooded areas. A simple power law expression does not adequately account for the complex velocity profile that results when wind flows over such non-uniform terrain.

Fortunately, practical methods exist for getting a better handle on these situations. RWDI makes use of the method recommended by ESDU (1990) for dealing with wind flowing over abrupt changes in terrain roughness. The method is based on the fact that an internal boundary layer develops downwind of an abrupt change. Above the top of this internal boundary layer, the velocity profile remains the same as upwind of the roughness change. Below the top of the internal boundary layer, the velocity profile is reflective of the changed terrain condition. The height of this layer increases with distance downwind of the roughness change. ESDU uses partly theoretical and partly empirical expressions to derive the ratio between the local wind speed at a site located a short distance downwind of a roughness change and the wind speed that would exist if the site were far downwind. This ratio can then be applied as a correction factor when scaling wind speeds from the height of the wind instrument to a reference height of 600m using power law expressions intended for homogeneous terrain.

ESDU provides a step-by-step procedure for performing the calculations, which RWDI has adopted. Note, however, that the Coriolis factor, f, comes into play in the ESDU calculations in such a way that the expressions can produce spurious results at low latitudes where f approaches 0. Consequently, RWDI has adopted the approach of fixing the latitude at 45 degrees when performing these calculations. This appears to give more realistic results.

In the present study, aerial photography and USGS topographical maps spanning the period from the 1950's through the 1990's were used to apply the ESDU method to each historical position of the wind instrument at each airport. The analysis was performed for 36 compass directions, in 10 degree increments. The results, expressed in terms of equivalent power law exponent, are summarized in Table 1. With these estimates of equivalent power law exponent in hand, Equations 1, 2 and 3 were then used to correct all measured wind speeds to 33ft above grade in open terrain.

Since the terrain roughness at Carl Portman's residence (Figure 1 shows the location) is relatively homogeneous in all directions, a simpler approach than the ESDU method was adopted for that site. A single representative power law exponent was derived based on a review of ground-based photography of the area. The resulting estimate is shown in Table 1.

TABLE 1: Estimated Equivalent Power Law Exponents

Site	**Period**	**Range of Equivalent Power Law Exponent**
Anchorage International	1953 to 1961	0.147 to 0.167
	1961 to 1972	0.146 to 0.174
	1972 to present	0.147 to 0.168
Elmendorf AFB	1953 to 1961	0.165 to 0.197
	1961 to present	0.157 to 0.182
Merrill Field	1953 to 1980	0.171 to 0.193
	1980 to present	0.160 to 0.197
Portman Residence	1984 to present	0.2

2.2 Estimation of Extreme Wind Speeds

By grouping and counting historical wind readings, we can obtain information on how often various wind speed ranges will occur. Mathematical expressions for the probability distribution can be fitted to the observed data and these expressions can then be used to estimate extreme wind speeds associated with various recurrence intervals.

Fitting techniques fall into two broad categories: those that make use of observed values of the annual maximum wind speed, and those that make use of observed hourly wind speeds. Probability distributions derived from annual maximum wind speeds are known as extreme value distributions and those derived from hourly observations are known as parent distributions. Both approaches were used in the present study.

Parent Distribution

If one counts hourly wind speed observations to determine how often the wind speed falls within various specified ranges, and then uses this information to plot the probability P that the wind speed will be below a value V, in coordinates of ln(-ln(P)) and ln(V), one frequently finds that the plotted curve approximates a straight line. The mathematical expression for a straight line in this coordinate system is known as the Weibull distribution.

The Weibull distribution has been widely used to represent the statistical distribution of hourly wind speed. Many examples can be cited. Pavia and O'brien (1986)[5], for example, applied it to wind speeds measured over the world's oceans, and Justus, et al. (1978)[6] have used it in wind energy applications.

There are several methods of fitting the Weibull distribution to observed data, and Conradsen and Nielsen (1984)[7] provide a good review. The maximum likelihood estimator is generally considered to be the most reliable method for all sizes of data set, but is computationally intensive. Simpler least squares methods have been most popular for wind data. Pavia and O'brien (1986) and Tuller and Brett (1984)[8], for example, preferred this approach. Least squares methods have been shown to perform reasonably well in comparison to maximum likelihood estimation (Conradsen and Nielsen., 1984).

The form of the Weibull distribution most commonly used with wind data, and that used in the present study, is as follows:

$$P(U) = 1 - e^{-(U/C)^k} \quad (4)$$

where P(U) is the probability of a velocity less than U (i.e., the cumulative probability), C is called the scale parameter and k the shape parameter. The probability density function is obtained by differentiating the distribution function, and is as follows:

$$p(U) = \frac{k}{C}\left(\frac{U}{C}\right)^{k-1} e^{-(U/C)^k} \quad (5)$$

Since Equation 4 forms a straight line in coordinates of ln(-ln (1-P)) and lnU, the least-square method can be applied in this coordinate system to estimate the parameters of the Weibull distribution. This approach was used in the present study.

The Weibull distribution provides information on hourly wind speed frequency. High hourly wind readings, however, tend to be clustered together in events that can last for several hours. The average duration of events tends to decrease with increasing wind speed and, at very high speeds, tends to be on the order of a few hours. Thus, a wind speed of 60 mph may be exceeded for 10 hours per year at some site, but may occur in only 3 events per year. In the present case, as in most wind engineering applications, it is of interest to know the frequency of events rather than the frequency of hourly wind speeds.

With this in mind, event frequencies were estimated using up-crossing theory. In essence, the up-crossing method involves statistically counting the number of times the wind speed crosses above a specified threshold, rather than counting the number of hourly occurrences of wind speed above the threshold. It can be shown that the average rate of crossing above a wind speed threshold, U, is related to the average absolute rate of change of hourly wind speed, by the following expression (based on Lepage and Irwin, 1985)[9]:

$$N = \frac{1}{2} \overline{|U'|} \, p(U) \tag{6}$$

where N is the crossing rate (s^{-1}) and U' is the rate of change of hourly wind speed (miles/hr^2). The average return period or recurrence interval, R, is obtained by taking the inverse of the crossing rate, 1/N.

The average absolute rate of change of hourly wind speed varies with wind speed and the following functional form has been found to fit well to observed values at most sites:

$$\overline{|U'|} = a\ U + b\ e^{-c\,U} \tag{7}$$

where a, b and c are empirical constants. In the present study, the average absolute rate of change of hourly wind speed was calculated directly from the historical hourly wind speed data. Rather than being true 1-hour averages, the historical hourly readings are approximate 1-minute averages taken on the hour, and the values of average absolute rate of change tend to be higher than would be obtained from true 1-hour averages (Lepage and Irwin, 1985). Consequently, a theoretical reduction factor was applied to the results to make them representative of true 1-hour averages. The corrected values of the average absolute rate of change were in the range from 1.2 to 4.7 mph at 33ft above grade in the open.

Extreme Value Distributions

The probability distribution of annual maximum wind speed is an example of an extreme value distribution. The mathematical form of the distribution is dependent on n, the number of independent wind storms that occur in a year. The mathematical form at the limit as n goes to infinity has long been studied by mathematicians and, because it is well known and understood, has been used to approximate the distribution when n is less than infinity but still large. The mathematical form most widely used with wind speed data is known as the Type I extreme value distribution, or the Gumbel distribution. This form of the distribution was used in determining extreme wind speeds for the ASCE 7 Standard in the United States (Simiu, et al., 1979; Peterka.and

Shahid, 1998[10]), and the National Building Code of Canada (Yip et al., 1995)[11]. Mathematically, the Type I distribution is expressed as follows:

$$P(U) = e^{-e^{-(U-\xi)/\theta}} = 1 - \frac{1}{N} \tag{8}$$

where P(U) is the annual probability of a velocity less than U, ξ is the scale parameter, θ is the shape parameter and N is the return period or recurrence interval in years.

As with the Weibull distribution, numerous methods are available for fitting observed data to a Type I distribution. *For the purposes of the present study, two methods previously used in the development of North American building codes have been used, namely, the method of moments and the method of the least square.*

In the method of moments, the scale and shape parameter are estimated from the observed sample mean and standard deviation, using the following expressions (Johnson and Kotz, 1970)[12]:

$$\theta = \frac{\sqrt{6}}{\pi}\,\sigma(U_{max}) \tag{9}$$

and,

$$\xi = \overline{U}_{max} - 0.57722\ \theta \tag{10}$$

where $\bar{U}_{max}$ is the average annual maximum wind speed and $\sigma(U_{max})$ is the standard deviation of annual maximum wind speed.

The least square method relies on the fact that the Type I distribution is linear in coordinates of ln(-lnP) and U. The observed values of annual maximum wind speed are ranked from lowest to highest value. The ith ranked speed, U_i, is assigned an estimated cumulative probability, $P_i = i/(N+1)$, where N is the number of years of data. The values of $\ln(-\ln P_i)$ and U_i are then subjected to least square fitting.

All methods of fitting probability distributions to observed data have inherent statistical sampling errors. Estimates of the sampling error are useful for assessing the level of confidence in the results. Simiu et al. (1979) used the following estimate of the standard deviation due to statistical sampling error, based on the method of moments:

$$\sigma(U_m) = \left[\frac{\pi^2}{6} + \frac{1.1396\ (y - 0.5772)}{\sqrt{6}} + 1.1\ (y - 0.5772\ )^2 \right]^{0.5} \frac{\xi}{\sqrt{n}} \qquad \textbf{(11)}$$

where $\sigma(U_m)$ is the standard deviation of the wind speed associated with the m-year recurrence interval, N is the number of years of data and y = -ln(-ln(1-1/N)). One standard deviation defines the 68% confidence interval (approximately), and two standard deviations defines the 95% confidence interval.

In the case of Anchorage International Airport, historical data on annual maximum wind speed were available for fastest mile wind speeds, peak gust speeds and the hourly 1-minute speeds. At Elmendorf AFB and Merrill Field, such data were available only for the hourly 1-minute speeds. At Carl Portman's residence, the data were available only for peak gust speeds. Type I distributions were fitted to all of these data sets. In the case of the hourly 1-minute speeds, a reduction factor was applied to the results to correct them to true 1-hour averages. The highest of the 1-minute readings are biased toward overestimating the true 1-hour average, and the resulting error in the probability distribution can be estimated by means of theoretical considerations. The correction factor to account for this error was estimated to be approximately 0.91.

As described in Section 2.1, the wind speeds were scaled to standard open terrain and a height of 33 ft above grade before probability distributions were fitted to the data. For the purposes of the Weibull distribution and up-crossing analysis, this was done using individual estimates of power law exponent for each wind direction sector and each historical period. For the purposes of the extreme value distributions, a single representative value of the power law exponent was used at each site (0.155 at Anchorage International, 0.17 at Elmendorf AFB and 0.18 at Merrill Field).

Scaling between 1-Hour Average, Fastest Mile and Peak Gust Speed

Having fitted probability distributions to the observed wind data and estimated extreme wind speeds associated with various recurrence intervals, the speeds were scaled to various averaging times, as desired for comparison purposes.

Appropriate scale factors were derived from plotted curves of the ratio of probable maximum wind speed over t seconds to hourly mean wind speed, as presented in ASCE 7-95[13]. These curves are applicable to a height of 33 ft above grade in open terrain and are consistent with Equations 2 and 3, presented earlier, in Section 2.1. The factor for conversion from 1-hour average to peak gust speed is approximately 1.52. The factor for conversion from 1-hour average to fastest-mile speed actually varies slightly depending on the magnitude of the speed but, to a good approximation, takes on a constant value of 1.27.

2.3 Results

Tables 2 through 5 show the predicted 50-year, 100-year, 250-year and 1000-year fastest mile speeds in mph. Table 6 shows the predicted 50-year peak gust speeds. The tables also show estimated standard deviations due to statistical sampling error. Appendices A through D show excerpts from the spreadsheets in which the analysis was performed, including graphs of the fitted probability distributions.

The various fitting techniques used in this study produced results that were reasonably consistent with each other. At Anchorage International Airport, for example, seven estimates of the 50-year fastest mile wind speed at 33 feet above grade in open terrain ranged between 68.5 and 74 mph. At Elmendorf AFB, three estimates ranged between 64 and 68 mph, and at Merrill Field, three estimates ranged between 75 and 79.3 mph. At Carl Portman's Residence, two estimates ranged from 105 to 111 mph.

TABLE 2: Predicted 50-Year Fastest Mile Wind speed (mph)

			Type I Extreme Value Distribution					
			Hourly 1-minute data		Fastest mile data		Peak gust data	
Station	Value	Weibull/ Upcross	Method of Moments	Least Square	Method of Moments	Least Square	Method of Moments	Least Square
Anchorage International	50 yr spd	71	72.2	74.2	68.5	73.2	70.6	72.6
	std. dev.	n/a	4.5	n/a	6.9	n/a	3.7	n/a
Elmendorf AFB	50 yr spd	64	66.3	68	n/a	n/a	n/a	n/a
	std. dev.	n/a	3.3	n/a	n/a	n/a	n/a	n/a
Merrill Field	50 yr spd	75	76.5	79.3	n/a	n/a	n/a	n/a
	std. dev.	n/a	6.2	n/a	n/a	n/a	n/a	n/a
Portman Residence	50 yr spd	n/a	n/a	n/a	n/a	n/a	105.4	111
	std. dev.	n/a	n/a	n/a	n/a	n/a	9.5	n/a

TABLE 3: Predicted 100-Year Fastest Mile Wind Speed (mph)

			Type I Extreme Value Distribution					
			Hourly 1-minute data		Fastest mile data		Peak gust data	
Station	Value	Weibull/ Upcross	Method of Moments	Least Square	Method of Moments	Least Square	Method of Moments	Least Square
Anchorage International	100 yr spd	75.2	77.7	80	73.9	79.4	74.9	77.3
	std. dev.	n/a	5.3	n/a	8.1	n/a	4.4	n/a
Elmendorf AFB	100 yr spd	68.1	70.7	72.7	n/a	n/a	n/a	n/a
	std. dev.	n/a	3.9	n/a	n/a	n/a	n/a	n/a
Merrill Field	100 yr spd	79.4	83.1	86.5	n/a	n/a	n/a	n/a
	std. dev.	n/a	7.3	n/a	n/a	n/a	n/a	n/a
Portman Residence	100 yr spd	n/a	n/a	n/a	n/a	n/a	111.7	118.3
	std. dev.	n/a	n/a	n/a	n/a	n/a	11.2	n/a

TABLE 4: Predicted 250-Year Fastest Mile Wind speed (mph)

			Type I Extreme Value Distribution					
			Hourly 1-minute data		Fastest mile data		Peak gust data	
Station	Value	Weibull/ Upcross	Method of Moments	Least Square	Method of Moments	Least Square	Method of Moments	Least Square
Anchorage International	250 yr spd	80	84.9	87.7	81	87	80.5	83.4
	std. dev.	n/a	6.4	n/a	9.8	n/a	5.3	n/a
Elmendorf AFB	250 yr spd	72.7	76.5	78.9	n/a	n/a	n/a	n/a
	std. dev.	n/a	4.7	n/a	n/a	n/a	n/a	n/a
Merrill Field	250 yr spd	85.2	91.8	95.9	n/a	n/a	n/a	n/a
	std. dev.	n/a	8.8	n/a	n/a	n/a	n/a	n/a
Portman Residence	250 yr spd	n/a	n/a	n/a	n/a	n/a	120.1	128
	std. dev.	n/a	n/a	n/a	n/a	n/a	13.4	n/a

TABLE 5: Predicted 1000-Year Fastest Mile Wind Speed (mph)

			Type I Extreme Value Distribution					
			Hourly 1-minute data		Fastest mile data		Peak gust data	
Station	Value	Weibull/ Upcross	Method of Moments	Least Square	Method of Moments	Least Square	Method of Moments	Least Square
Anchorage International	1000 yr spd	87	95.7	99.2	91.6	100	89	92.7
	std. dev.	n/a	8	n/a	12.3	n/a	6.6	n/a
Elmendorf AFB	1000 yr spd	78.5	85.3	88.3	n/a	n/a	n/a	n/a
	std. dev.	n/a	5.9	n/a	n/a	n/a	n/a	n/a
Merrill Field	1000 yr spd	92.7	105	110.1	n/a	n/a	n/a	n/a
	std. dev.	n/a	11	n/a	n/a	n/a	n/a	n/a
Portman Residence	1000 yr spd	n/a	n/a	n/a	n/a	n/a	132.7	142.6
	std. dev.	n/a	n/a	n/a	n/a	n/a	16.9	n/a

TABLE 6: Predicted 50-year Peak Gust Speed (mph)

			Type I Extreme Value Distribution					
			Hourly 1-minute data		Fastest mile data		Peak gust data	
Station	Value	Weibull/ Upcross	Method of Moments	Least Square	Method of Moments	Least Square	Method of Moments	Least Square
Anchorage International	50 yr spd	85.3	86.5	88.8	82	87.6	84.5	86.9
	std. dev.	n/a	5.4	n/a	8.2	n/a	4.4	n/a
Elmendorf AFB	50 yr spd	77.5	79.4	81.4	n/a	n/a	n/a	n/a
	std. dev.	n/a	4	n/a	n/a	n/a	n/a	n/a
Merrill Field	50 yr spd	89.7	91.5	95	n/a	n/a	n/a	n/a
	std. dev.	n/a	7.4	n/a	n/a	n/a	n/a	n/a
Portman Residence	50 yr spd	n/a	n/a	n/a	n/a	n/a	126.2	132.8
	std. dev.	n/a	n/a	n/a	n/a	n/a	11.4	n/a

3. SPATIAL DISTRIBUTION OF WIND SPEED

3.1 Overview of Methods

The historical wind data used in the statistical analysis were limited to just four available sites in the Anchorage area. Consequently, it is difficult to assess the spatial distribution of extreme wind speeds with great precision. The 50-year fastest mile wind speed is less than 80 mph at Anchorage International, Elmendorf AFB and Merrill Field, and is on the order of 105 mph at Carl Portman's Residence in the Rabbit Creek Canyon. No statistical information is available for the large area that lies between the Portman Residence and the other three sites.

Other information, however, is available that sheds some additional light on the spatial distribution of wind speeds in the area. Spot wind readings from the Rabbit Creek Fire Station and the Edmund Schuster Residence, both of which are located in the same general vicinity as the Carl Portman Residence (see Figure 1), suggest that these locations experience similar wind speeds to those recorded at the Portman site. Historical information on wind damage (Hopkins, 1994)[14] indicates that the typical zone of moderate to heavy wind damage covers a broad area lying east of the Seward Highway, with the greatest amount of damage occurring in the vicinity of Muldoon Road.

The following approach was adopted to make a best estimate of trial wind speed zones for the Anchorage area with the limited available information.

- Meteorological observations for 10 historical wind storms were extrapolated to predict the approximate spatial distribution of wind speed during these events. A sophisticated meteorological interpolation model known as CALMET (Scire, 1990)[15] was used for this purpose.

- The CALMET results for one of the 10 events was selected as a representative case for use in developing design wind speed zones.

- Contours of 50-year fastest mile wind speed were then approximated by examining the CALMET results in combination with the wind damage map published by Hopkins (1994), and the predicted 50-year wind speeds shown previously in Table 2.

- The resulting contours of 50-year wind speed were adjusted to produce trial wind speed zones with boundaries conforming to city streets.

3.2 CALMET Modeling

CALMET is a meteorological model capable of generating 3-dimensional meteorological fields by interpolating available surface and upper air weather data, over a pre-defined grid, while taking into account topographical effects and differences between over-land and over-water atmospheric boundary layers. The main features of the CALMET meteorological model are presented below.

- Diagnostic Wind Field Module of CALMET
  - Slope Flows
  - Kinematic Terrain Effects
  - Terrain Blocking Effects
  - Divergence Minimization
  - Produces Gridded Fields of U, V, W Wind Components (3-D)
  - Inputs Include: Domain-Scale Winds, Observations, and (optionally) Prognostic Model Winds
  - Lambert Conformal Projection Capability

- Boundary Layer Modules of CALMET
  - Overland Boundary Layer - Energy Balance Method
  - Overwater Boundary Layer - Profile Method

The modeling involved a two step approach in the computation of the wind fields. In the first step, an initial-guess wind field was adjusted for terrain effects. In the present case, upper air data collected at Anchorage International Airport were used on their own to establish the initial-guess field. In the second step, an objective analysis is used to adjust the step-1 wind field based on the rest of the observational data, which in the present case consisted of the surface data from Anchorage International Airport, Merrill Field and Elmendorf AFB. A range of options are available for specifying how the objective analysis is to be carried out.

