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Subject: [External_Sender] Meteorological Data - Uranerz Nichols Ranch ISR Project (Electronic Submission Only)
Date: Monday, November 14, 2016 12:26:44 PM
Attachments: [Nichols Ranch Year 5 Wind and Atmospheric Stability Analysis Revised 11-....pdf](#)

Ron,

Attached is an updated report of the meteorological data to include:

1. Wind rose for the past year, and
2. Recovery rates based on individual years.

This is an Electronic Submission Only – no hard copy will follow.

If questions, please let me know.

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Wind Rose and Atmospheric Stability Analysis

Annual Update for Nichols Ranch Site

8 November 2016

**Uranerz Energy Corporation
(an Energy Fuels Company)**

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Introduction

Baseline hourly meteorological data were collected at the Nichols Ranch site from 6/28/2011 to 7/3/2012. This period was established as the baseline year and results were provided in a previous report. Meteorological monitoring at Nichols Ranch has continued through 6/27/2016, providing an additional 4 years of hourly data. This report summarizes the wind monitoring results from the most recent year of monitoring and compares these to the baseline year and to the years 2 through 4. These results include wind roses, wind speed and direction frequency distributions, atmospheric stability class distributions, and joint distributions of stability class, wind speed and wind direction. Also included is a summary of hourly wind data recovery for each of the five monitoring years and for the entire monitoring period.

Wind Monitoring Results

July 2015 – June 2016

Figure 1 shows the most recent yearly wind rose (year 5) for Nichols Ranch. Joint wind speed and direction data recovery was 99% for this period. The highest wind speeds occur from the north-northwest and southwest directions. The dominant wind direction overall is from the east. A previous report demonstrated that this pattern is due mostly to night-time drainage, or downslope convection winds from nearby North Pumpkin Butte.

Project-to-Date Results

Figures 2 through 5 show the yearly wind roses for the baseline monitoring year (year 1) and for subsequent monitoring years (year 2 through 4). For ease of comparison, wind roses for all five monitoring years appear in Figure 6, which demonstrates similar wind patterns at Nichols Ranch from year to year. Table 1 presents the yearly and project-to-date data recovery statistics, which easily exceed the 90% minimum joint data recovery requirement in NRC's Regulatory Guide 3.63. Table 2 presents project-to-date monitoring results for all recorded meteorological parameters. Joint wind speed and wind direction data recovery was 99.1% over the entire monitoring period. East winds accounted for nearly 16% of the total hours.