Limited wind data were available from the Carl Portman Residence on Upper De Armoun, the Rabbit Creek Fire Station and the Edmund Schuster Residence at Glen Alps (See Figure 1). Not being available in hourly format, these data were not suitable for use in CALMET, but were useful for checking the model's performance in predicting wind speeds at these locations.

Implementation of CALMET

The CALMET meteorological model was programmed to generate three dimensional wind fields for Anchorage, Alaska. The model was implemented for ten individual storm events identified from the historical meteorological data. In each case, a 72 hour period bracketing the storm event was analyzed. The model was applied to a 16 x 21 mile area covering the City of Anchorage, part of Knik Arm, part of the Turnagain Arm and part of the Chugach Mountains to the east of Anchorage. The study domain was divided into a 52 x 65 grid with a horizontal spacing of 1640 ft (500 m) between grid points.

The ten storms that were selected for analysis consisted of five from each of the two types of wind storms that occur at Anchorage: those associated with northeasterly winds and those associated with southeasterly winds. The dates of the storms were as follows:

Northeasterly Wind Storms

- November 15, 1978
- February 14, 1979
- March 4, 1989
- February 3, 1993
- February 20, 1994

Southeasterly Downslope Wind Storms

- November 9, 1986
- December 26, 1991
- December 1, 1992
- November 22, 1993
- December 3, 1994

Input Data and Assumptions

CALMET requires routinely-measured surface and upper air meteorological data. The surface data are required on an hourly basis, and the upper air data are required on a twice-per-day basis, as a minimum. The surface data used in the model consisted of hourly readings of wind speed, wind direction, ceiling height, opaque sky cover, temperature, relative humidity, atmospheric pressure, and precipitation code (0 = none, 1-18 = wet, 19-45 = frozen). The upper air data consisted of vertically integrated measurements of atmospheric pressure, height of measurement, temperature, wind direction, and wind speed, taken at 0000 and 1200 hours, Greenwich Mean Time (GMT).

The model also requires geophysical data including grids of terrain elevations and land use categories. Other inputs in the present case included surface roughness length, albedo, Bowen ratio, a soil heat flux parameter, anthropogenic heat flux, and vegetation leaf area index, which were specified as a function of land use. For this application, the U.S. Geological Survey's 14-Category land use system, which is available within CALMET, was used.

The terrain in the study area is fairly complex due to the presence of the Chugach Mountains to the east. Spot elevations corresponding to each 1640 ft x 1640 ft grid cell in the computational domain were obtained from topographic maps. These data were used to compute the grid-averaged ground elevations.

Topographic maps were used to identify five broad land use categories in the study domain. A summary of the five land use categories and their associated geophysical parameters are presented in Table 7.

TABLE 7: Land use Categories and the Geophysical Parameters

Land Use Category	Description	Surface Roughness (m)	Albedo	Bowen Ratio	Soil Heat Flux Parameter	Anthropogenic Heat Flux (W/m²)	Leaf Area Index
10	Urban / Built-up Area	1.00	0.18	1.5	0.25	0.0	0.2
30	Rangeland	0.05	0.25	1.0	0.15	0.0	0.5
40	Forest Land	1.00	0.10	1.0	0.15	0.0	7.0
80	Tundra	0.20	0.30	0.5	0.15	0.0	0.0
90	Perennial Snow or Ice	0.20	0.70	0.5	0.15	0.0	0.0

3.3 CALMET Results

Contour plots of maximum hourly wind speed for the ten storms are shown in Appendix E. Actual measured maximum wind speeds at the available weather stations are also shown for comparison. The speeds shown in these plots are in miles per hour at 33ft above grade.

It turns out that the storms associated with northeasterly winds tend to be characterized by strong winds at the airports, but relatively light winds in the vicinity of the Carl Portman and Edmund Schuster residences. CALMET failed to reproduce this pattern. It relatively accurately predicted winds in the western portion but over estimated the winds in the eastern portion of Anchorage. Evidently, local scale meteorological and/or topographical effects take place during these events that cannot be adequately addressed by an objective interpolation scheme such as CALMET. It is fortunate that, since these storms tend to produce relatively low winds in the eastern portion of Anchorage, they are of lesser importance in terms of developing trial wind speed zones for that area.

The storms associated with southeasterly winds tend to be characterized by very strong winds in the eastern portion of Anchorage and more moderate winds at the airports. CALMET provided a reasonably realistic reproduction of this pattern in four out of the five southeasterly wind storms. The contour plots for those four cases were similar to each other in terms of general characteristics. The fifth storm was unique in that the reported wind speeds at the airports were much lower than in the other storms, and yet the reported wind speeds at the Portman and Schuster residences remained very high.

3.4 Trial Wind Zone Map

The CALMET contour plot for the storm of December 1, 1992, which was the most severe of the five southeasterly wind storms that were examined and has been documented in the published literature, was chosen as a representative plot to serve as a guide in developing trial wind speed zones. The predicted wind speeds for this case were scaled to represent the fastest mile speed at 33ft above grade in open terrain. The resulting map is shown in Figure 2.

A published map of typical wind damage patterns in Anchorage (Hopkins, 1994) and discussions with the author served as an additional guide in developing the design wind speed zones. The heaviest wind damage has historically occurred in the Muldoon Road area. This may in part be due to the fact that much of the construction in that area was older and lacked wind load measures (hurricane clips, etc.) that have been adopted in more recent construction. Hopkins, however, reported a reliable gust speed measurement of 112 mph at a school in the Muldoon Road area during the storm of December 1, 1992. The maximum gust speed recorded by Carl Portman during the same storm was109 mph. The maximum gust at Edmund Schuster's residence in Glen Alps was only 77 mph, and the maximum gust at Anchorage International Airport was only 55 mph.

The above information suggests that the Muldoon Road area and the area around Carl Portman's residence should be included within the same design wind speed zone, corresponding to a 50-year wind fastest mile speed of approximately 105 mph, at 33ft above grade in open terrain. The draft wind zone map has been drawn accordingly, and is shown in Figure 3. All wind speeds shown on the map are 50-year fastest mile speeds at 33ft above grade in open terrain.

4. CONCLUSION

Suitable historical wind data for statistical analysis were available from only four weather stations in the Anchorage area. Ironically, three of these stations were located in the northern and western parts of Anchorage where the 50-year wind speed was expected to be relatively uniform, and only one station was located in the southeastern part of Anchorage, where the 50-year wind speed was expected to vary considerably from one place to another. Fortunately, other resources (a published wind damage map and the experience of local meteorologists) were available to gain some insight into how extreme wind speeds vary in the area.

The statistical analyses of historical wind data from the four weather stations indicated that the 50-year fastest mile wind speed at 10m above grade in open terrain ranges from less than 80 mph to more than 100 mph in the Anchorage area. A trial wind zone map was developed, reflecting our best estimate of the spatial variation in 50-year wind speed (Figure 3).

The proposed Phase 3 of this study involves setting up additional wind-recording sites to supplement those currently operating in the city. The approach could consist of providing hourly data-recording capabilities at locations where wind instruments are already in place, such as some of the local schools and a network of new sites being coordinated by the National Weather Service, or it could consist of installing complete new wind-recording systems. The program would operate for a period of two years, providing useful information on the spatial distribution of wind speed during strong wind events. At the same time, it would be useful to search out more historical wind records that may exist in hard-copy format for locations such as Edmund Schuster's residence, the Rabbit Creek Fire Station and some of the schools. Given the limited spatial resolution of the historical data currently available, Phase 3 is recommended.

5. REFERENCES

1. Counihan, J., 1975: *Adiabatic Atmospheric Boundary Layer: A Review of Data from the Period 1880-1972*, Atmospheric Environment, 9 (10), pp. 871-905.

2. Snyder, W. H., 1981: *Guideline for Fluid Modeling of Atmospheric Diffusion*, US EPA Report 600/8-81-009.

3. Engineering Science Data Unit, 1990: *Strong Winds in the Atmospheric Boundary Layer, Part 1: Mean-Hourly Wind Speeds*, Item Number 82026.

4. Simiu, E., M. J. Changery and J. J. Filliben, 1979: *Extreme Wind Speeds at 129 Stations in the Contiguous United States*, NBS Building Series 118, National Bureau of Standards.

5. Pavia, E. G. and J. J. O'Brien, 1986: *Weibull Statistics of Wind Speed over the Ocean*, J. Clim. App. Met., 25, pp. 1324-1332.

6. Justus, C. G., et al., 1978: *Methods for Estimating Wind Speed Frequency Distributions*, J. App. Met., 17, pp. 350-353.

7. Conradsen, K. and L. B. Nielsen, 1984: *Review of Weibull Statistics for Estimation of Wind Speed Distributions*, J. Am. Met. Soc., 23, pp. 1173-1183.

8. Tuller, S. E. and A. C. Brett, 1984: *The Characteristics of Wind Velocity that Favour the Fitting of a Weibull Distribution in Wind Speed Analysis*: J. Clim. App. Met., 23, pp. 124-134.

9. Lepage, M. F. and P. A. Irwin, 1985: *A Technique for Combining Historical Wind Data with Wind Tunnel Tests to Predict Extreme Wind Loads*, Proc. 5th US Nat. Conf. Wind Eng., Lubbock, Texas, pp. 2B-71 to 2B-78.

10. Peterka, J. A. and S. Shahid, 1998: *Design Gust Wind Speeds in the United States*, J. Struct. Eng., February 1998, pp. 207-213.

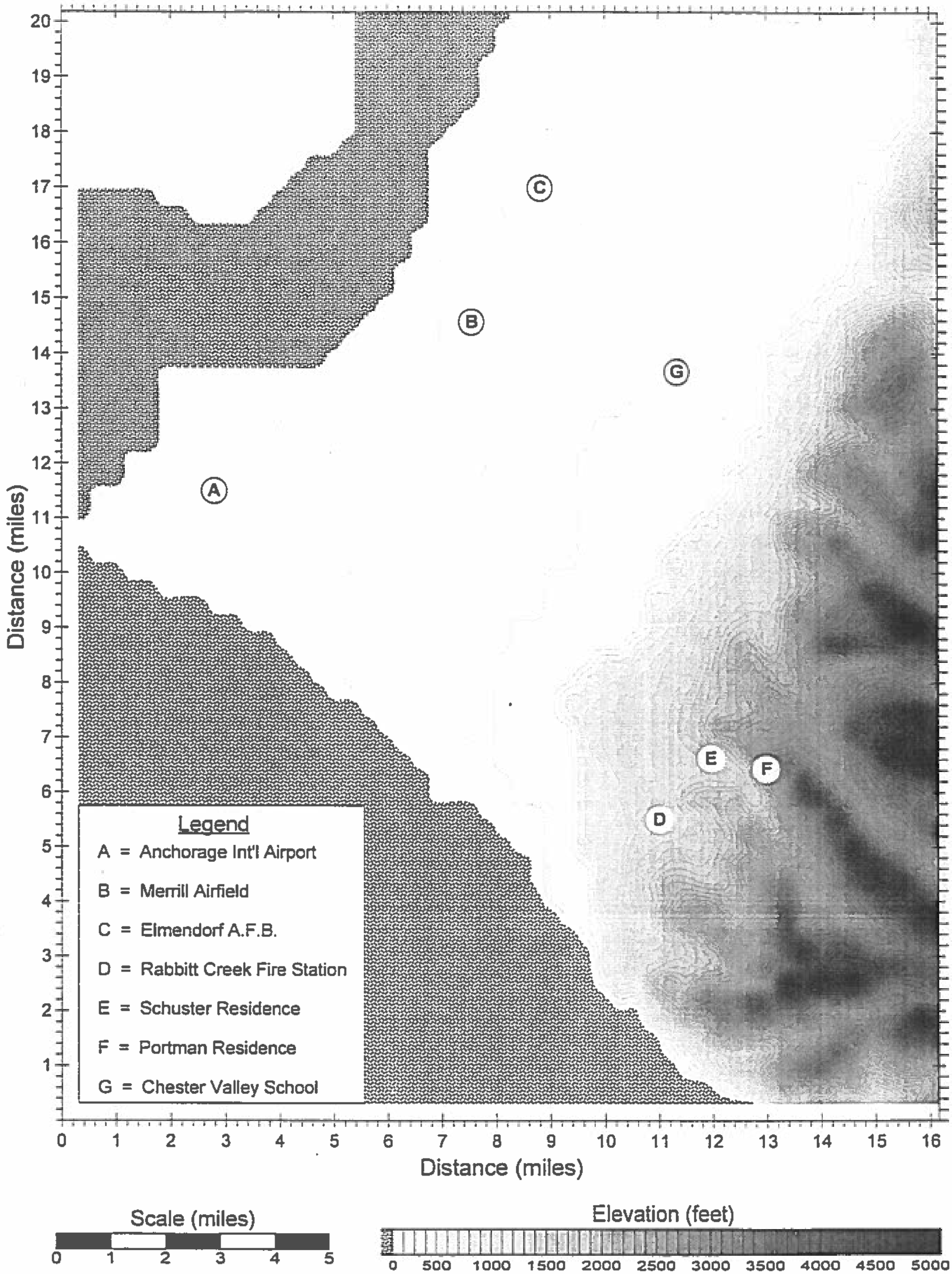
11. Yip, T. C., H. Auld and W. Dnes, 1995: *Recommendations for Updating the 1995 National Building Code of Canada Wind Pressures*, Proc. 9th Int. Conf. Wind Eng., New Delhi, India.

12. Johnson, N. L. and S. Kotz, 1970: *Continuous Univariate Distributions-1*, Houghton Mifflin Co., Boston, pp. 272-289.

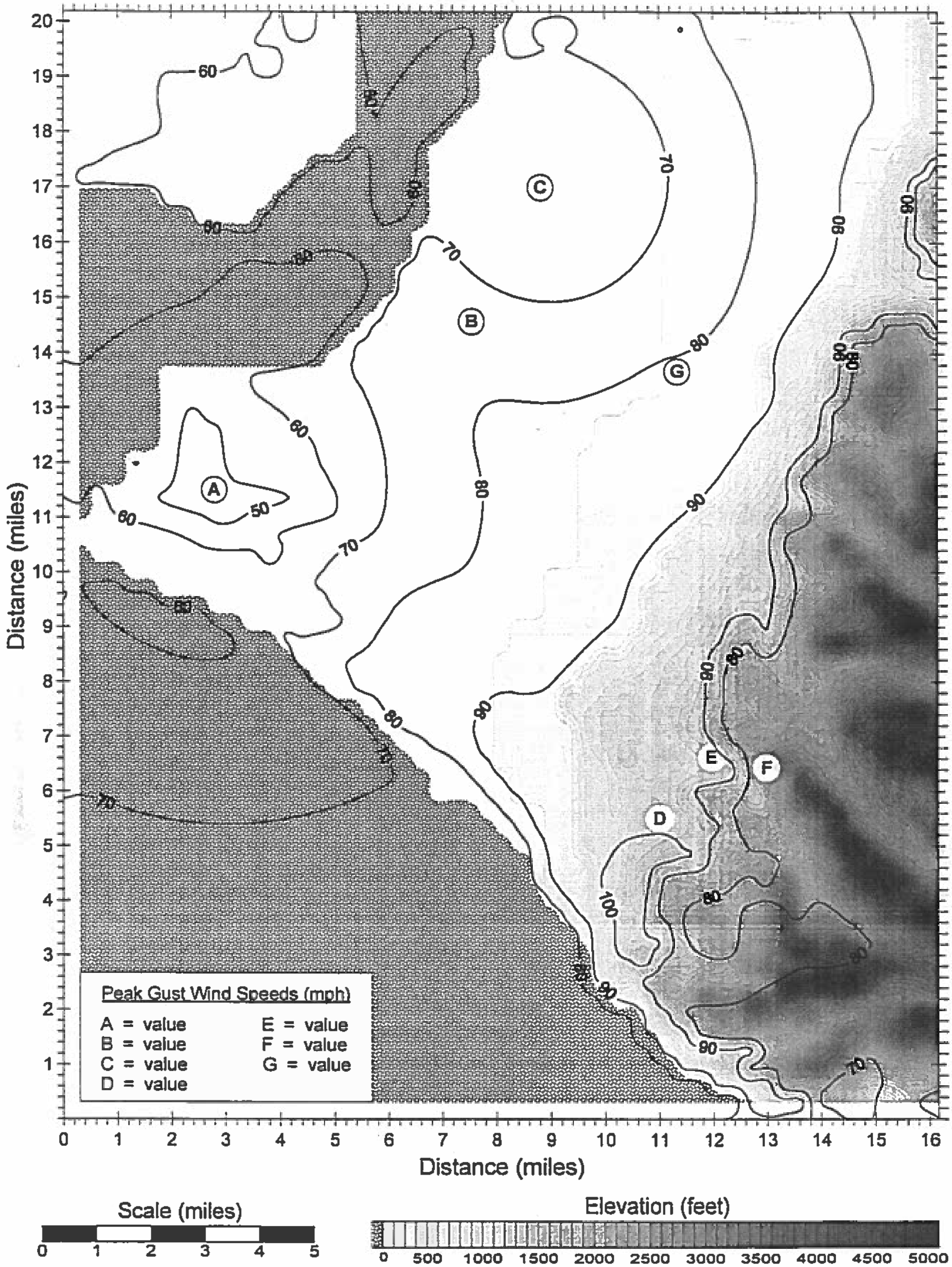
13. ASCE, 1995: *Minimum Design Loads for Buildings and Other Structures, ASCE 7-95*, American Society of Civil Engineers, New York, NY.

14. Hopkins, R. H., 1994: *Anchorage Windstorm of 1 December 1992*, Weather and Forecasting, 9 (4), pp. 469-478.

15. Scire, J.S. et al., 1990: *Model Formulation and User's Guide for CALMET Meteorological Model*. Prepared for California Air Resources Board by Sigma Research Corporation, Concord, Massachusetts, USA.



CALMET Basemap and Data Sources	True North	Figure: 1	RWDI
Anchorage Area-Wide Wind Speed Study - Anchorage, Alaska	Job No. 98-362	Date: Nov. 26, 1998	



Fastest Mile Wind Speed Contours (mph) Corrected for Open Terrain for the Dec. 01, 1992 Storm.

Anchorage Area-Wide Wind Speed Study - Anchorage, Alaska

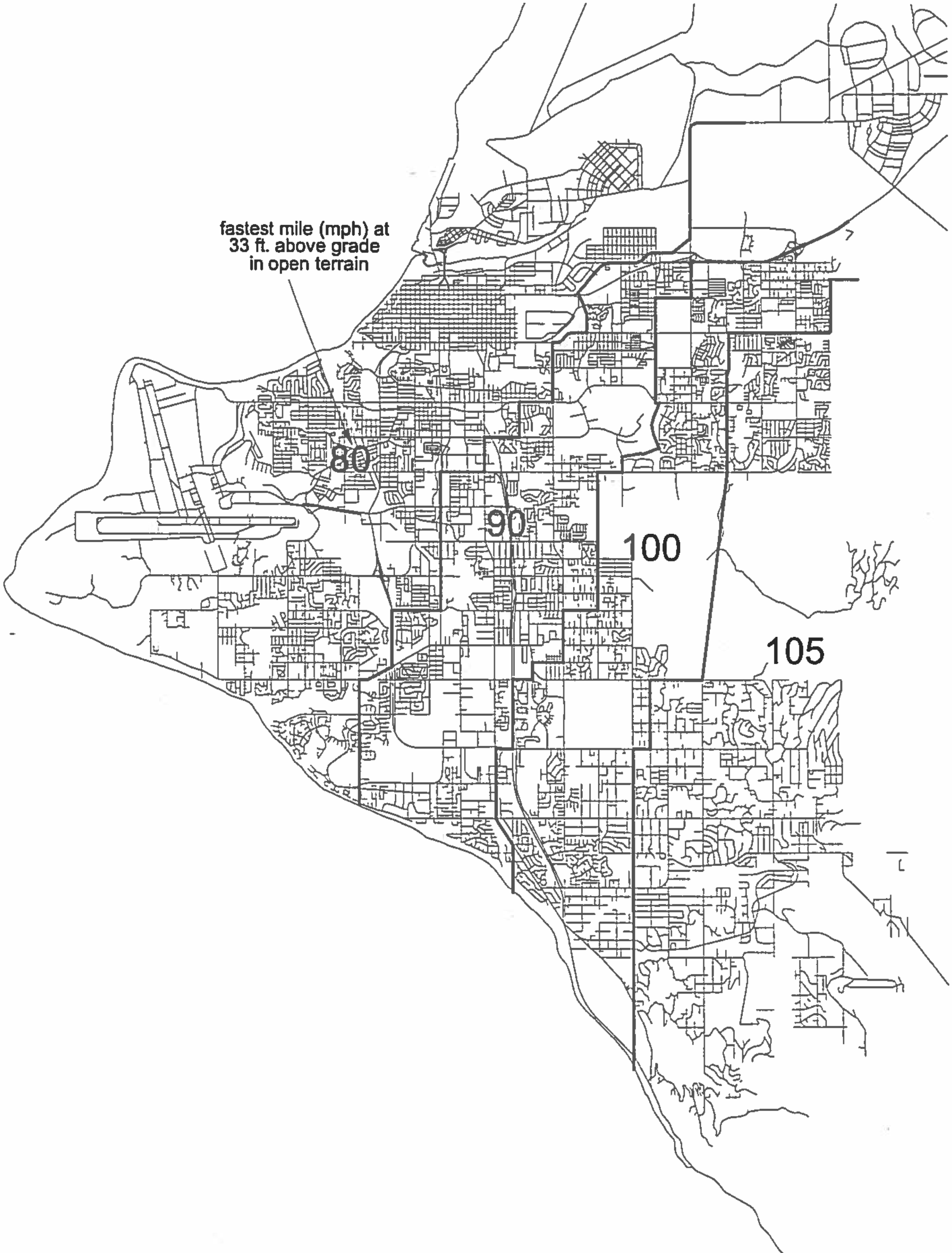
True North

Job No. 98-362

Figure: 2

Date: Nov. 26, 1998

RWDI



Trial Wind Zone Map Anchorage Building Service Area Anchorage Area-Wide Wind Speed Study - Anchorage, Alaska	True North Job No. 98-362	Drawn by: SKM	Figure: 3	RWDI
		Approx. Scale:	N.T.S	
		Date Revised:	Dec 2, 1998	

APPENDIX A

APPENDIX A
EXCERPTS OF SPREADSHEET CALCULATIONS FOR ANCHORAGE INTERNATIONAL AIRPORT

TABLE OF CONTENTS

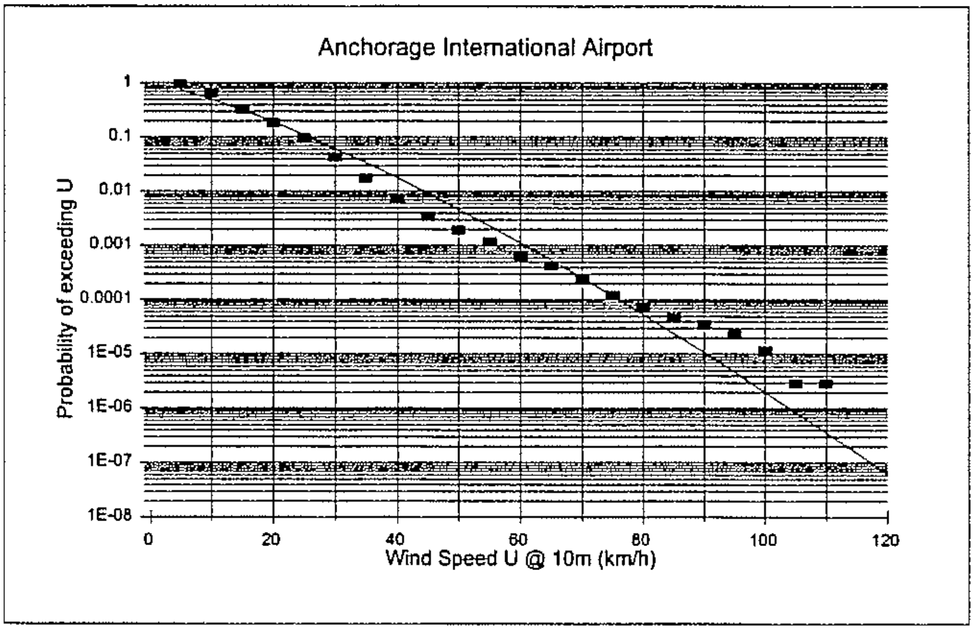
Anchorage International Airport

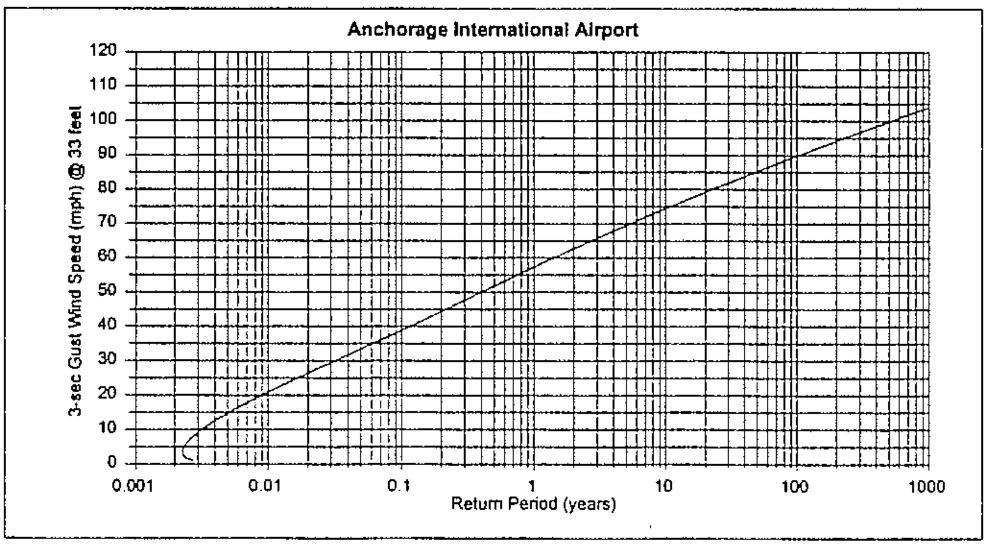
Udotbar Constants (before correction)		**Weibull Parameters**	
UC1	0.074	A	0.907436
UC2	2.111	C	13.59265
UC3	-0.045	K	1.289505

50 year return, mean hourly wind speed @ 33 feet

Umh@33	90.09 kph
Umh@33	55.979 mph

gust factor	1.269	gust factor	1.524
50 year return fastest-mile wind speed	71.04 mph	50 year return 3-sec gust wind speed	85.31 mph





TYPE I EXTREME VALUE DISTRIBUTION

I. Import Data from Fastest Mile Spreadsheet

Station: Anchorage International

$V1 := Data^{<0>}$ $Va := V1 \cdot mph$ Input Wind Speed

$H1 := Data^{<1>}$ $Ha := H1 \cdot ft$ Instrument Height

II. Scale Speeds to 10m in Open Terrain

$n := 18$ Range of Input Data

$i := 0 .. n$

NOTE: Position 1 is the actual anemometer location, Position 2 is at the top of the boundary layer, and Position 3 is at 10m in open terrain

$Z1_i := Ha_i$

Upk is the peak gust speed and Ufm is the fastest mile speed

$U2_i := U1 \cdot \left(\frac{Z2}{Z1_i}\right)^{\alpha 1}$ Scale from anemometer to top of boundary layer

$U3_i := U2_i \cdot \left(\frac{Z3}{Z2}\right)^{\alpha}$ Scale from top of boundary layer to 10m in open terrain

$\sigma 3_i := 0.17 \cdot U3_i$ rms of wind speed at 10m in the open

Peak gust and fastest mile speed relationships:

$Upk1 := U1 + 3 \cdot \sigma 1$ $Upk2_i := U2_i + 3 \cdot \sigma 2$ $Upk3_i := U3_i + 3 \cdot \sigma 3_i$

$Ufm1 := 0.5 \cdot (Upk1 + U1)$ $Ufm2_i := 0.5 \cdot (Upk2_i + U2_i)$ $Ufm3_i := 0.5 \cdot (Upk3_i + U3_i)$

Velocity Ratios:

$f0_i := \frac{Ufm3_i}{Ufm1}$ $f1_i := \frac{U3_i}{U1}$ $f2_i := \frac{Upk3_i}{Upk1}$ $U1 \equiv 1 \cdot \frac{m}{sec}$ arbitrary value of U1

$Z2 \equiv 600 \cdot m$ $Z3 \equiv 10 \cdot m$ $\sigma 2 \equiv 0 \cdot \frac{m}{sec}$ $\alpha \equiv 0.14$

$\sigma 1 \equiv 0.19 \cdot U1$ $\alpha 1 \equiv 0.155$ input data

$f0 = $

	0
0	1.003
1	1.003
2	1.003

$f1 = $

	0
0	1.027
1	1.027
2	1.027

$f2 = $

	0
0	0.988
1	0.988
2	0.988

$fs_i := f0_i$ — Choose the appropriate scale factor

$V10a_i := Va_i \cdot fs_i$ — Scale velocities by the appropriate factor

$V10 := sort(V10a)$ — Sort scaled velocities in ascending order

III. Method of Moments (Pf)

$U := mean(V10)$ $U = 63.134 \cdot ft \cdot sec^{-1}$ — Sample Mean

$\sigma := Stdev\left(\frac{V10}{\frac{ft}{sec}}\right)$ $\sigma = 14.427$ — Standard Deviation

$\theta := \frac{\sqrt{6}}{\pi} \cdot \sigma \cdot \frac{ft}{sec}$ $\theta = 11.249 \cdot ft \cdot sec^{-1}$ — Scale Parameter

$\xi := U - 0.57722 \cdot \theta$ $\xi = 56.641 \cdot ft \cdot sec^{-1}$ — Location Parameter

$P_i := 1 - \frac{i+1}{n+2}$ — Observed Probabilities

$Pf_i := 1 - \exp\left[-\exp\left[\frac{-(V10_i - \xi)}{\theta}\right]\right]$ — Fitted Probabilities

$R_i := \frac{1}{P_i}$ $Rf_i := \frac{1}{Pf_i}$ — Observed and Fitted Return Periods

$j := 2 .. 1000$

$V_j := \xi - \theta \cdot \ln\left(-\ln\left(1 - \frac{1}{j}\right)\right)$ — Velocities for a range of return periods

IV. Method of Least Squares (Pf2)

$$L_i := \ln(-\ln(1 - P_i))$$

$\theta 2 := -\text{slope}(L, V10)$ $\qquad \theta 2 = 13.09 \cdot ft \cdot sec^{-1}$

$\xi 2 := \text{intercept}(L, V10)$ $\qquad \xi 2 = 56.304 \cdot ft \cdot sec^{-1}$

$$Pf2_i := 1 - \exp\left[-\exp\left[\frac{-(V10_i - \xi 2)}{\theta 2}\right]\right]$$ Ftted Probability

$$Rf2_i := \frac{1}{Pf2_i}$$ Fitted Return Period

$$Vb_j := \xi 2 - \theta 2 \cdot \ln\left(-\ln\left(1 - \frac{1}{j}\right)\right)$$ Velocities for a range of return periods

-

V. Sampling Error, Method of Moments

$$Y_j := -\ln\left(-\ln\left(1 - \frac{1}{j}\right)\right)$$

$$\sigma VN_j := \left[\frac{\pi^2}{6} + 1.1396\,\frac{(Y_j - 0.5772)}{\sqrt{6}} + 1.1\,(Y_j - 0.5772)^2\right]^{0.5}\frac{\theta}{\sqrt{n+1}}$$

VI. Correction to True 1-hour, Fastest-Mile, Peak Gust (50 year Values)

$Cf := \frac{1}{1.27}$ correction from 1-minute reading on the hour to true 1-hour

$Vhr_j := V_j \cdot Cf$ $\qquad \sigma hr_j := \sigma VN_j\, Cf$

$Vhrb_j := Vb_j \cdot Cf$

$Cfm := 1.27$ correction from 1-hour ave. to fastest mile

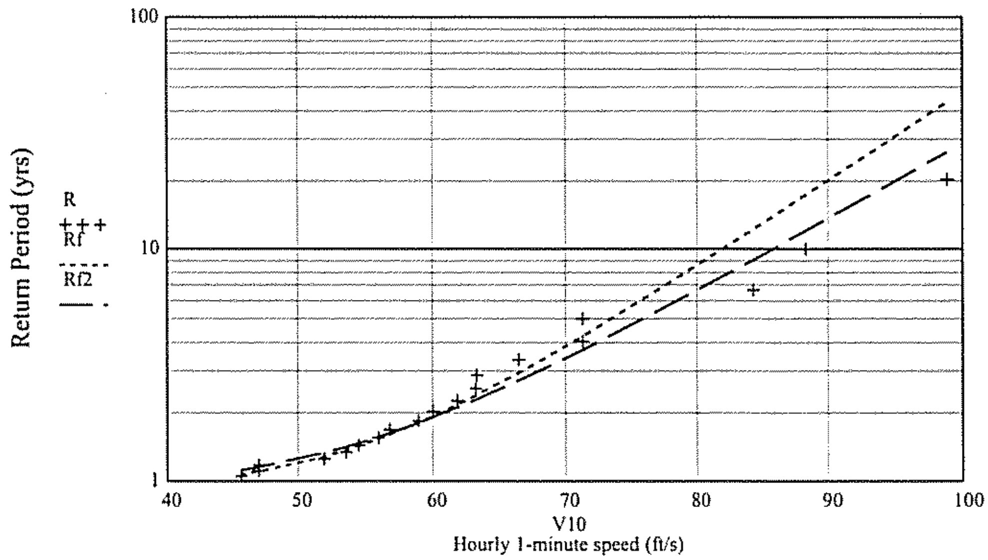
$Vfm_j := Vhr_j \cdot Cfm$

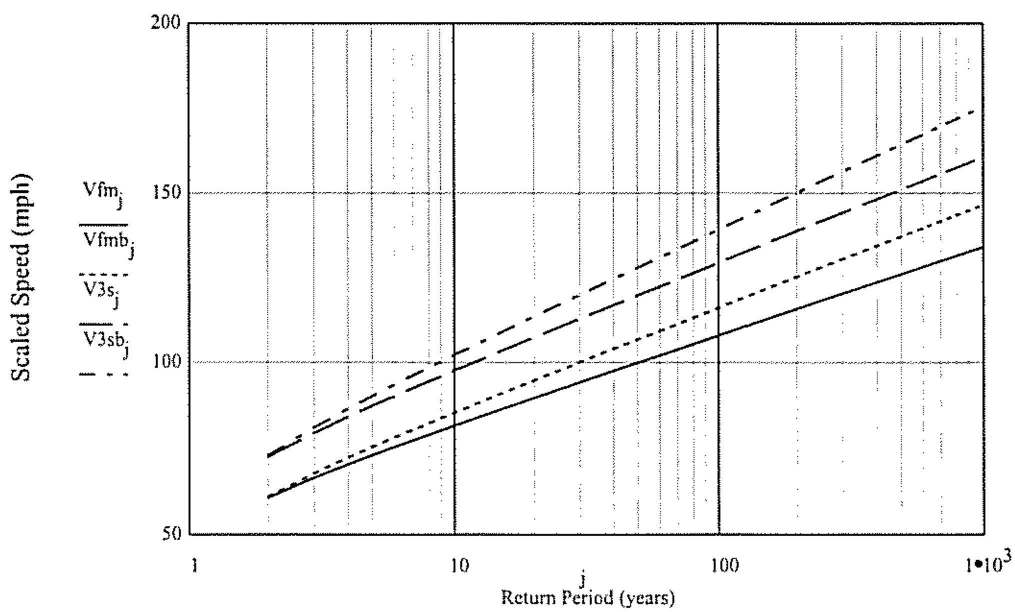
$Vfmb_j := Vhrb_j \cdot Cfm$ $\sigma fm_j := \sigma hr_j \cdot Cfm$

$C3s := 1.52$ correction from 1-hour ave. to 3-sec gust

$V3s_j := Vhr_j \cdot C3s$

$V3sb_j := Vhrb_j \cdot C3s$ $\sigma 3s_j := \sigma hr_j \cdot C3s$





Station: Anchorage International
Data Set: Annual Maximum Fastest Mile Readings

Return Period (years)	*Fastest Mile Wind Speed.*	*Peak Gust Wind Speed.*
$k := 50$	$Vfm_k = 68.5 \cdot mph$	$V3s_k = 82 \cdot mph$
	$Vfmb_k = 73.2 \cdot mph$	$V3sb_k = 87.6 \cdot mph$
	$\sigma fm_k = 6.9 \cdot mph$	$\sigma 3s_k = 8.3 \cdot mph$
$k := 100$	$Vfm_k = 73.9 \cdot mph$	$V3s_k = 88.4 \cdot mph$
	$Vfmb_k = 79.4 \cdot mph$	$V3sb_k = 95.1 \cdot mph$
	$\sigma fm_k = 8.1 \cdot mph$	$\sigma 3s_k = 9.7 \cdot mph$
$k := 250$	$Vfm_k = 81 \cdot mph$	$V3s_k = 96.9 \cdot mph$
	$Vfmb_k = 87.6 \cdot mph$	$V3sb_k = 104.9 \cdot mph$
	$\sigma fm_k = 9.8 \cdot mph$	$\sigma 3s_k = 11.7 \cdot mph$
$k := 1000$	$Vfm_k = 91.6 \cdot mph$	$V3s_k = 109.6 \cdot mph$
	$Vfmb_k = 100 \cdot mph$	$V3sb_k = 119.7 \cdot mph$
	$\sigma fm_k = 12.3 \cdot mph$	$\sigma 3s_k = 14.7 \cdot mph$

TYPE I EXTREME VALUE DISTRIBUTION

I. Import Data from Peak Gust Spreadsheet

Station: Anchorage International

$V1 := Data^{\langle 0 \rangle}$ $Va := V1 \cdot mph$ Input Wind Speed

$H1 := Data^{\langle 1 \rangle}$ $Ha := H1 \cdot ft$ Instrument Height

II. Scale Speeds to 10m in Open Terrain

$n := 41$ Range of Input Data

$i := 0 .. n$

NOTE: Position 1 is the actual anemometer location, Position 2 is at the top of the boundary layer, and Position 3 is at 10m in open terrain

$Z1_i := Ha_i$

Upk is the peak gust speed and Ufm is the fastest mile speed

$U2_i := U1 \cdot \left(\frac{Z2}{Z1_i}\right)^{\alpha 1}$ Scale from anemometer to top of boundary layer

$U3_i := U2_i \cdot \left(\frac{Z3}{Z2}\right)^{\alpha}$ Scale from top of boundary layer to 10m in open terrain

$\sigma 3_i := 0.17 \cdot U3_i$ rms of wind speed at 10m in the open

Peak gust and fastest mile speed relationships:

$Upk1 := U1 + 3 \cdot \sigma 1$ $Upk2_i := U2_i + 3 \cdot \sigma 2$ $Upk3_i := U3_i + 3 \cdot \sigma 3_i$

$Ufm1 := 0.5 \cdot (Upk1 + U1)$ $Ufm2_i := 0.5 \cdot \left(Upk2_i + U2_i\right)$ $Ufm3_i := 0.5 \cdot \left(Upk3_i + U3_i\right)$

Velocity Ratios:

$f0_i := \frac{Ufm3_i}{Ufm1}$ $f1_i := \frac{U3_i}{U1}$ $f2_i := \frac{Upk3_i}{Upk1}$ $U1 \equiv 1 \cdot \frac{m}{sec}$ arbitrary value of U1

$Z2 \equiv 600 \cdot m$ $Z3 \equiv 10 \cdot m$ $\sigma 2 \equiv 0 \cdot \frac{m}{sec}$ $\alpha \equiv 0.14$

$\sigma 1 \equiv 0.19 \cdot U1$ $\alpha 1 \equiv 0.155$ input data

$f0 = $

	0
0	1.003
1	1.003
2	1.003
3	1.003

$f1 = $

	0
0	1.027
1	1.027
2	1.027

$f2 = $

	0
0	0.988
1	0.988
2	0.988

$fs_i := f2_i$ — Choose the appropriate scale factor

$V10a_i := Va_i \cdot fs_i$ — Scale velocities by the appropriate factor

$V10 := \text{sort}(V10a)$ — Sort scaled velocities in ascending order

III. Method of Moments (Pf)

$U := \text{mean}(V10)$ $\quad U = 88.115 \cdot ft \cdot sec^{-1}$ — Sample Mean

$\sigma := \text{Stdev}\left(\frac{V10}{\frac{ft}{sec}}\right)$ $\quad \sigma = 13.802$ — Standard Deviation

$\theta := \frac{\sqrt{6}}{\pi} \cdot \sigma \cdot \frac{ft}{sec}$ $\quad \theta = 10.761 \cdot ft \cdot sec^{-1}$ — Scale Parameter