Figure 1. Nichols Ranch Year 5 Wind Rose

YR 5 WIND ROSE Nichols Ranch Met Station

Wright, WY
7/1/2015 Hr. 1 to 6/27/2016 Hr. 8

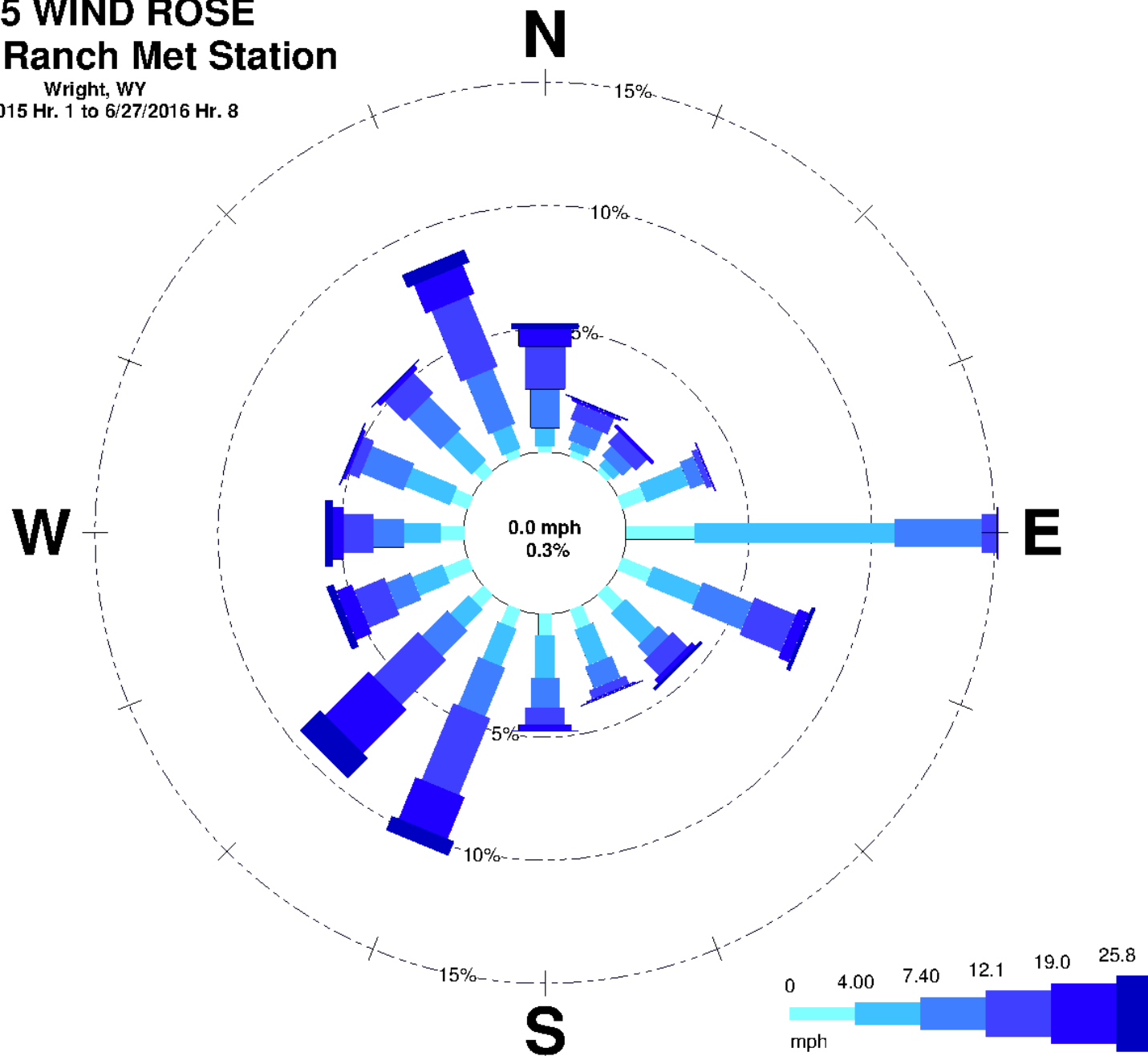
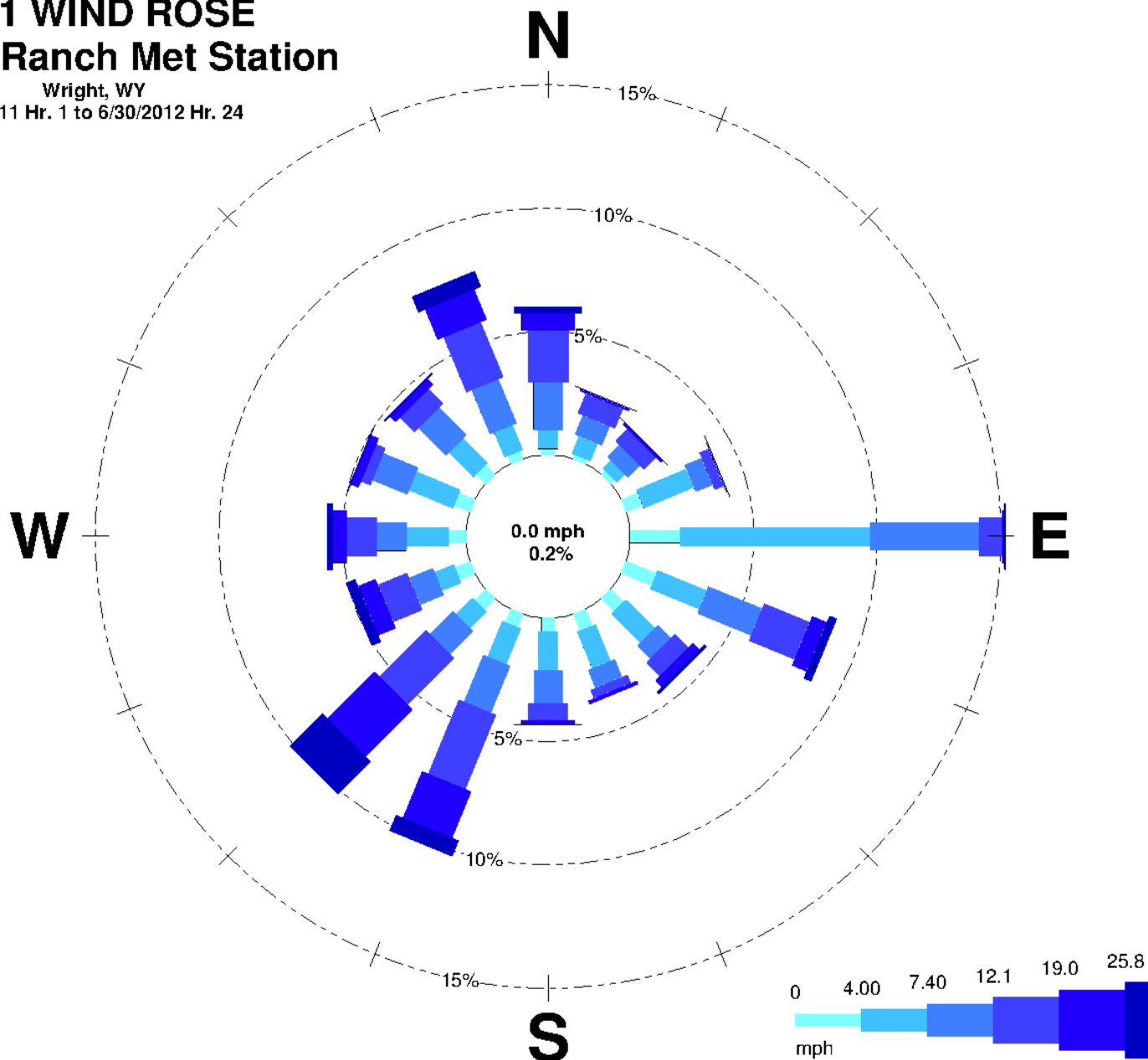