$\xi := U - 0.57722 \cdot \theta$ $\quad \xi = 81.903 \cdot ft \cdot sec^{-1}$ — Location Parameter

$P_i := 1 - \frac{i+1}{n+2}$ — Observed Probabilities

$Pf_i := 1 - \exp\left[-\exp\left[\frac{-(V10_i - \xi)}{\theta}\right]\right]$ — Fitted Probabilities

$R_i := \frac{1}{P_i}$ $\quad Rf_i := \frac{1}{Pf_i}$ — Observed and Fitted Return Periods

$j := 2 .. 1000$

$V_j := \xi - \theta \cdot \ln\left(-\ln\left(1 - \frac{1}{j}\right)\right)$ — Velocities for a range of return periods

IV. Method of Least Squares (Pf2)

$L_i := \ln(-\ln(1 - P_i))$

$\theta 2 := -\text{slope}(L, V10)$ $\theta 2 = 11.734 \cdot ft \cdot sec^{-1}$

$\xi 2 := \text{intercept}(L, V10)$ $\xi 2 = 81.723 \cdot ft \cdot sec^{-1}$

$Pf2_i := 1 - \exp\left[-\exp\left[\frac{-(V10_i - \xi 2)}{\theta 2}\right]\right]$ Ftted Probability

$Rf2_i := \frac{1}{Pf2_i}$ Fitted Return Period

$Vb_j := \xi 2 - \theta 2 \cdot \ln\left(-\ln\left(1 - \frac{1}{j}\right)\right)$ Velocities for a range of return periods

V. Sampling Error, Method of Moments

$Y_j := -\ln\left(-\ln\left(1 - \frac{1}{j}\right)\right)$

$\sigma VN_j := \left[\frac{\pi^2}{6} + 1.1396\,\frac{(Y_j - 0.5772)}{\sqrt{6}} + 1.1\,(Y_j - 0.5772)^2\right]^{0.5} \frac{\theta}{\sqrt{n+1}}$

VI. Correction to True 1-hour, Fastest-Mile, Peak Gust (50 year Values)

$Cf := \frac{1}{1.52}$ correction from 1-minute reading on the hour to true 1-hour

$Vhr_j := V_j \cdot Cf$ $\sigma hr_j := \sigma VN_j\, Cf$

$Vhrb_j := Vb_j \cdot Cf$

$Cfm := 1.27$ correction from 1-hour ave. to fastest mile

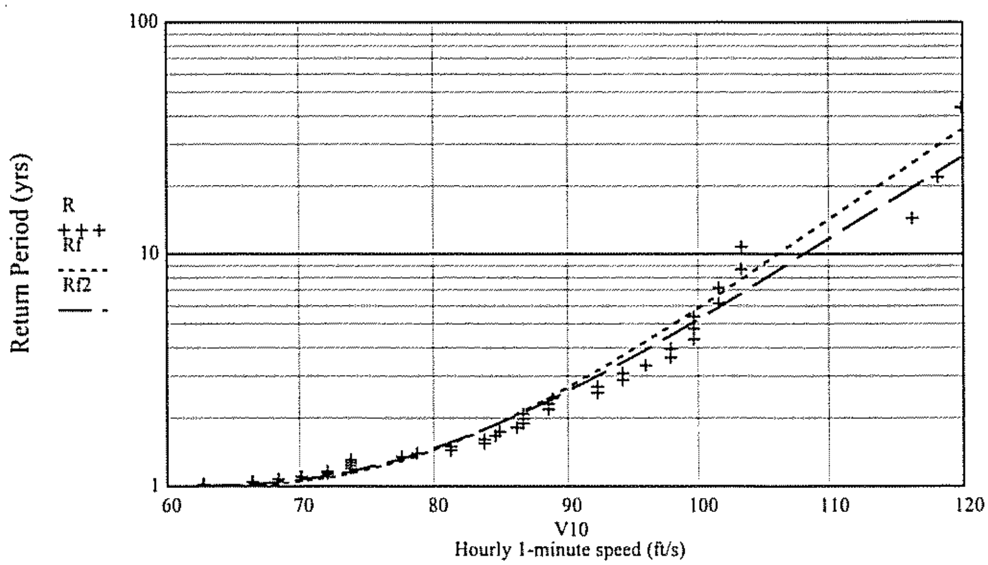
$Vfm_j := Vhr_j \cdot Cfm$

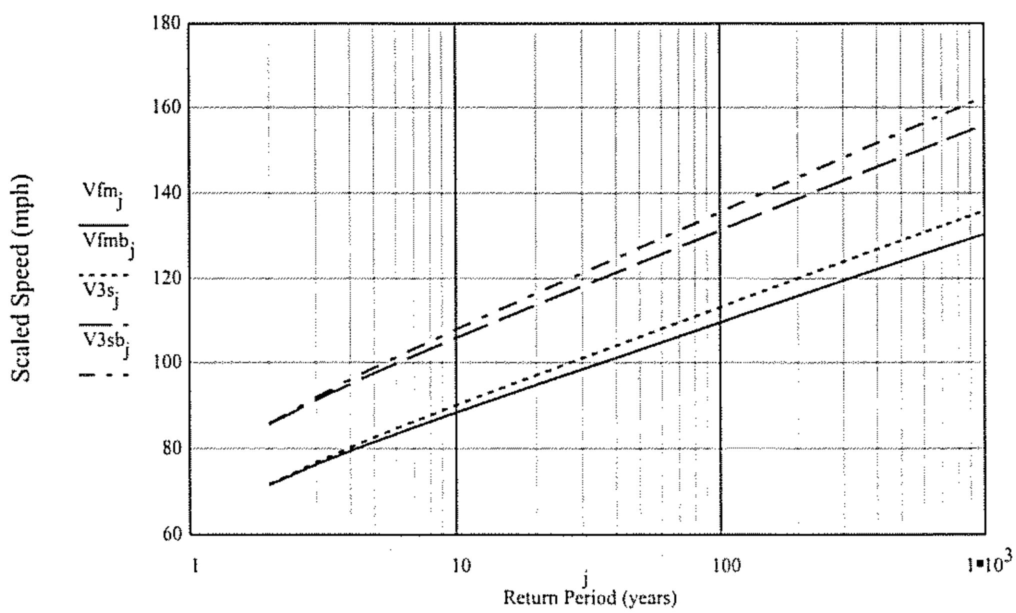
$Vfmb_j := Vhrb_j \cdot Cfm$ $\sigma fm_j := \sigma hr_j \cdot Cfm$

$C3s := 1.52$ correction from 1-hour ave. to 3-sec gust

$V3s_j := Vhr_j \cdot C3s$

$V3sb_j := Vhrb_j \cdot C3s$ $\sigma 3s_j := \sigma hr_j \cdot C3s$





Station: Anchorage International
Data Set: Annual Maximum Peak Gust Readings

Return Period (years)	*Fastest Mile Wind Speed.*	*Peak Gust Wind Speed.*
$k := 50$	$Vfm_k = 70.6 \cdot mph$	$V3s_k = 84.5 \cdot mph$
	$Vfmb_k = 72.6 \cdot mph$	$V3sb_k = 86.9 \cdot mph$
	$\sigma fm_k = 3.7 \cdot mph$	$\sigma 3s_k = 4.4 \cdot mph$
$k := 100$	$Vfm_k = 74.9 \cdot mph$	$V3s_k = 89.6 \cdot mph$
	$Vfmb_k = 77.3 \cdot mph$	$V3sb_k = 92.5 \cdot mph$
	$\sigma fm_k = 4.4 \cdot mph$	$\sigma 3s_k = 5.2 \cdot mph$
$k := 250$	$Vfm_k = 80.5 \cdot mph$	$V3s_k = 96.3 \cdot mph$
	$Vfmb_k = 83.4 \cdot mph$	$V3sb_k = 99.9 \cdot mph$
	$\sigma fm_k = 5.3 \cdot mph$	$\sigma 3s_k = 6.3 \cdot mph$
$k := 1000$	$Vfm_k = 89 \cdot mph$	$V3s_k = 106.5 \cdot mph$
	$Vfmb_k = 92.7 \cdot mph$	$V3sb_k = 111 \cdot mph$
	$\sigma fm_k = 6.6 \cdot mph$	$\sigma 3s_k = 7.9 \cdot mph$

TYPE I EXTREME VALUE DISTRIBUTION

I. Import Data from ASCII File

$\text{Data} :=$ N:\..\Maxspeed.txt

Station: Anchorage International

$V1 := \text{Data}^{\langle 3 \rangle}$ $\qquad Va := V1 \cdot \frac{km}{hr}$ $\qquad$ Input Wind Speed

$H1 := \text{Data}^{\langle 9 \rangle}$ $\qquad Ha := H1 \cdot m$ $\qquad$ Instrument Height

II. Scale Speeds to 10m in Open Terrain

$n := 45$ $\qquad$ Range of Input Data

$i := 0 .. n$

NOTE: Position 1 is the actual anemometer location, Position 2 is at the top of the boundary layer, and Position 3 is at 10m in open terrain

$Z1_i := Ha_i$

Upk is the peak gust speed and Ufm is the fastest mile speed

$U2_i := U1 \cdot \left(\frac{Z2}{Z1_i} \right)^{\alpha 1}$ $\qquad$ Scale from anemometer to top of boundary layer

$U3_i := U2_i \cdot \left(\frac{Z3}{Z2} \right)^{\alpha}$ $\qquad$ Scale from top of boundary layer to 10m in open terrain

$\sigma 3_i := 0.17 \cdot U3_i$ $\qquad$ rms of wind speed at 10m in the open

Peak gust and fastest mile speed relationships:

$Upk1 := U1 + 3 \cdot \sigma 1$ $\qquad Upk2_i := U2_i + 3\ \sigma 2$ $\qquad Upk3_i := U3_i + 3 \cdot \sigma 3_i$

$Ufm1 := 0.5 \cdot (Upk1 + U1)$ $\qquad Ufm2_i := 0.5\ \left(Upk2_i + U2_i \right)$ $\qquad Ufm3_i := 0.5 \cdot \left(Upk3_i + U3_i \right)$

Velocity Ratios:

$f0_i := \frac{Ufm3_i}{Ufm1}$ $\qquad f1_i := \frac{U3_i}{U1}$ $\qquad f2_i := \frac{Upk3_i}{Upk1}$ $\qquad U1 \equiv 1 \cdot \frac{m}{sec}$ $\qquad$ arbitrary value of U1

$Z2 \equiv 600 \cdot m$ $\qquad Z3 \equiv 10 \cdot m$ $\qquad \sigma 2 \equiv 0 \cdot \frac{m}{sec}$ $\qquad \alpha \equiv 0.14$

$\sigma 1 \equiv 0.19 \cdot U1$ $\qquad \alpha 1 \equiv 0.155$ $\qquad$ input data

$f0 = $

	0
0	1.003
1	1.003
2	1.003

$f1 = $

	0
0	1.027
1	1.027
2	1.027

$f2 = $

	0
0	0.988
1	0.988
2	0.988

$fs_i := f0_i$ Choose the appropriate scale factor

$V10a_i := Va_i \cdot fs_i$ Scale velocities by the appropriate factor

$V10 := \text{sort}(V10a)$ Sort scaled velocities in ascending order

III. Method of Moments (Pf)

$U := \text{mean}(V10)$ $U = 58.706 \cdot ft \cdot sec^{-1}$ Sample Mean

$\sigma := \text{Stdev}\left(\frac{V10}{\frac{ft}{sec}}\right)$ $\sigma = 12.715$ Standard Deviation

$\theta := \frac{\sqrt{6}}{\pi} \cdot \sigma \cdot \frac{ft}{sec}$ $\theta = 9.914 \cdot ft \cdot sec^{-1}$ Scale Parameter

$\xi := U - 0.57722 \cdot \theta$ $\xi = 52.984 \cdot ft \cdot sec^{-1}$ Location Parameter

$P_i := 1 - \frac{i+1}{n+2}$ Observed Probabilities

$Pf_i := 1 - \exp\left[-\exp\left[\frac{-(V10_i - \xi)}{\theta}\right]\right]$ Fitted Probabilities

$R_i := \frac{1}{P_i}$ $Rf_i := \frac{1}{Pf_i}$ Observed and Fitted Return Periods

$j := 2 .. 1000$

$V_j := \xi - \theta \cdot \ln\left(-\ln\left(1 - \frac{1}{j}\right)\right)$ Velocities for a range of return periods

IV. Method of Least Squares (Pf2)

$L_i := \ln(-\ln(1 - P_i))$

$\theta 2 := -\text{slope}(L, V10)$ $\theta 2 = 10.566 \cdot ft \cdot sec^{-1}$

$\xi 2 := \text{intercept}(L, V10)$ $\xi 2 = 52.929 \cdot ft \cdot sec^{-1}$

$Pf2_i := 1 - \exp\left[-\exp\left[\frac{-(V10_i - \xi 2)}{\theta 2}\right]\right]$ Ftted Probability

$Rf2_i := \frac{1}{Pf2_i}$ Fitted Return Period

$Vb_j := \xi 2 - \theta 2 \cdot \ln\left(-\ln\left(1 - \frac{1}{j}\right)\right)$ Velocities for a range of return periods

V. Sampling Error, Method of Moments

$Y_j := -\ln\left(-\ln\left(1 - \frac{1}{j}\right)\right)$

$\sigma VN_j := \left[\frac{\pi^2}{6} + 1.1396\,\frac{(Y_j - 0.5772)}{\sqrt{6}} + 1.1\,(Y_j - 0.5772)^2\right]^{0.5} \frac{\theta}{\sqrt{n+1}}$

VI. Correction to True 1-hour, Fastest-Mile, Peak Gust (50 year Values)

$Cf := 0.91$ correction from 1-minute reading on the hour to true 1-hour

$Vhr_j := V_j \cdot Cf$

$Vhrb_j := Vb_j \cdot Cf$ $\sigma hr_j := \sigma VN_j\, Cf$

$Cfm := 1.27$ correction from 1-hour ave. to fastest mile

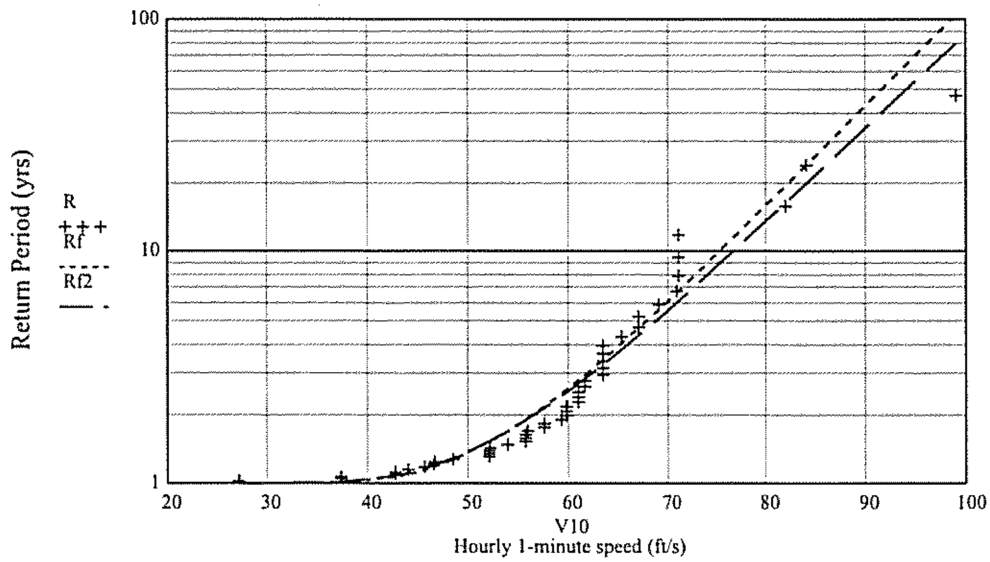
$Vfm_j := Vhr_j \cdot Cfm$

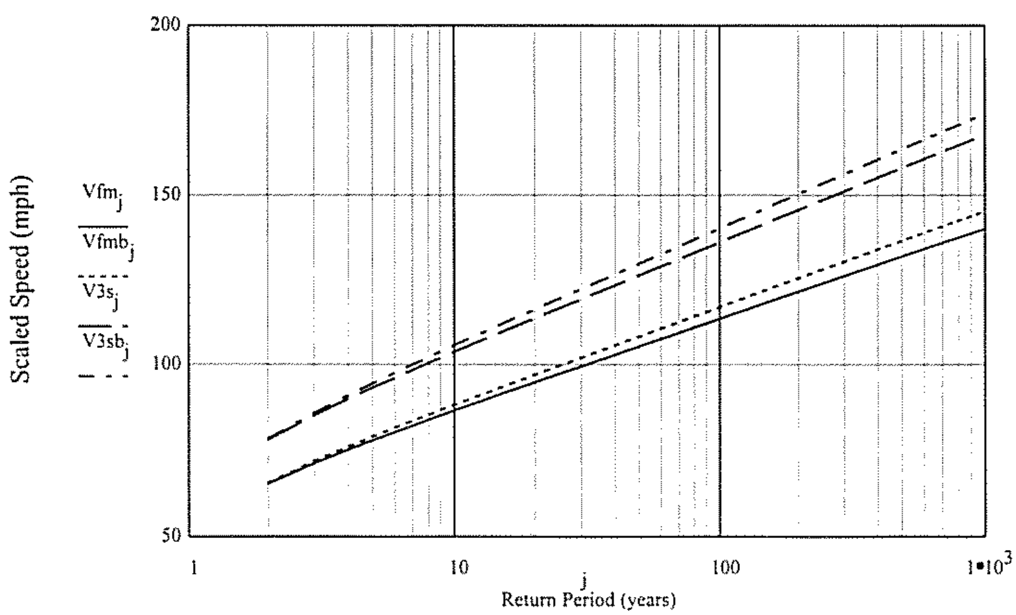
$Vfmb_j := Vhrb_j \cdot Cfm$ $\sigma fm_j := \sigma hr_j \cdot Cfm$

$C3s := 1.52$ correction from 1-hour ave. to 3-sec gust

$V3s_j := Vhr_j \cdot C3s$

$V3sb_j := Vhrb_j \cdot C3s$ $\sigma 3s_j := \sigma hr_j \cdot C3s$





APPENDIX B

APPENDIX B
EXCERPTS OF SPREADSHEET CALCULATIONS FOR ELMENDORF AFB

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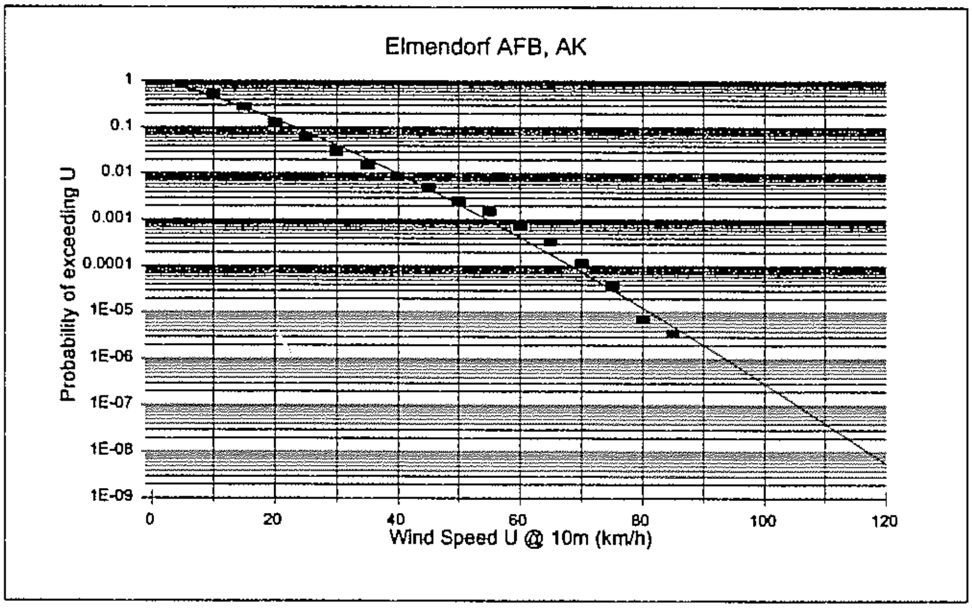
Elmendorf AFB, AK