Figure 2. Nichols Ranch Baseline Year Wind Rose

YR 1 WIND ROSE Nichols Ranch Met Station

Wright, WY
7/1/2011 Hr. 1 to 6/30/2012 Hr. 24



YR 2 WIND ROSE
Nichols Ranch Met Station

7/1/2012 Hr. 1 to 6/30/2013 Hr. 24



Figure 4. Nichols Ranch Year 3 Wind Rose

YR 3 WIND ROSE Nichols Ranch Met Station

Wright, WY
7/1/2013 Hr. 1 to 6/30/2014 Hr. 24

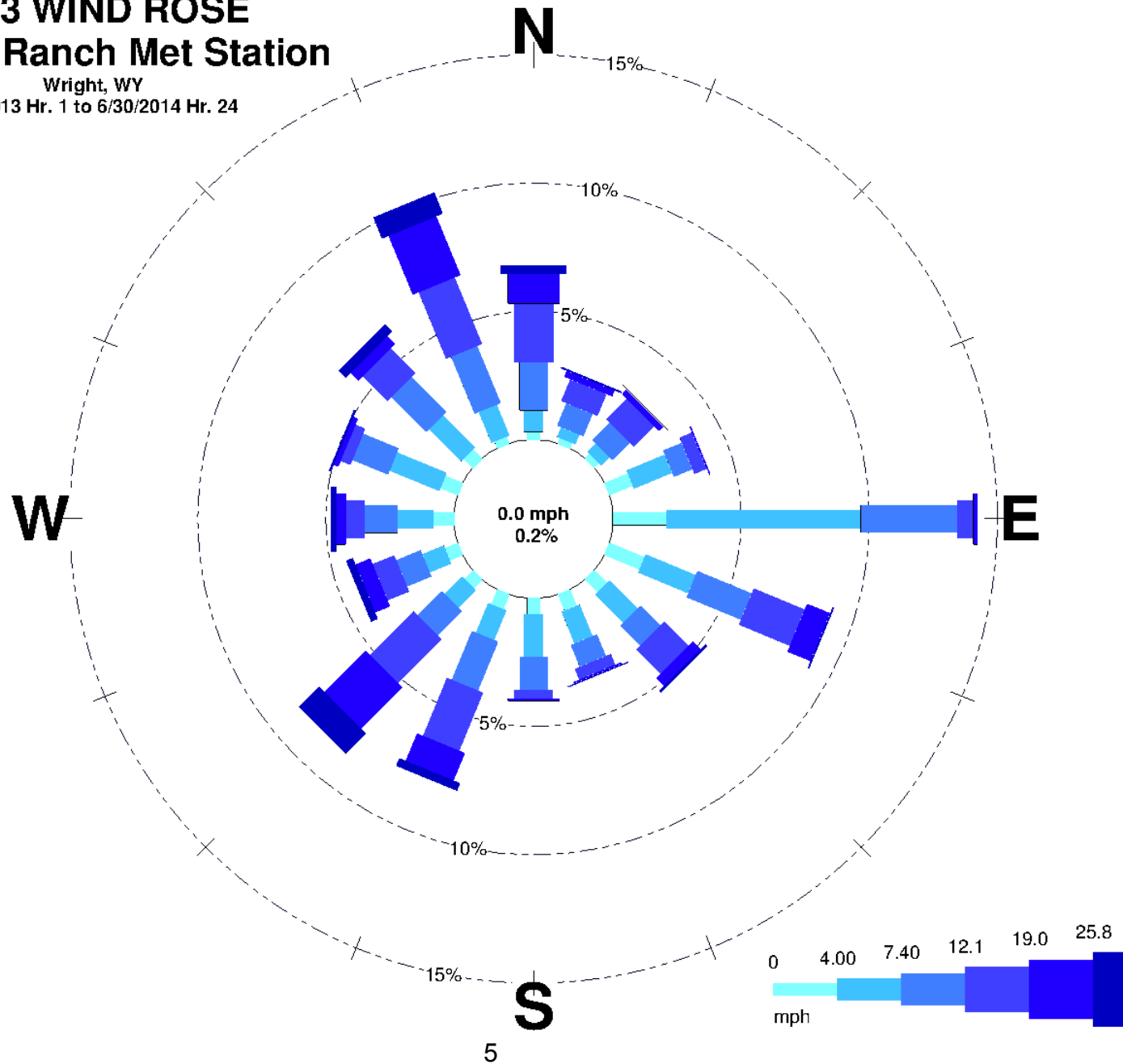


Figure 5. Nichols Ranch Year 4 Wind Rose

YR 4 WIND ROSE Nichols Ranch Met Station

Wright, WY
7/1/2014 Hr. 1 to 6/30/2015 Hr. 24

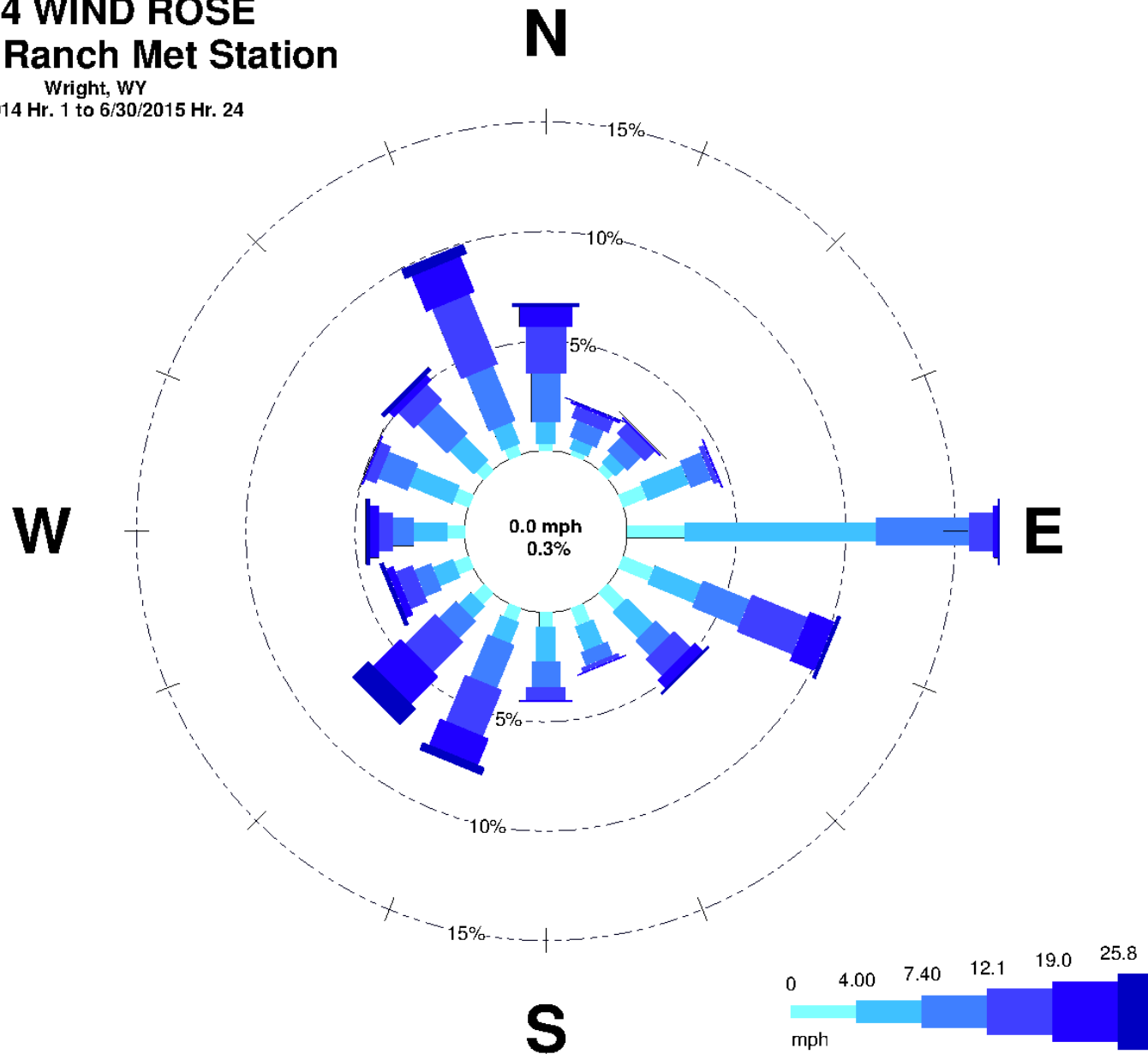


Figure 6. Nichols Ranch Year-to-Year Wind Roses

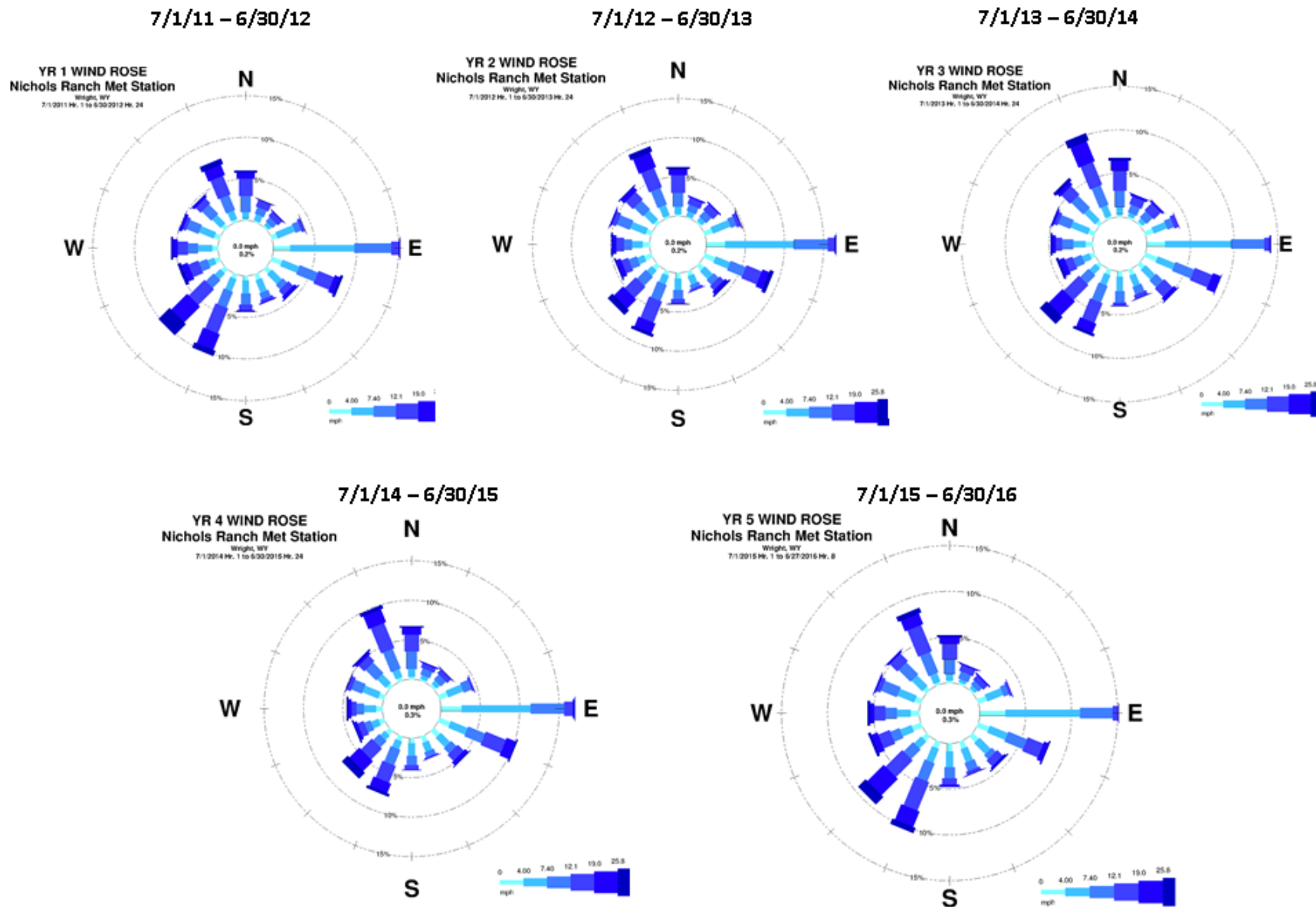


Table 1. Nichols Ranch Yearly Wind Data Recovery

Year	Dates	Wind Speed	Wind Direction	Sigma Theta	Temperature
Baseline	7/1/11 – 6/30/12	100.00 %	100.00 %	100.00%	98.43%
2	7/1/12 – 6/30/13	99.98%	99.98%	99.98%	99.98%
3	7/1/13 – 6/30/14	99.99%	99.99%	99.99%	99.99%
4	7/1/14 – 6/30/15	96.00%	96.00%	96.00%	96.14%
5	7/1/15 – 6/30/16	98.99%	98.99%	98.99%	98.98%
PTD	7/1/11 – 6/30/16	99.12%	99.12%	99.12%	98.70%

Table 2. Nichols Ranch PTD Meteorological Summary

Nichols Ranch

Meteorological Data Summary

6/28/2011 - 6/27/2016

Hourly Data

	Average/Total	Max	Min
Wind Speed (mph)	10.7	51.3	0.3
Sigma-Theta (°)	15.9	82.7	1.3
Temperature (C)	8.7	38.2	-32.5

Predominant wind direction was from the E sector,
accounting for 15.6% of the possible winds