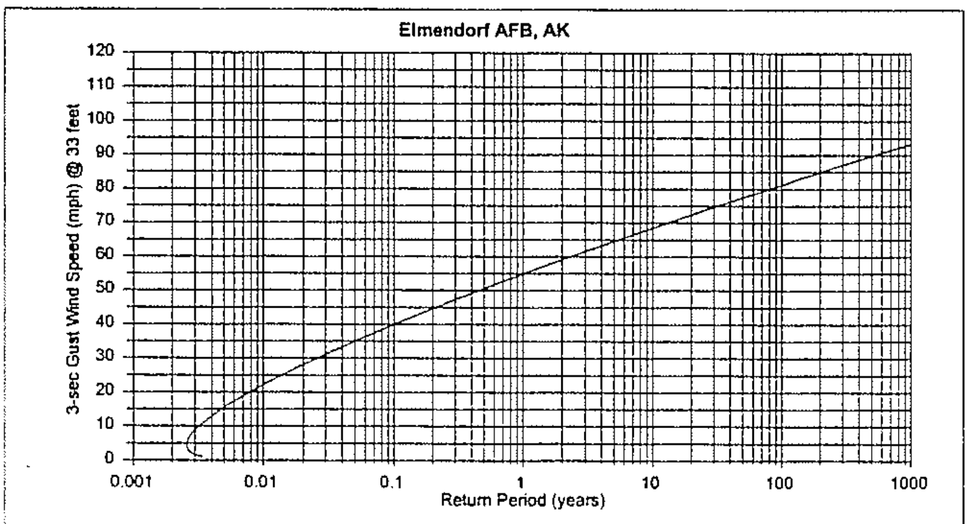
Udotbar Constants (before correction)		Weibull Parameters	
UC1	0.06	A	0.773294
UC2	1.676	C	12.20297
UC3	0	K	1.287826

50 year return, mean hourly wind speed @ 33 feet

Umh@33	81.84	kph
Umh@33	50.853	mph

gust factor	1.258		gust factor	1.524	
50 year return fastest-mile wind speed	63.97	mph	50 year return 3-sec gust wind speed	77.50	mph





TYPE I EXTREME VALUE DISTRIBUTION

I. Import Data from ASCII File

Data :=

N:\..\Maxspeed.txt

Station: Elmendorf AFB

$V1 := Data^{\langle 3 \rangle}$ $\quad Va := V1 \cdot \frac{km}{hr}$ Input Wind Speed

$H1 := Data^{\langle 9 \rangle}$ $\quad Ha := H1 \cdot m$ Instrument Height

II. Scale Speeds to 10m in Open Terrain

$n := 55$ Range of Input Data

$i := 0 .. n$

NOTE: Position 1 is the actual anemometer location,
Position 2 is at the top of the boundary layer, and
Position 3 is at 10m in open terrain

$Z1_i := Ha_i$

Upk is the peak gust speed and
Ufm is the fastest mile speed

$U2_i := U1 \cdot \left(\frac{Z2}{Z1_i} \right)^{\alpha 1}$ Scale from anemometer to top of boundary layer

$U3_i := U2_i \cdot \left(\frac{Z3}{Z2} \right)^{\alpha}$ Scale from top of boundary layer to 10m in open terrain

$\sigma 3_i := 0.17 \cdot U3_i$ rms of wind speed at 10m in the open

Peak gust and fastest mile speed relationships:

$Upk1 := U1 + 3 \cdot \sigma 1$ $\quad Upk2_i := U2_i + 3 \ \sigma 2$ $\quad Upk3_i := U3_i + 3 \cdot \sigma 3_i$

$Ufm1 := 0.5 \cdot (Upk1 + U1)$ $\quad Ufm2_i := 0.5 \ (Upk2_i + U2_i)$ $\quad Ufm3_i := 0.5 \cdot (Upk3_i + U3_i)$

Velocity Ratios:

$f0_i := \frac{Ufm3_i}{Ufm1}$ $\quad f1_i := \frac{U3_i}{U1}$ $\quad f2_i := \frac{Upk3_i}{Upk1}$ $\quad U1 \equiv 1 \cdot \frac{m}{sec}$ arbitrary value of U1

$Z2 \equiv 600 \cdot m$ $\quad Z3 \equiv 10 \cdot m$ $\quad \sigma 2 \equiv 0 \cdot \frac{m}{sec}$ $\quad \alpha \equiv 0.14$

$\sigma 1 \equiv 0.22 \cdot U1$ $\quad \alpha 1 \equiv 0.17$ input data

$f0 = $

	0
0	1.011
1	1.011
2	1.011

$f1 = $

	0
0	1.072
1	1.072
2	1.072

$f2 = $

	0
0	0.975
1	0.975
2	0.975

$fs_i := f0_i$ — Choose the appropriate scale factor

$V10a_i := Va_i \cdot fs_i$ — Scale velocities by the appropriate factor

$V10 := \mathrm{sort}(V10a)$ — Sort scaled velocities in ascending order

III. Method of Moments (Pf)

$U := \mathrm{mean}(V10)$ $\quad U = 57.515 \cdot ft \cdot sec^{-1}$ — Sample Mean

$\sigma := \mathrm{Stdev}\left(\frac{V10}{\frac{ft}{sec}}\right)$ $\quad \sigma = 10.283$ — Standard Deviation

$\theta := \frac{\sqrt{6}}{\pi} \cdot \sigma \cdot \frac{ft}{sec}$ $\quad \theta = 8.018 \cdot ft \cdot sec^{-1}$ — Scale Parameter

$\xi := U - 0.57722 \cdot \theta$ $\quad \xi = 52.887 \cdot ft \cdot sec^{-1}$ — Location Parameter

$P_i := 1 - \frac{i+1}{n+2}$ — Observed Probabilities

$Pf_i := 1 - \exp\left[-\exp\left[\frac{-(V10_i - \xi)}{\theta}\right]\right]$ — Fitted Probabilities

$R_i := \frac{1}{P_i}$ $\quad Rf_i := \frac{1}{Pf_i}$ — Observed and Fitted Return Periods

$j := 2 .. 1000$

$V_j := \xi - \theta \cdot \ln\left(-\ln\left(1 - \frac{1}{j}\right)\right)$ — Velocities for a range of return periods

IV. Method of Least Squares (Pf2)

$$L_i := \ln(-\ln(1 - P_i))$$

$\theta 2 := -\mathrm{slope}(L, V10)$ $\qquad$ $\theta 2 = 8.585 \cdot ft \cdot sec^{-1}$

$\xi 2 := \mathrm{intercept}(L, V10)$ $\qquad$ $\xi 2 = 52.787 \cdot ft \cdot sec^{-1}$

$$Pf2_i := 1 - \exp\left[-\exp\left[\frac{-(V10_i - \xi 2)}{\theta 2}\right]\right]$$ Ftted Probability

$$Rf2_i := \frac{1}{Pf2_i}$$ Fitted Return Period

$$Vb_j := \xi 2 - \theta 2 \cdot \ln\left(-\ln\left(1 - \frac{1}{j}\right)\right)$$ Velocities for a range of return periods

V. Sampling Error, Method of Moments

$$Y_j := -\ln\left(-\ln\left(1 - \frac{1}{j}\right)\right)$$

$$\sigma VN_j := \left[\frac{\pi^2}{6} + 1.1396\,\frac{(Y_j - 0.5772)}{\sqrt{6}} + 1.1\,(Y_j - 0.5772)^2\right]^{0.5}\,\frac{\theta}{\sqrt{n+1}}$$

VI. Correction to True 1-hour, Fastest-Mile, Peak Gust (50 year Values)

$Cf := 0.91$ correction from 1-minute reading on the hour to true 1-hour

$Vhr_j := V_j \cdot Cf$

$Vhrb_j := Vb_j \cdot Cf$ $\qquad$ $\sigma hr_j := \sigma VN_j\, Cf$

$Cfm := 1.27$ correction from 1-hour ave. to fastest mile

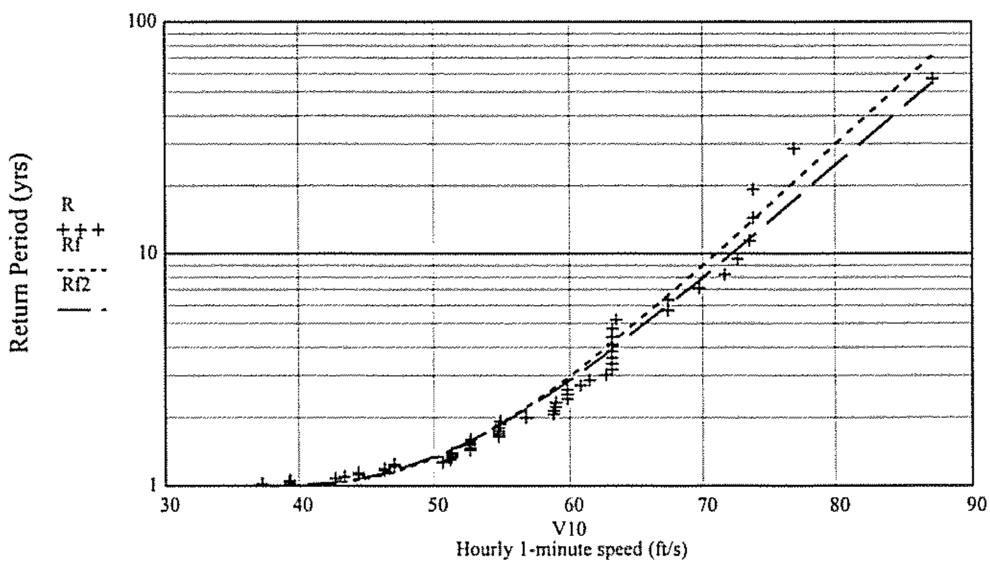
$Vfm_j := Vhr_j \cdot Cfm$

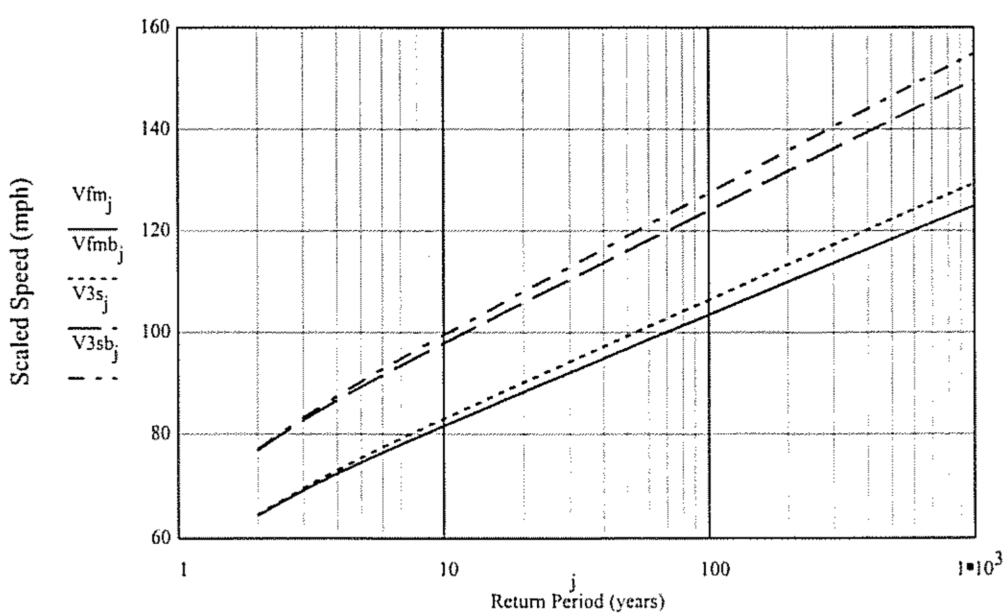
$Vfmb_j := Vhrb_j \cdot Cfm$ $\sigma fm_j := \sigma hr_j \cdot Cfm$

$C3s := 1.52$ correction from 1-hour ave. to 3-sec gust

$V3s_j := Vhr_j \cdot C3s$

$V3sb_j := Vhrb_j \cdot C3s$ $\sigma 3s_j := \sigma hr_j \cdot C3s$





Station: *Elmendorf AFB*
Data Set: Annual Maximum Hourly 1-Minute Readings

Return Period (years)	*Fastest Mile Wind Speed.*	*Peak Gust Wind Speed.*
$k := 50$	$Vfm_k = 66.3 \cdot mph$	$V3s_k = 79.4 \cdot mph$
	$Vfmb_k = 68 \cdot mph$	$V3sb_k = 81.4 \cdot mph$
	$\sigma fm_k = 3.3 \cdot mph$	$\sigma 3s_k = 4 \cdot mph$
$k := 100$	$Vfm_k = 70.7 \cdot mph$	$V3s_k = 84.7 \cdot mph$
	$Vfmb_k = 72.7 \cdot mph$	$V3sb_k = 87 \cdot mph$
	$\sigma fm_k = 3.9 \cdot mph$	$\sigma 3s_k = 4.7 \cdot mph$
$k := 250$	$Vfm_k = 76.5 \cdot mph$	$V3s_k = 91.6 \cdot mph$
	$Vfmb_k = 78.9 \cdot mph$	$V3sb_k = 94.5 \cdot mph$
	$\sigma fm_k = 4.7 \cdot mph$	$\sigma 3s_k = 5.6 \cdot mph$
$k := 1000$	$Vfm_k = 85.3 \cdot mph$	$V3s_k = 102.1 \cdot mph$
	$Vfmb_k = 88.3 \cdot mph$	$V3sb_k = 105.7 \cdot mph$
	$\sigma fm_k = 5.9 \cdot mph$	$\sigma 3s_k = 7 \cdot mph$

APPENDIX C

APPENDIX C
EXCERPTS OF SPREADSHEET CALCULATIONS FOR MERRILL FIELD

TABLE OF CONTENTS

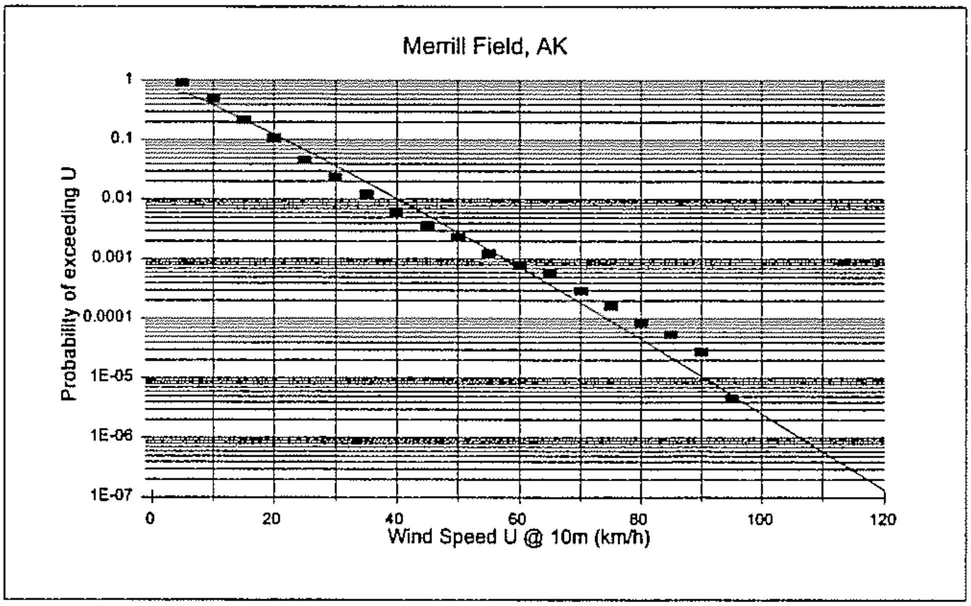
Merrill Field, AK

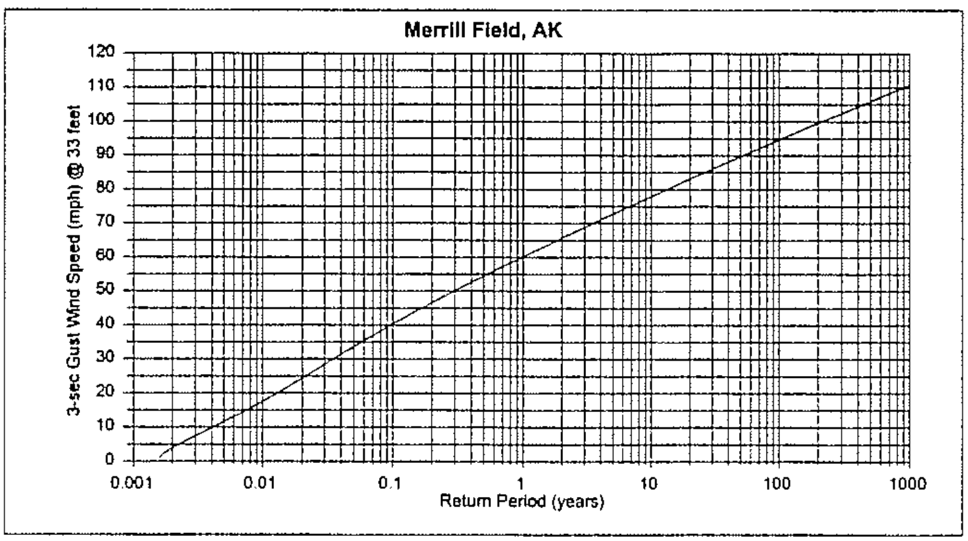
Udotbar Constants (before correction)		Weibull Parameters	
UC1	0.102	A	0.786994
UC2	2.618	C	10.46357
UC3	-0.093	K	1.132059

50 year return, mean hourly wind speed @ 33 feet

Umh@33	94.758 kph
Umh@33	58.880 mph

gust factor	1.274	gust factor	1.524
50 year return fastest-mile wind speed	75.01 mph	50 year return 3-sec gust wind speed	89.73 mph





TYPE I EXTREME VALUE DISTRIBUTION

I. Import Data from ASCII File

Data :=

N:\..\Maxspeed.txt

Station: Merrill Field

$V1 := Data^{\langle 3 \rangle}$ $\qquad$ $Va := V1 \cdot \frac{km}{hr}$ $\qquad$ Input Wind Speed

$H1 := Data^{\langle 9 \rangle}$ $\qquad$ $Ha := H1 \cdot m$ $\qquad$ Instrument Height

II. Scale Speeds to 10m in Open Terrain

$n := 35$ $\qquad$ Range of Input Data

$i := 0..n$

NOTE: Position 1 is the actual anemometer location,
Position 2 is at the top of the boundary layer, and
Position 3 is at 10m in open terrain

$Z1_i := Ha_i$

Upk is the peak gust speed and
Ufm is the fastest mile speed

$U2_i := U1 \cdot \left(\frac{Z2}{Z1_i}\right)^{\alpha 1}$ $\qquad$ Scale from anemometer to top of boundary layer

$U3_i := U2_i \cdot \left(\frac{Z3}{Z2}\right)^{\alpha}$ $\qquad$ Scale from top of boundary layer to 10m in open terrain

$\sigma 3_i := 0.17 \cdot U3_i$ $\qquad$ rms of wind speed at 10m in the open

Peak gust and fastest mile speed relationships:

$Upk1 := U1 + 3 \cdot \sigma 1$ $\qquad$ $Upk2_i := U2_i + 3\ \sigma 2$ $\qquad$ $Upk3_i := U3_i + 3 \cdot \sigma 3_i$

$Ufm1 := 0.5 \cdot (Upk1 + U1)$ $\qquad$ $Ufm2_i := 0.5\ (Upk2_i + U2_i)$ $\qquad$ $Ufm3_i := 0.5 \cdot (Upk3_i + U3_i)$

Velocity Ratios:

$f0_i := \frac{Ufm3_i}{Ufm1}$ $\qquad$ $f1_i := \frac{U3_i}{U1}$ $\qquad$ $f2_i := \frac{Upk3_i}{Upk1}$ $\qquad$ $U1 \equiv 1 \cdot \frac{m}{sec}$ $\qquad$ arbitrary value of U1

$Z2 \equiv 600 \cdot m$ $\qquad$ $Z3 \equiv 10 \cdot m$ $\qquad$ $\sigma 2 \equiv 0 \cdot \frac{m}{sec}$ $\qquad$ $\alpha \equiv 0.14$

$\sigma 1 \equiv 0.24 \cdot U1$ $\qquad$ $\alpha 1 \equiv 0.18$ $\qquad$ input data

$f0 = $

	0
0	1.223
1	1.223
2	1.223

$f1 = $

	0
0	1.325
1	1.325
2	1.325

$f2 = $

	0
0	1.163
1	1.163
2	1.163

$fs_i := f0_i$ — Choose the appropriate scale factor

$V10a_i := Va_i \cdot fs_i$ — Scale velocities by the appropriate factor

$V10 := \mathrm{sort}(V10a)$ — Sort scaled velocities in ascending order

III. Method of Moments (Pf)

$U := \mathrm{mean}(V10)$ $\quad U = 57.008 \cdot ft \cdot sec^{-1}$ — Sample Mean

$\sigma := \mathrm{Stdev}\left(\frac{V10}{\frac{ft}{sec}}\right)$ $\quad \sigma = 15.438$ — Standard Deviation

$\theta := \frac{\sqrt{6}}{\pi} \cdot \sigma \cdot \frac{ft}{sec}$ $\quad \theta = 12.037 \cdot ft \cdot sec^{-1}$ — Scale Parameter

$\xi := U - 0.57722 \cdot \theta$ $\quad \xi = 50.06 \cdot ft \cdot sec^{-1}$ — Location Parameter

$P_i := 1 - \frac{i+1}{n+2}$ — Observed Probabilities

$Pf_i := 1 - \exp\left[-\exp\left[\frac{-(V10_i - \xi)}{\theta}\right]\right]$ — Fitted Probabilities

$R_i := \frac{1}{P_i}$ $\quad Rf_i := \frac{1}{Pf_i}$ — Observed and Fitted Return Periods

$j := 2 .. 1000$

$V_j := \xi - \theta \cdot \ln\left(-\ln\left(1 - \frac{1}{j}\right)\right)$ — Velocities for a range of return periods

IV. Method of Least Squares (Pf2)

$L_i := \ln(-\ln(1 - P_i))$

$\theta 2 := -\mathrm{slope}(L, V10)$ $\theta 2 = 12.996 \cdot ft \cdot sec^{-1}$

$\xi 2 := \mathrm{intercept}(L, V10)$ $\xi 2 = 49.977 \cdot ft \cdot sec^{-1}$

$$Pf2_i := 1 - \exp\left[-\exp\left[\frac{-(V10_i - \xi 2)}{\theta 2}\right]\right]$$ Ftted Probability

$$Rf2_i := \frac{1}{Pf2_i}$$ Fitted Return Period

$$Vb_j := \xi 2 - \theta 2 \cdot \ln\left(-\ln\left(1 - \frac{1}{j}\right)\right)$$ Velocities for a range of return periods

V. Sampling Error, Method of Moments

$$Y_j := -\ln\left(-\ln\left(1 - \frac{1}{j}\right)\right)$$

$$\sigma VN_j := \left[\frac{\pi^2}{6} + 1.1396\,\frac{(Y_j - 0.5772)}{\sqrt{6}} + 1.1\,(Y_j - 0.5772)^2\right]^{0.5} \frac{\theta}{\sqrt{n+1}}$$

VI. Correction to True 1-hour, Fastest-Mile, Peak Gust (50 year Values)

$Cf := 0.91$ correction from 1-minute reading on the hour to true 1-hour

$Vhr_j := V_j \cdot Cf$

$Vhrb_j := Vb_j \cdot Cf$ $\sigma hr_j := \sigma VN_j\, Cf$

$Cfm := 1.27$ correction from 1-hour ave. to fastest mile

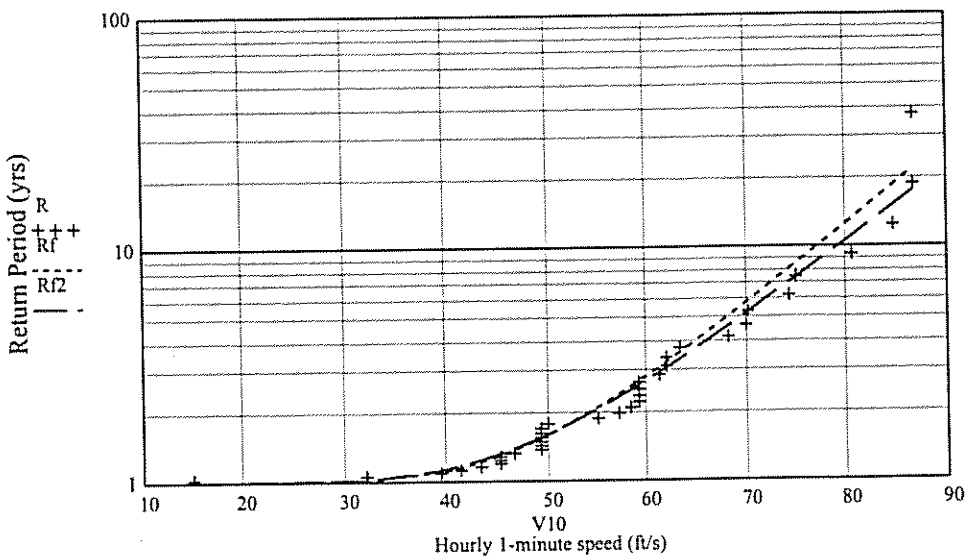
$Vfm_j := Vhr_j \cdot Cfm$

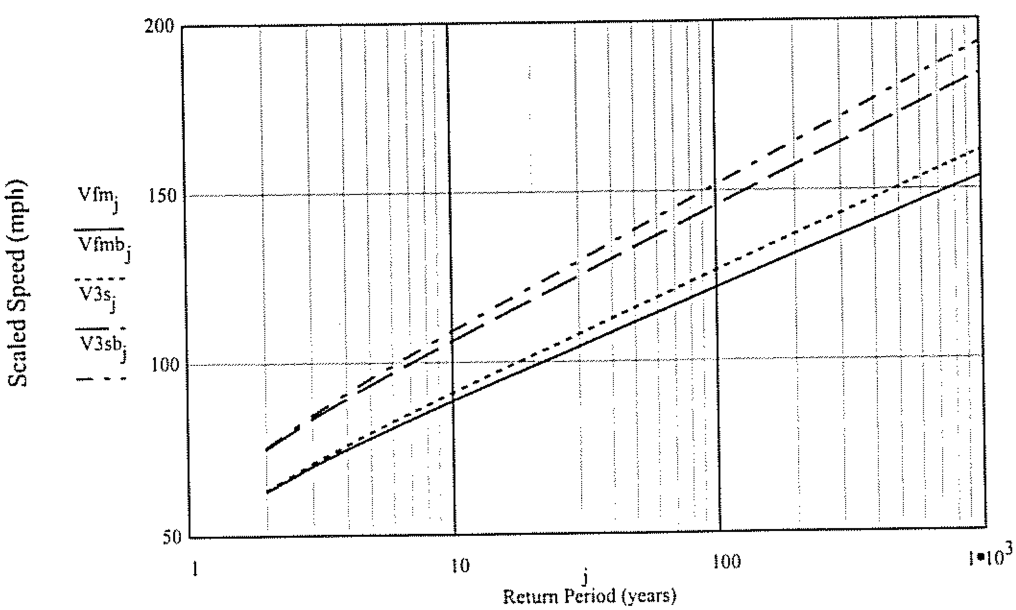
$Vfmb_j := Vhrb_j \cdot Cfm$ $\sigma fm_j := \sigma hr_j \cdot Cfm$

$C3s := 1.52$ correction from 1-hour ave. to 3-sec gust

$V3s_j := Vhr_j \cdot C3s$

$V3sb_j := Vhrb_j \cdot C3s$ $\sigma 3s_j := \sigma hr_j \cdot C3s$





Station: *Merrill Field*
Data Set: Annual Maximum Hourly 1-Minute Readings

Return Period (years)	*Fastest Mile Wind Speed.*	*Peak Gust Wind Speed.*
$k := 50$	$Vfm_k = 76.5 \cdot mph$	$V3s_k = 91.5 \cdot mph$
	$Vfmb_k = 79.3 \cdot mph$	$V3sb_k = 95 \cdot mph$
	$\sigma fm_k = 6.2 \cdot mph$	$\sigma 3s_k = 7.4 \cdot mph$
$k := 100$	$Vfm_k = 83.1 \cdot mph$	$V3s_k = 99.4 \cdot mph$
	$Vfmb_k = 86.5 \cdot mph$	$V3sb_k = 103.5 \cdot mph$
	$\sigma fm_k = 7.3 \cdot mph$	$\sigma 3s_k = 8.7 \cdot mph$
$k := 250$	$Vfm_k = 91.8 \cdot mph$	$V3s_k = 109.9 \cdot mph$
	$Vfmb_k = 95.9 \cdot mph$	$V3sb_k = 114.8 \cdot mph$
	$\sigma fm_k = 8.8 \cdot mph$	$\sigma 3s_k = 10.5 \cdot mph$
$k := 1000$	$Vfm_k = 105 \cdot mph$	$V3s_k = 125.6 \cdot mph$
	$Vfmb_k = 110.1 \cdot mph$	$V3sb_k = 131.8 \cdot mph$
	$\sigma fm_k = 11 \cdot mph$	$\sigma 3s_k = 13.2 \cdot mph$

APPENDIX D

APPENDIX D
EXCERPTS OF SPREADSHEET CALCULATIONS FOR THE PORTMAN RESIDENCE

TABLE OF CONTENTS

TYPE I EXTREME VALUE DISTRIBUTION

I. Import Data from Peak Gust Spreadsheet

Station: Portman Residence

$V1 := Data^{\langle 0 \rangle}$ $Va := V1 \cdot mph$ Input Wind Speed

$H1 := Data^{\langle 1 \rangle}$ $Ha := H1 \cdot ft$ Instrument Height

II. Scale Speeds to 10m in Open Terrain

$n := 13$ Range of Input Data

$i := 0 .. n$

NOTE: Position 1 is the actual anemometer location, Position 2 is at the top of the boundary layer, and Position 3 is at 10m in open terrain

$Z1_i := Ha_i$

Upk is the peak gust speed and Ufm is the fastest mile speed

$U2_i := U1 \cdot \left(\frac{Z2}{Z1_i}\right)^{\alpha 1}$ Scale from anemometer to top of boundary layer

$U3_i := U2_i \cdot \left(\frac{Z3}{Z2}\right)^{\alpha}$ Scale from top of boundary layer to 10m in open terrain

$\sigma 3_i := 0.17 \cdot U3_i$ rms of wind speed at 10m in the open

Peak gust and fastest mile speed relationships:

$Upk1 := U1 + 3 \cdot \sigma 1$ $Upk2_i := U2_i + 3\ \sigma 2$ $Upk3_i := U3_i + 3 \cdot \sigma 3_i$

$Ufm1 := 0.5 \cdot (Upk1 + U1)$ $Ufm2_i := 0.5\ (Upk2_i + U2_i)$ $Ufm3_i := 0.5 \cdot (Upk3_i + U3_i)$

Velocity Ratios:

$f0_i := \frac{Ufm3_i}{Ufm1}$ $f1_i := \frac{U3_i}{U1}$ $f2_i := \frac{Upk3_i}{Upk1}$ $U1 \equiv 1 \cdot \frac{m}{sec}$ arbitrary value of U1

$Z2 \equiv 600 \cdot m$ $Z3 \equiv 10 \cdot m$ $\sigma 2 \equiv 0 \cdot \frac{m}{sec}$ $\alpha \equiv 0.14$

$\sigma 1 \equiv 0.27 \cdot U1$ $\alpha 1 \equiv 0.20$ input data

$$f0 = \begin{array}{c|c} & 0 \\ \hline 0 & 1.109 \\ 1 & 1.109 \\ 2 & 1.109 \\ 3 & 1.109 \end{array} \qquad f1 = \begin{array}{c|c} & 0 \\ \hline 0 & 1.241 \\ 1 & 1.241 \\ 2 & 1.241 \end{array} \qquad f2 = \begin{array}{c|c} & 0 \\ \hline 0 & 1.036 \\ 1 & 1.036 \\ 2 & 1.036 \end{array}$$

$fs_i := f2_i$ — Choose the appropriate scale factor

$V10a_i := Va_i \cdot fs_i$ — Scale velocities by the appropriate factor

$V10 := \mathrm{sort}(V10a)$ — Sort scaled velocities in ascending order

III. Method of Moments (Pf)

$U := \mathrm{mean}(V10) \qquad U = 132.153 \cdot ft \cdot sec^{-1}$ — Sample Mean

$\sigma := \mathrm{Stdev}\left(\frac{V10}{\frac{ft}{sec}}\right) \qquad \sigma = 20.406$ — Standard Deviation

$\theta := \frac{\sqrt{6}}{\pi} \cdot \sigma \cdot \frac{ft}{sec} \qquad \theta = 15.91 \cdot ft \cdot sec^{-1}$ — Scale Parameter

$\xi := U - 0.57722 \cdot \theta \qquad \xi = 122.97 \cdot ft \cdot sec^{-1}$ — Location Parameter

$P_i := 1 - \frac{i+1}{n+2}$ — Observed Probabilities

$Pf_i := 1 - \exp\left[-\exp\left[\frac{-(V10_i - \xi)}{\theta}\right]\right]$ — Fitted Probabilities

$R_i := \frac{1}{P_i} \qquad Rf_i := \frac{1}{Pf_i}$ — Observed and Fitted Return Periods

$j := 2 .. 1000$

$V_j := \xi - \theta \cdot \ln\left(-\ln\left(1 - \frac{1}{j}\right)\right)$ — Velocities for a range of return periods

IV. Method of Least Squares (Pf2)

$$L_i := \ln(-\ln(1 - P_i))$$

$\theta 2 := -\text{slope}(L, V10)$ $\qquad \theta 2 = 18.458 \cdot \text{ft} \cdot \text{sec}^{-1}$

$\xi 2 := \text{intercept}(L, V10)$ $\qquad \xi 2 = 122.739 \cdot \text{ft} \cdot \text{sec}^{-1}$

$$Pf2_i := 1 - \exp\left[-\exp\left[\frac{-(V10_i - \xi 2)}{\theta 2}\right]\right]$$ Ftted Probability

$$Rf2_i := \frac{1}{Pf2_i}$$ Fitted Return Period

$$Vb_j := \xi 2 - \theta 2 \cdot \ln\left(-\ln\left(1 - \frac{1}{j}\right)\right)$$ Velocities for a range of return periods

V. Sampling Error, Method of Moments

$$Y_j := -\ln\left(-\ln\left(1 - \frac{1}{j}\right)\right)$$

$$\sigma VN_j := \left[\frac{\pi^2}{6} + 1.1396\,\frac{(Y_j - 0.5772)}{\sqrt{6}} + 1.1\,(Y_j - 0.5772)^2\right]^{0.5} \frac{\theta}{\sqrt{n+1}}$$

VI. Correction to True 1-hour, Fastest-Mile, Peak Gust (50 year Values)

$Cf := \frac{1}{1.52}$ correction from 1-minute reading on the hour to true 1-hour

$Vhr_j := V_j \cdot Cf$ $\qquad \sigma hr_j := \sigma VN_j\, Cf$

$Vhrb_j := Vb_j \cdot Cf$

$Cfm := 1.27$ correction from 1-hour ave. to fastest mile

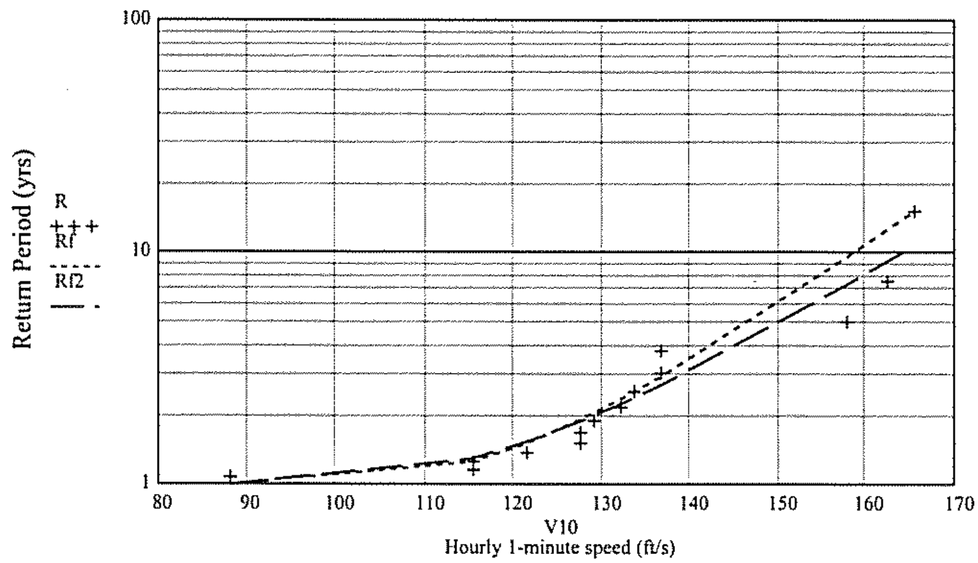
$Vfm_j := Vhr_j \cdot Cfm$

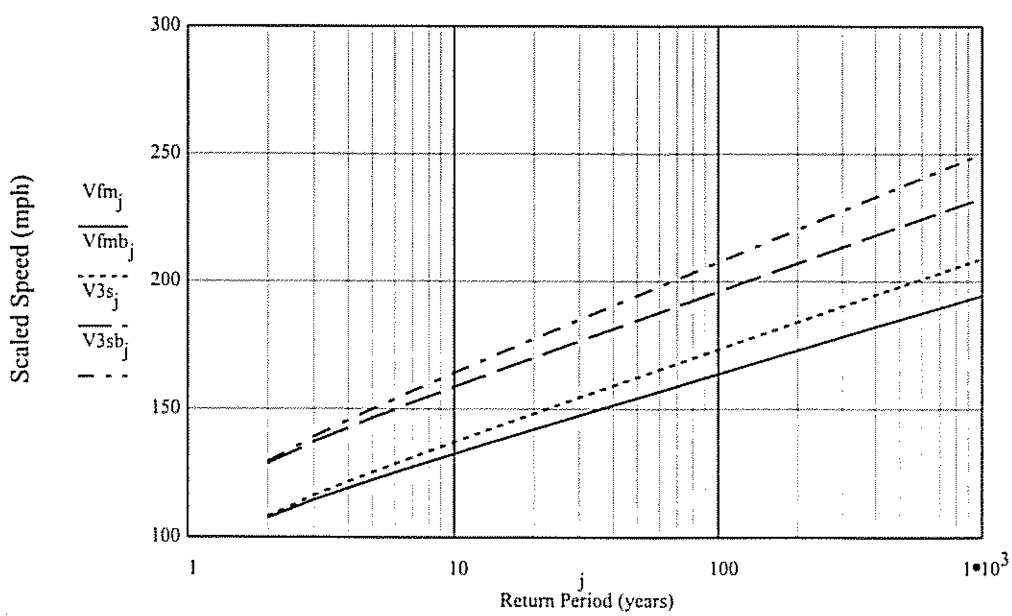
$Vfmb_j := Vhrb_j \cdot Cfm$ $\sigma fm_j := \sigma hr_j \cdot Cfm$