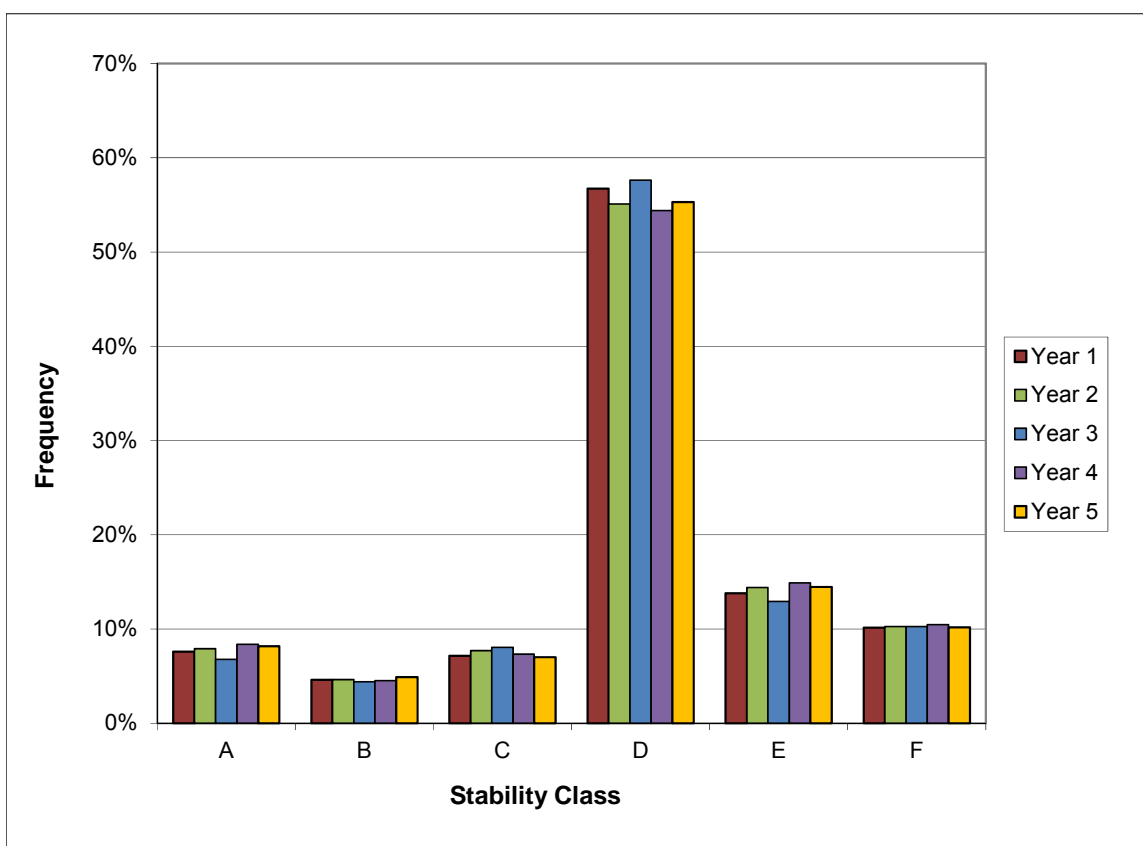
Data Recovery

Parameter	Possible (hours)	Reported (hours)	Recovery
Wind Speed	43848	43463	99.12%
Wind Direction	43848	43463	99.12%
Sigma-Theta	43848	43463	99.12%
Temperature	43848	43279	98.70%

Atmospheric Stability Results

Figure 7 compares the atmospheric stability class distributions for the five monitoring years at Nichols Ranch, demonstrating pronounced similarities from year to year. Between 55% and 58% of the winds at the project site consistently fall into stability class D, which represents near neutral to slightly unstable conditions. The light-to-calm winds which accompany stable environments, corresponding to stability class F, are also quite consistent for the five periods.

Figure 7. Nichols Ranch Atmospheric Stability Class Distribution by Year



The σ_θ method was used to determine the Pasquill-Gifford stability class, where σ_θ refers to the standard deviation of the horizontal wind azimuth angle in degrees. This method is also referred to as the σ_A method in EPA's Meteorological Monitoring Guidance for Regulatory Modeling Applications (February 2000). It is a lateral turbulence based method which uses the standard deviation of the wind direction in combination with the scalar mean horizontal wind speed. Wind speed and direction data are recorded hourly at a height of 10 meters. To minimize the effects of wind meander, the 1-hour σ_θ is defined using

15-minute σ_θ values which are in turn based on more frequent sampling of wind direction (e.g. every five seconds). According to this method, initial stability classes are assigned based solely on standard deviation of wind direction, or σ_θ . The initial assignments are then adjusted for horizontal wind speed. The magnitude of this adjustment depends on whether the measurement is taken during daylight or nighttime hours, a diurnal dependency that varies with the time of year.

Tables 3 and 4 present the most recent 12-month joint frequency distribution (JFD) at Nichols Ranch. Stability classes A, B, and C appear in Table 3, while stability classes D, E, and F appear in Table 4. Tables 5 and 6 present the project-to-date JFD. Stability classes A, B, and C appear in Table 5, while stability classes D, E, and F appear in Table 6. The JFD partitions hourly wind speed and direction by stability class, wind direction sector, and wind speed category. It is the basis for meteorological input to the MILDOS dispersion model.