$C3s := 1.52$ correction from 1-hour ave. to 3-sec gust

$V3s_j := Vhr_j \cdot C3s$

$V3sb_j := Vhrb_j \cdot C3s$ $\sigma 3s_j := \sigma hr_j \cdot C3s$



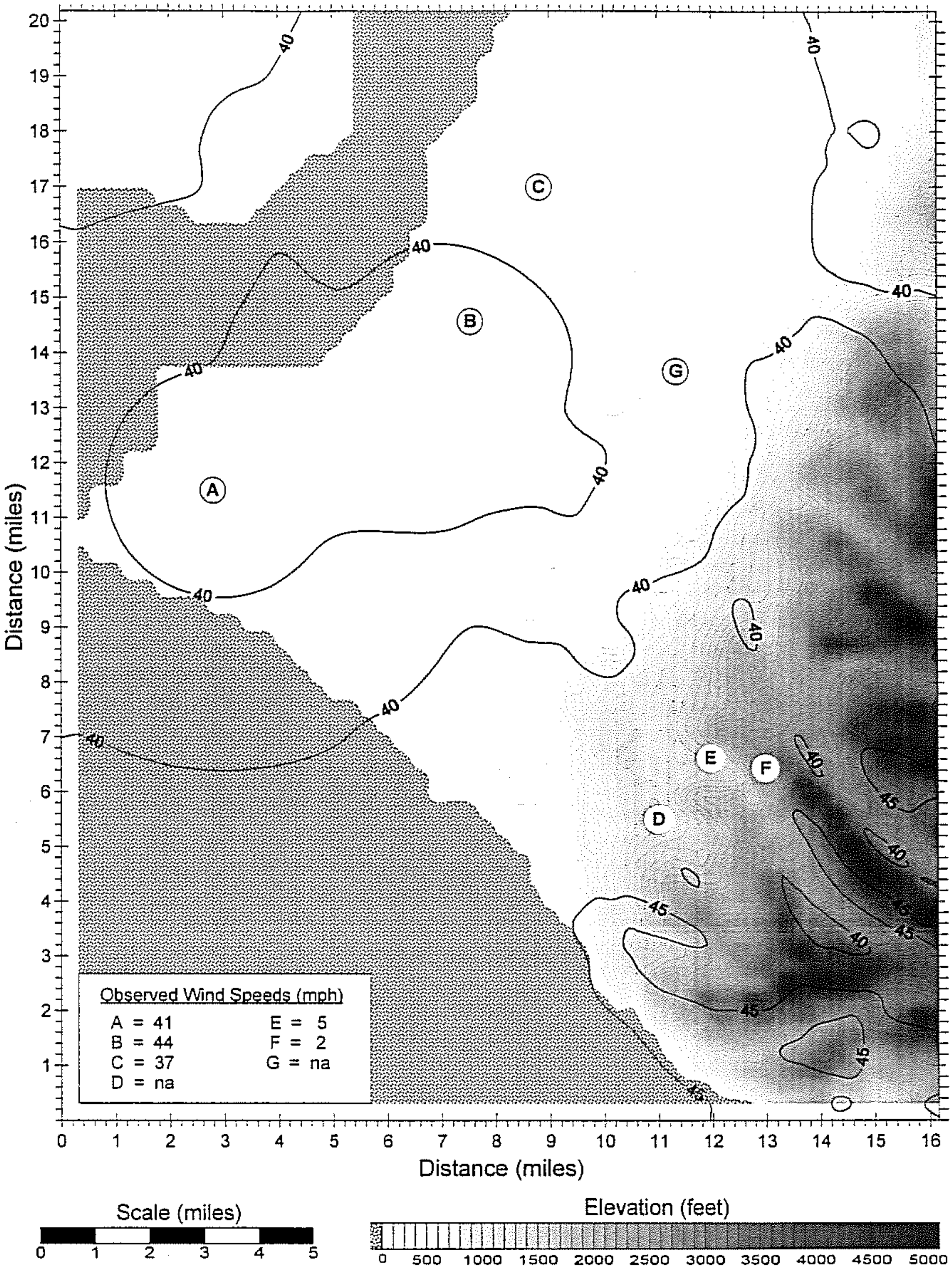


Station: *Portman Residence*
Data Set: Annual Maximum Peak Gust Readings

Return Period (years)	Fastest Mile Wind Speed.	Peak Gust Wind Speed.
$k := 50$	$Vfm_k = 105.4 \cdot mph$	$V3s_k = 126.2 \cdot mph$
	$Vfmb_k = 111 \cdot mph$	$V3sb_k = 132.8 \cdot mph$
	$\sigma fm_k = 9.5 \cdot mph$	$\sigma 3s_k = 11.4 \cdot mph$
$k := 100$	$Vfm_k = 111.7 \cdot mph$	$V3s_k = 133.7 \cdot mph$
	$Vfmb_k = 118.3 \cdot mph$	$V3sb_k = 141.6 \cdot mph$
	$\sigma fm_k = 11.2 \cdot mph$	$\sigma 3s_k = 13.4 \cdot mph$
$k := 250$	$Vfm_k = 120.1 \cdot mph$	$V3s_k = 143.7 \cdot mph$
	$Vfmb_k = 128 \cdot mph$	$V3sb_k = 153.1 \cdot mph$
	$\sigma fm_k = 13.4 \cdot mph$	$\sigma 3s_k = 16.1 \cdot mph$
$k := 1000$	$Vfm_k = 132.7 \cdot mph$	$V3s_k = 158.8 \cdot mph$
	$Vfmb_k = 142.6 \cdot mph$	$V3sb_k = 170.6 \cdot mph$
	$\sigma fm_k = 16.9 \cdot mph$	$\sigma 3s_k = 20.2 \cdot mph$

$$Data \equiv \begin{bmatrix} 85 & 38 \\ 84 & 38 \\ 104 & 38 \\ 84 & 38 \\ 80 & 38 \\ 88 & 38 \\ 76 & 38 \\ 107 & 38 \\ 109 & 38 \\ 90 & 38 \\ 90 & 38 \\ 76 & 38 \\ 58 & 38 \\ 87 & 38 \end{bmatrix}$$

APPENDIX E



Appendix E - Maximum Hourly Wind Speed Contours (mph) for the Nov. 15, 1978 Storm.

Anchorage Area-Wide Wind Speed Study - Anchorage, Alaska

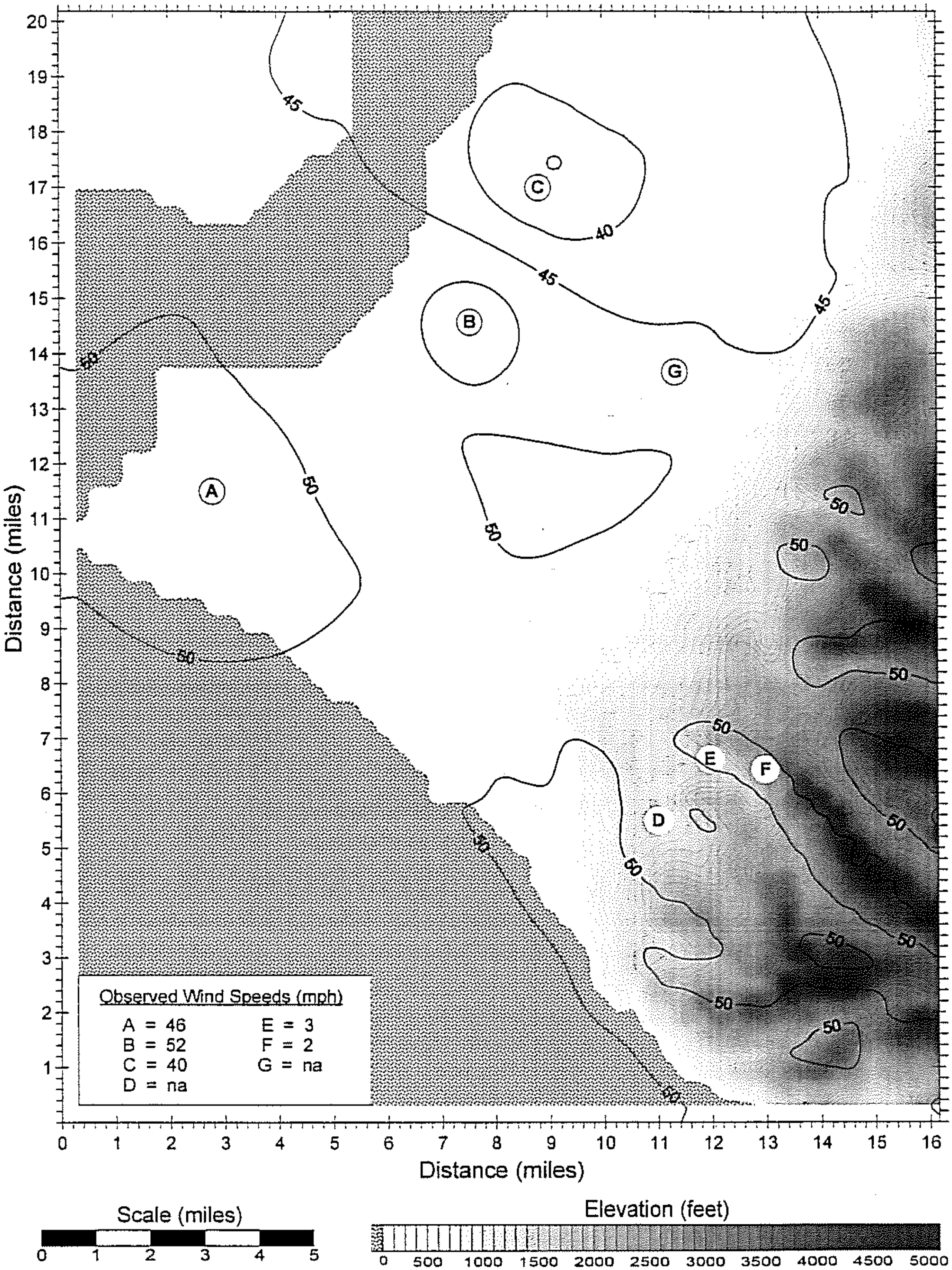
True North

Job No. 98-362

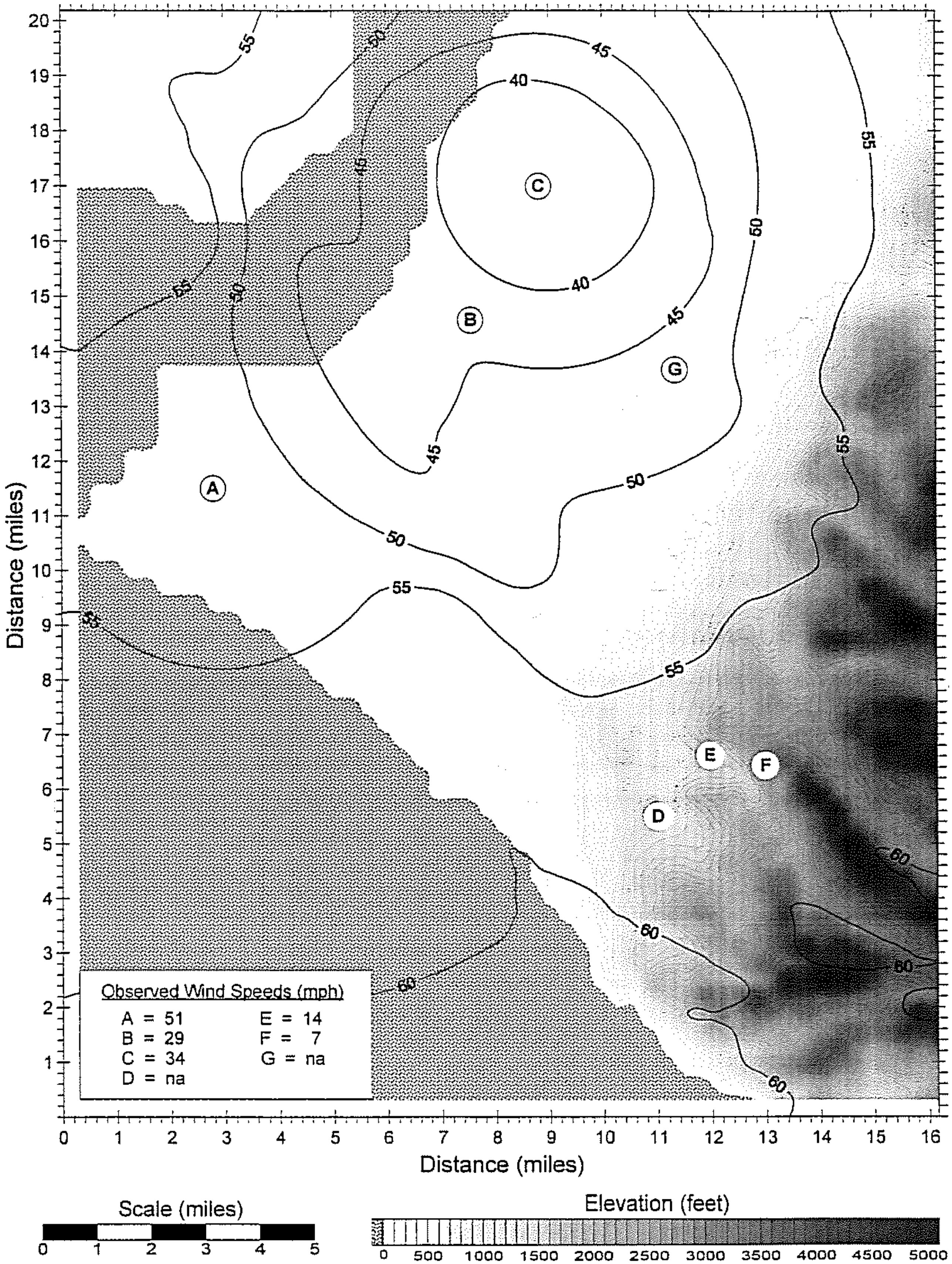
Figure: E-1

Date: Nov. 26, 1998

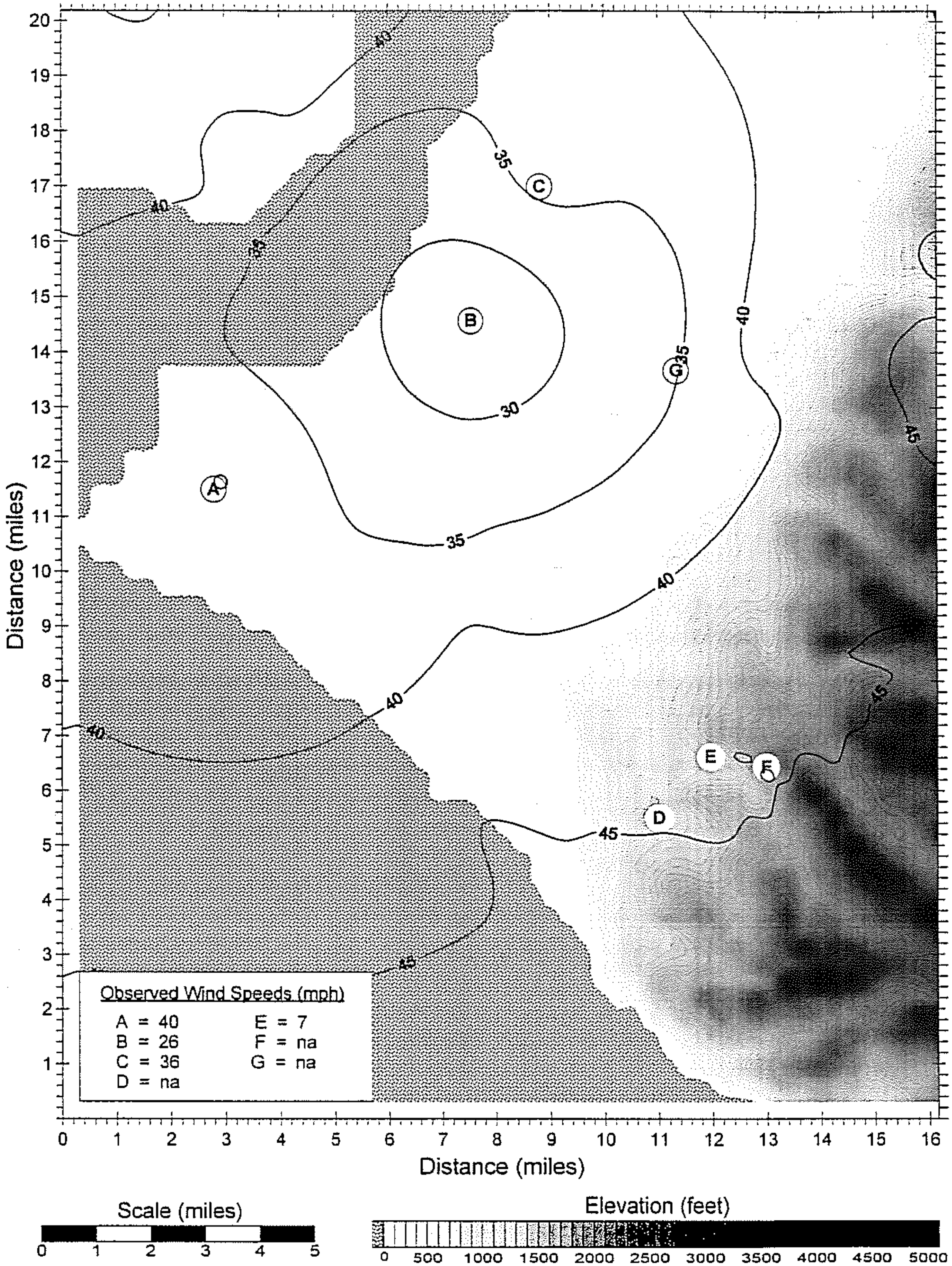
RWDI



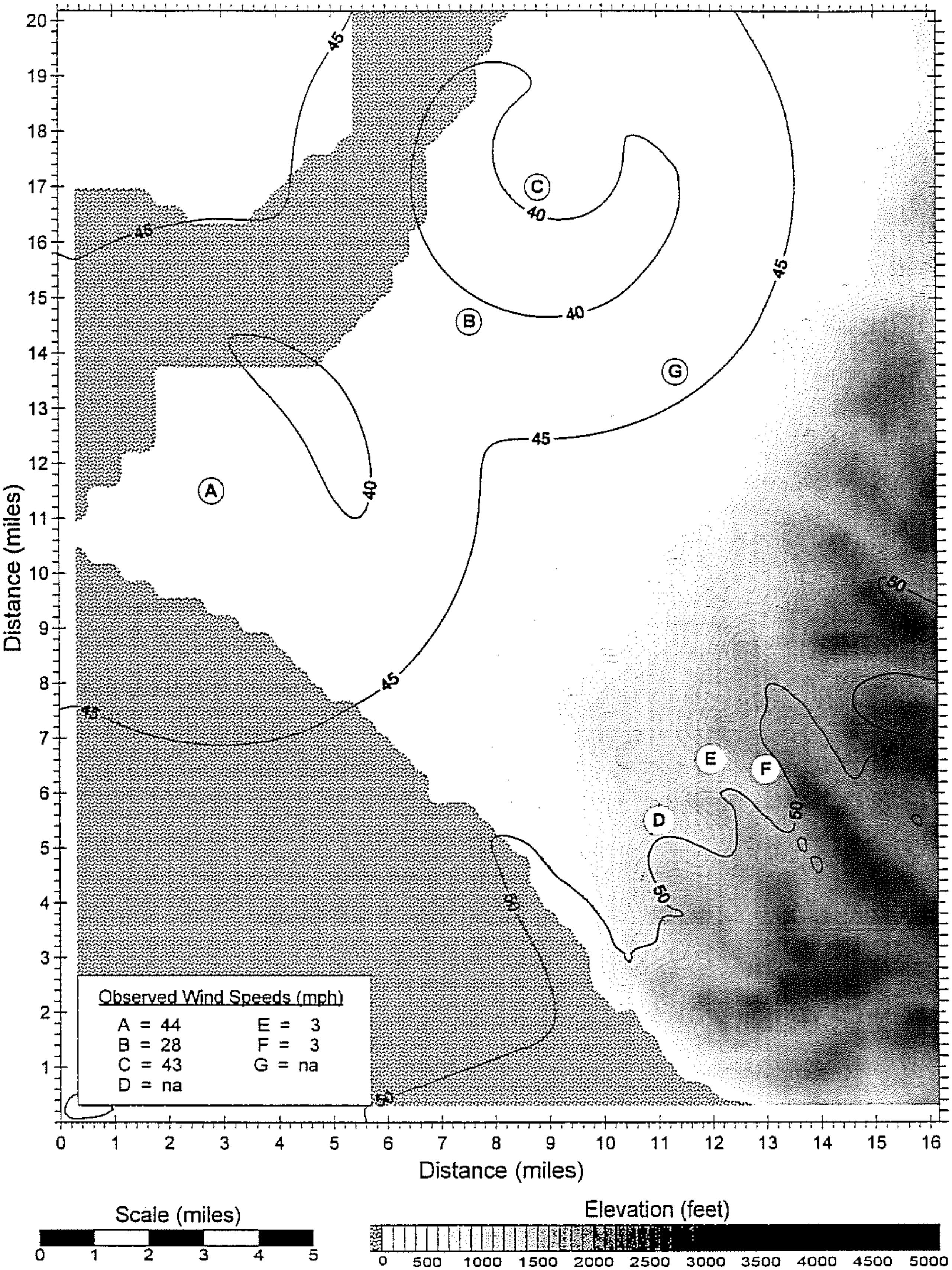
Appendix E - Maximum Hourly Wind Speed Contours (mph) for the Feb. 14, 1979 Storm.	Figure: E-2	RWDI
Anchorage Area-Wide Wind Speed Study - Anchorage, Alaska — True North — Job No. 98-362	Date: Nov. 26, 1998	



Appendix E - Maximum Hourly Wind Speed Contours (mph) for the Mar. 04, 1989 Storm. Anchorage Area-Wide Wind Speed Study - Anchorage, Alaska True North Job No. 98-362	Figure: E-3 Date: Nov. 26, 1998	RWDI



Appendix E - Maximum Hourly Wind Speed Contours (mph) for the Feb. 03, 1993 Storm.	True North	Figure: E-4	RWDI
Anchorage Area-Wide Wind Speed Study - Anchorage, Alaska	Job No. 98-362	Date: Nov. 26, 1998	



Appendix E - Maximum Hourly Wind Speed Contours (mph) for the Feb. 20, 1994 Storm.

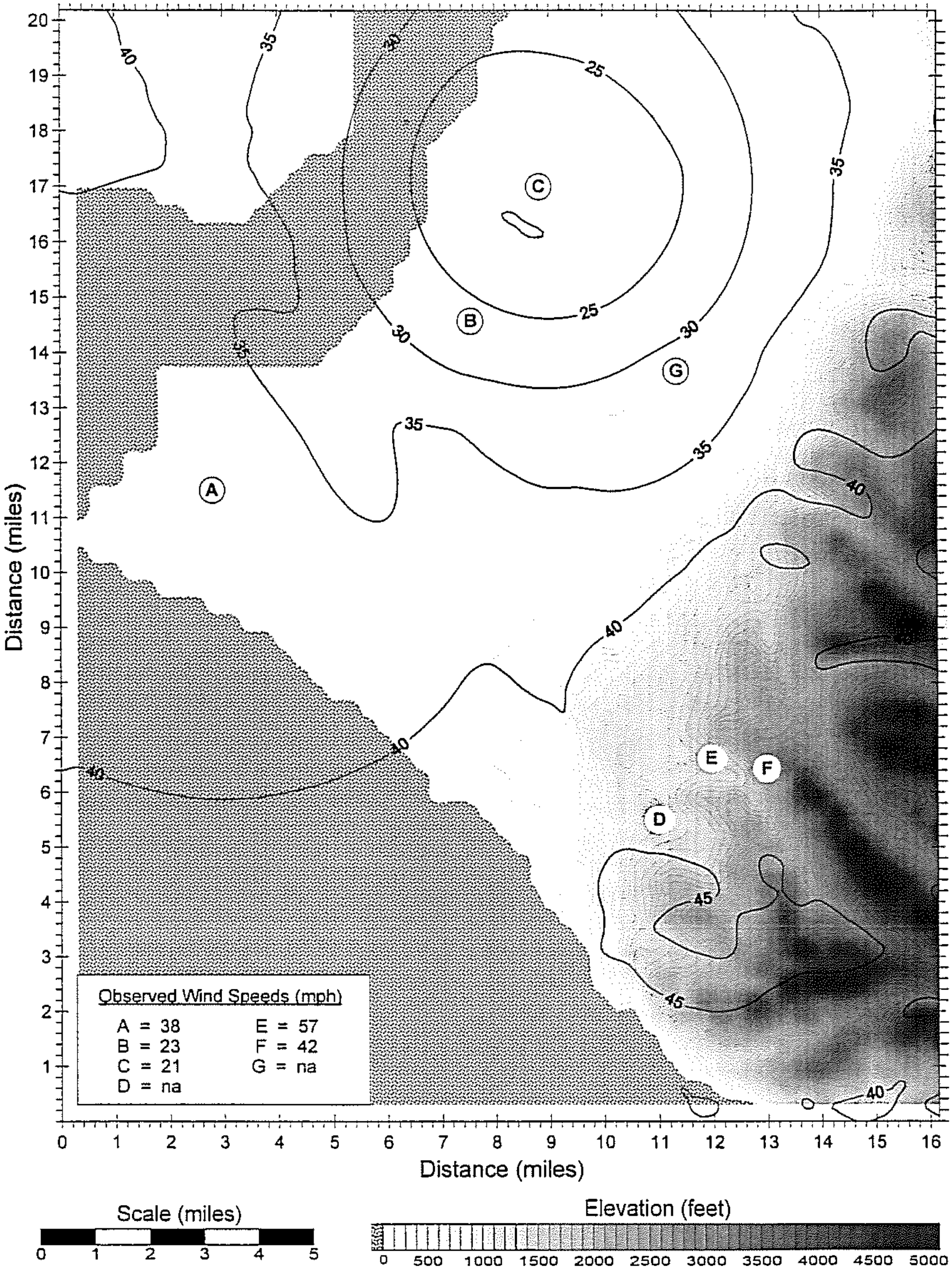
Anchorage Area-Wide Wind Speed Study - Anchorage, Alaska

True North

Job No. 98-362

Figure:	E-5
Date:	Nov. 26, 1998

RWDI



Appendix E - Maximum Hourly Wind Speed Contours (mph) for the Nov. 09, 1986 Storm.

Anchorage Area-Wide Wind Speed Study - Anchorage, Alaska

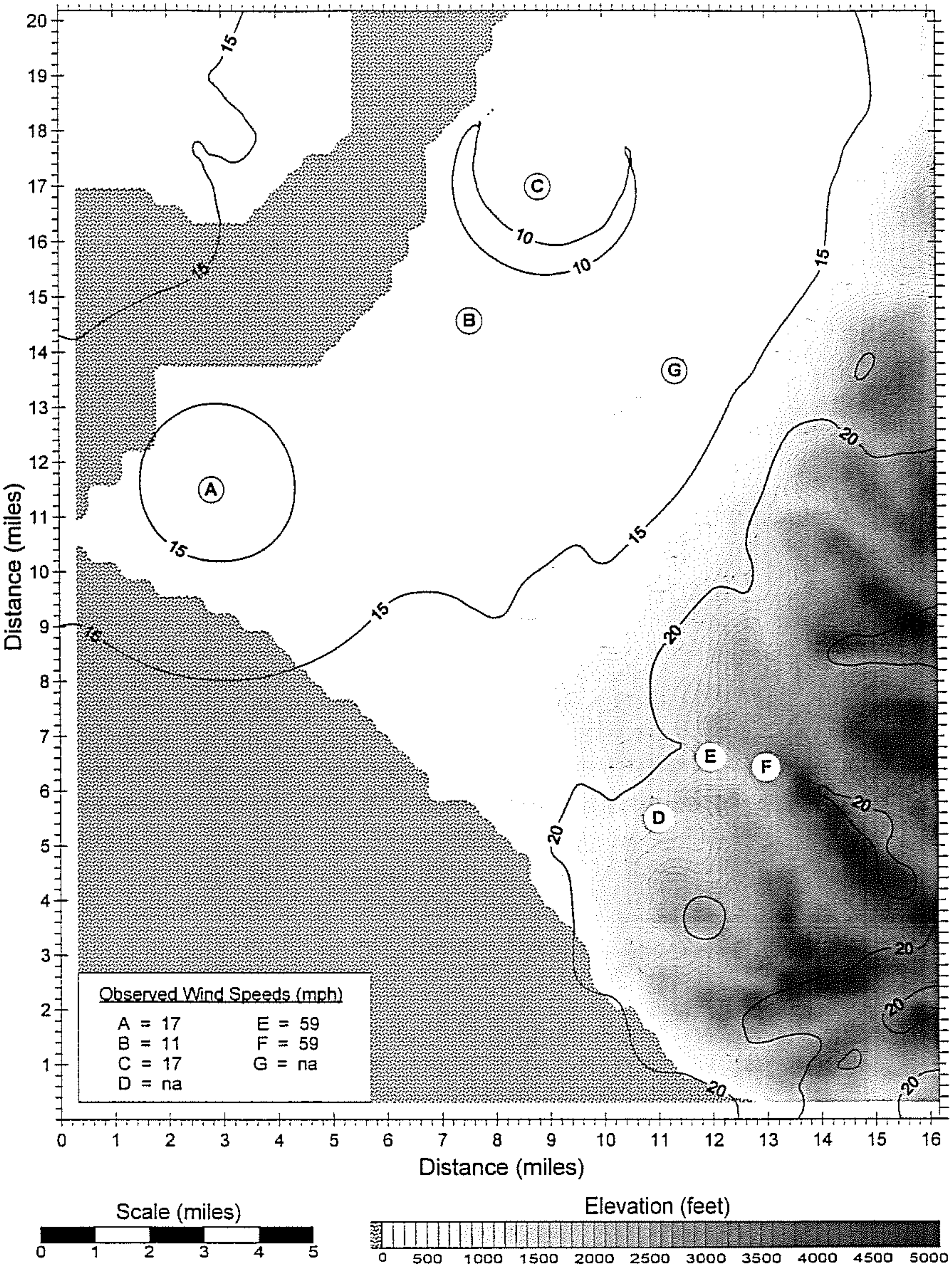
True North

Job No. 98-362

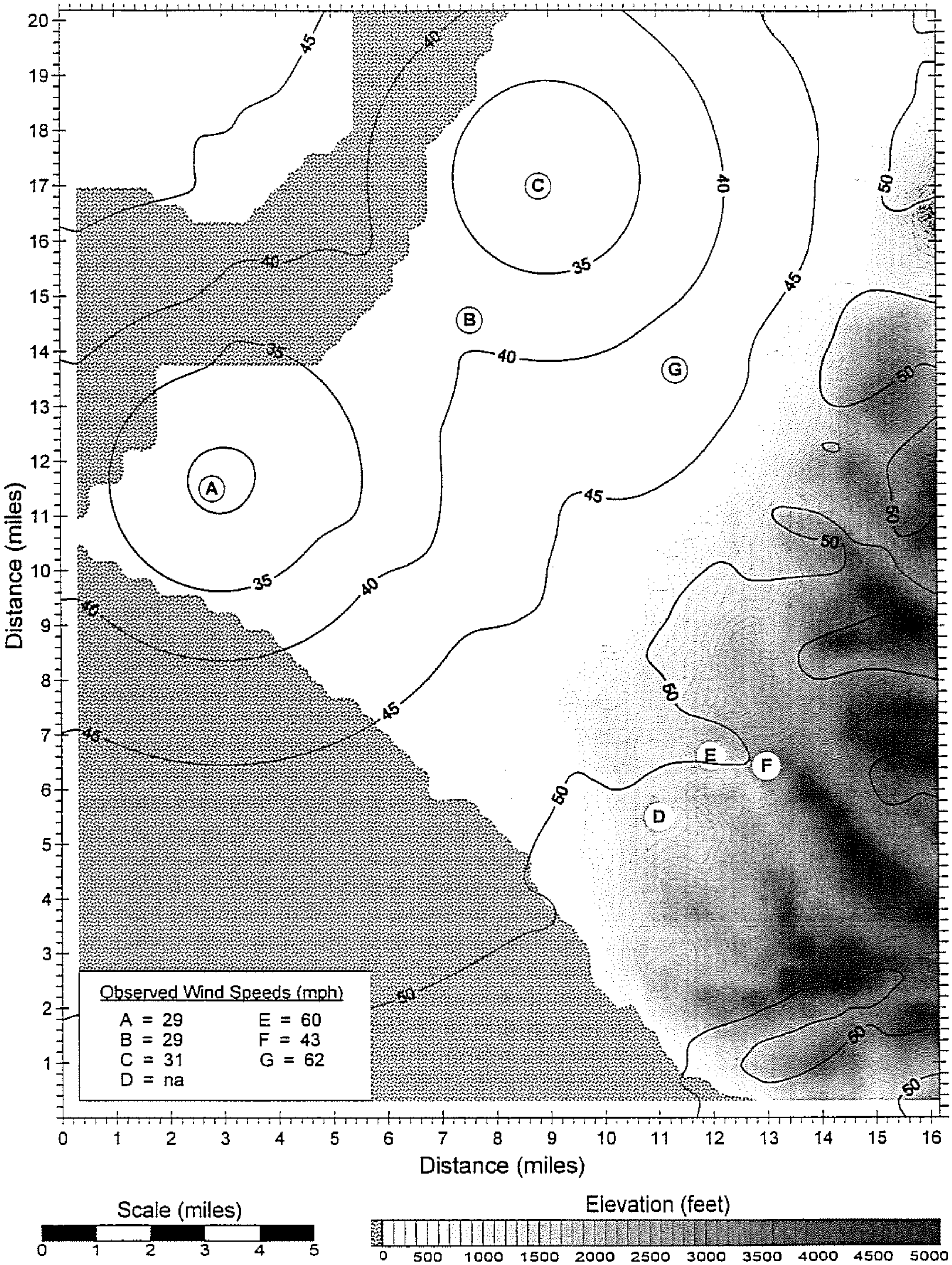
Figure: E-6

Date: Nov. 26, 1998

RWDI



Appendix E - Maximum Hourly Wind Speed Contours (mph) for the Dec. 26, 1991 Storm.	True North	Figure: E-7	RWDI
Anchorage Area-Wide Wind Speed Study - Anchorage, Alaska	Job No. 98-362	Date: Nov. 26, 1998	



Appendix E - Maximum Hourly Wind Speed Contours (mph) for the Dec. 01, 1992 Storm.

Anchorage Area-Wide Wind Speed Study - Anchorage, Alaska

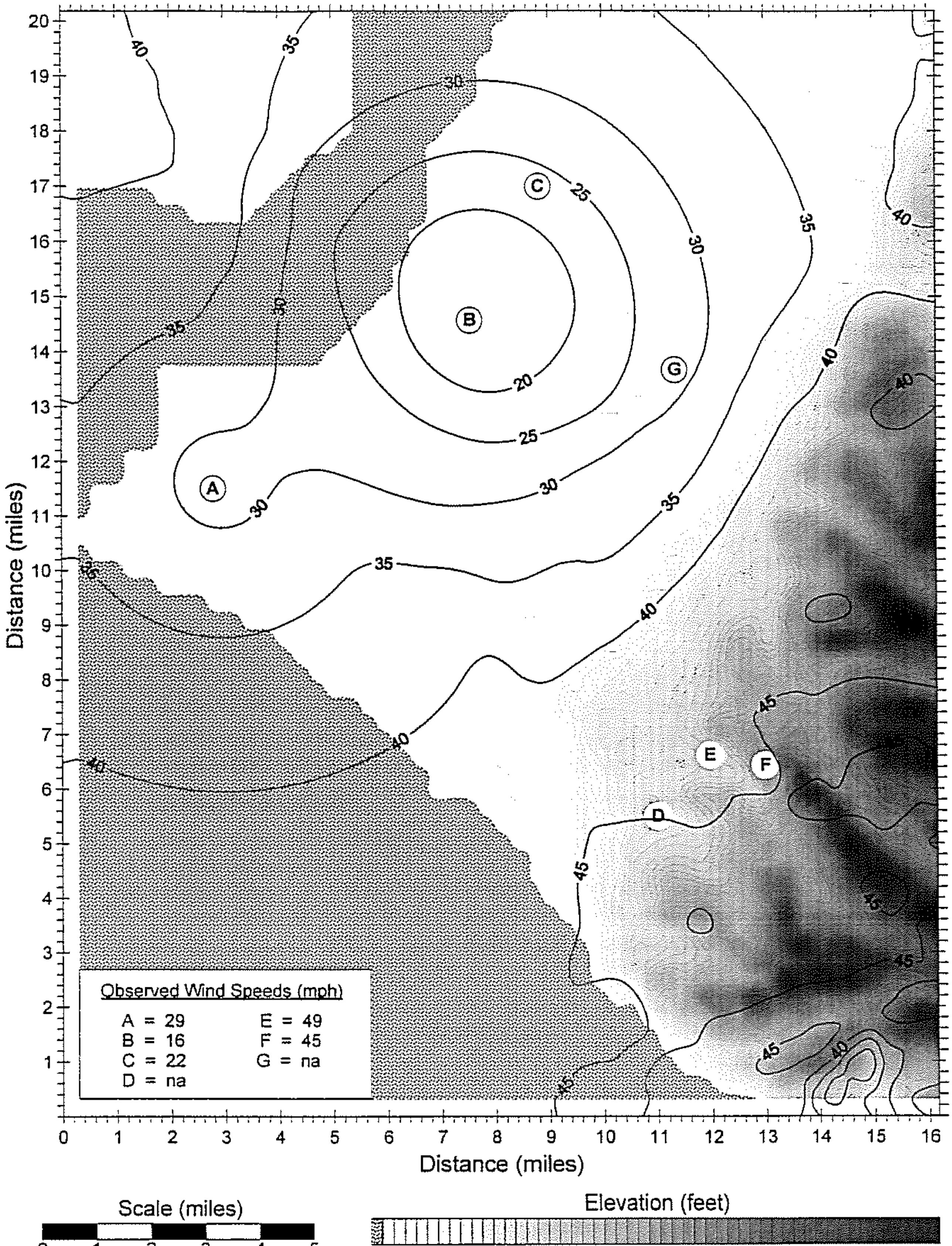
True North

Job No. 98-362

Figure: E-8

Date: Nov. 26, 1998

RWDI



Appendix E - Maximum Hourly Wind Speed Contours (mph) for the Nov. 22, 1992 Storm.

Anchorage Area-Wide Wind Speed Study - Anchorage, Alaska

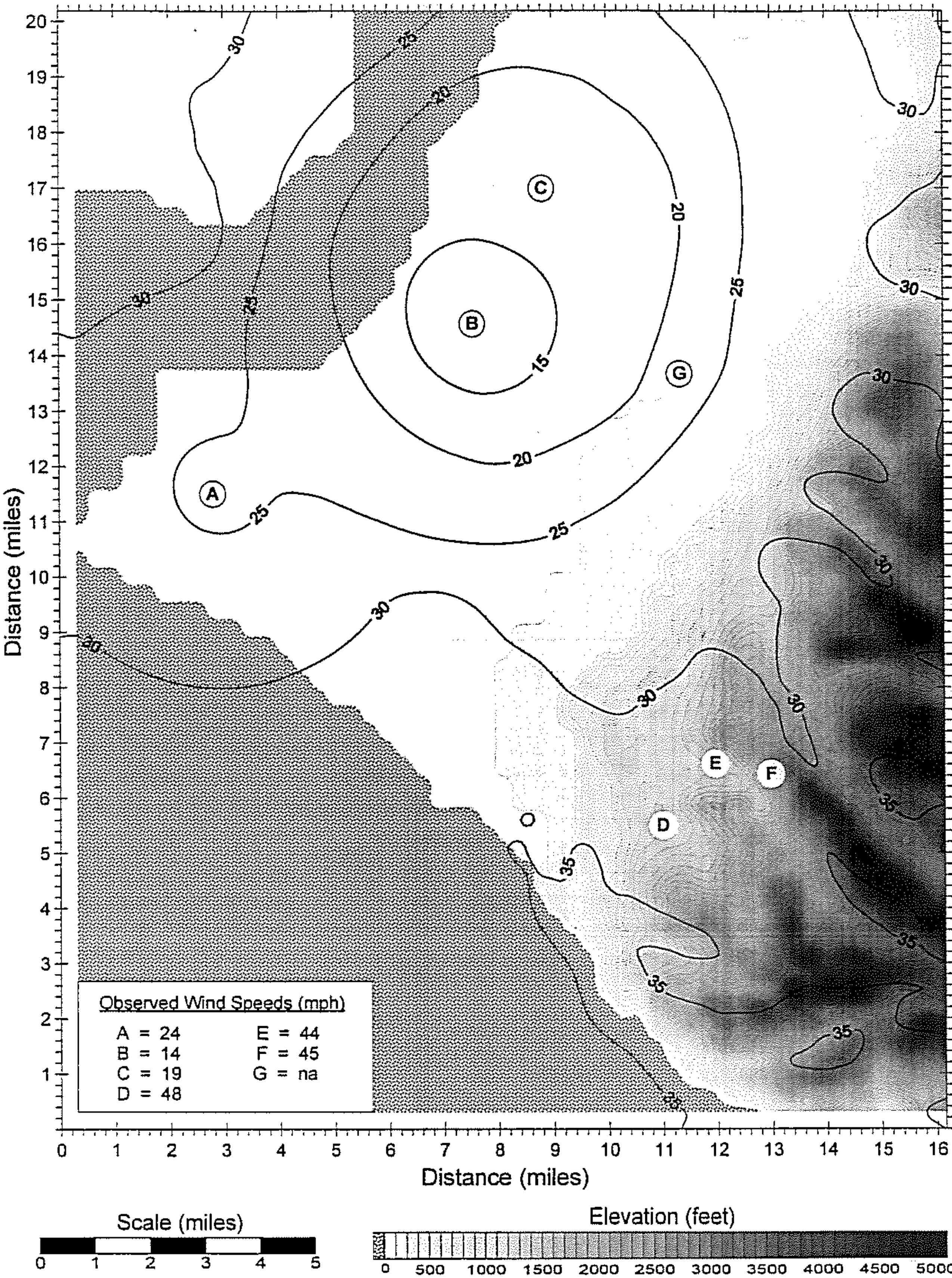
True North

Job No. 98-362

Figure: E-9

Date: Nov. 26, 1998

RWDI



Appendix E - Maximum Hourly Wind Speed Contours (mph) for the Dec. 03, 1994 Storm.	True North	Figure: E-10	RWDI
Anchorage Area-Wide Wind Speed Study - Anchorage, Alaska	Job No. 98-362	Date: Nov. 26, 1998	