Table 3. Nichols Ranch Year 5 JFD, Classes A-C

Stability Class	Wind Direction	Wind Speed (mph) - Monitoring Year 5					
		< 3	4 - 7	8 - 12	13 - 18	19 - 24	> 24
A	N	0.000823	0.002185				
	NNE	0.000941	0.000345				
	NE	0.000353	0.000690				
	ENE	0.001294	0.000690				
	E	0.003176	0.001150				
	ESE	0.003411	0.003565				
	SE	0.002470	0.003680				
	SSE	0.002235	0.003565				
	S	0.002941	0.004255				
	SSW	0.002823	0.004715				
	SW	0.002941	0.003910				
	WSW	0.003529	0.004140				
	W	0.002235	0.004600				
	WNW	0.002941	0.003680				
	NW	0.001176	0.003105				
	NNW	0.001765	0.002300				
B	N	0.000118	0.002530	0.000115			
	NNE		0.000690				
	NE		0.000345	0.000115			
	ENE	0.000471	0.000805				
	E	0.000471	0.000920	0.000115			
	ESE	0.000588	0.001265	0.000115			
	SE	0.000118	0.002530	0.000115			
	SSE	0.000471	0.002760	0.000230			
	S	0.000471	0.003220				
	SSW	0.000235	0.003105	0.000115			
	SW	0.000235	0.003910	0.000230			
	WSW	0.000588	0.004025	0.000460			
	W	0.000471	0.002530	0.000345			
	WNW	0.000353	0.006325	0.000460			
	NW	0.000353	0.003105				
	NNW	0.000118	0.002760	0.000575			
C	N		0.000115	0.002415			
	NNE		0.000575	0.001380			
	NE	0.000235	0.000230	0.000920			
	ENE	0.000235	0.000575	0.000345			
	E	0.002117	0.001265	0.000690			
	ESE	0.000471	0.000690	0.001840			
	SE	0.000118	0.001150	0.000920			
	SSE	0.000118	0.000690	0.002530			
	S		0.001035	0.003335			
	SSW	0.000118	0.001035	0.005290			
	SW	0.000471	0.001380	0.005405			
	WSW	0.000471	0.001955	0.004025			
	W	0.000706	0.002070	0.006325			
	WNW	0.000353	0.001610	0.003680			
	NW	0.000118	0.002070	0.003680			
	NNW	0.000118	0.000690	0.004600			

Table 4. Nichols Ranch Year 5 JFD, Classes D-F

Stability Class	Wind Direction	Wind Speed (mph) - Monitoring Year 5					
		< 3	4 - 7	8 - 12	13 - 18	19 - 24	> 24
D	N	0.000118	0.004025	0.015526	0.013801	0.004600	0.001380
	NNE	0.000118	0.001380	0.006095	0.004600	0.000920	0.000230
	NE	0.000118	0.001495	0.004485	0.004255	0.000460	
	ENE	0.002588	0.008281	0.004025	0.001610	0.000230	
	E	0.008234	0.043473	0.010006	0.002760	0.000230	
	ESE	0.000471	0.008051	0.017596	0.012766	0.003105	0.000920
	SE	0.000235	0.002645	0.005750	0.006440	0.001150	0.000575
	SSE	0.000235	0.003795	0.004485	0.001610	0.000575	0.000230
	S	0.000118	0.004715	0.007246	0.004370	0.001610	
	SSW	0.000235	0.007131	0.022197	0.028522	0.013456	0.003450
	SW		0.002875	0.012076	0.029097	0.017366	0.008396
	WSW	0.000588	0.002990	0.006210	0.011961	0.004830	0.002070
	W	0.001412	0.005750	0.005865	0.009201	0.004255	0.001840
	WNW	0.000471	0.009661	0.006901	0.002760	0.001035	0.000345
	NW	0.000941	0.008396	0.011616	0.007706	0.000690	0.000230
	NNW		0.006440	0.021967	0.026107	0.009316	0.003105
E	N	0.000118	0.001725	0.000805			
	NNE		0.001725	0.001610			
	NE		0.001495	0.001380			
	ENE	0.002000	0.009201	0.000575			
	E	0.005999	0.050259	0.008856			
	ESE	0.001647	0.006325	0.005520			
	SE	0.000471	0.002645	0.000805			
	SSE	0.000823	0.003335	0.000345			
	S	0.000235	0.004255	0.000345			
	SSW	0.000588	0.002530	0.000690			
	SW	0.000706	0.001150	0.000115			
	WSW	0.001529	0.002760	0.000460			
	W	0.000941	0.002530	0.000690			
	WNW	0.000588	0.004945	0.001265			
	NW	0.000823	0.003565	0.001725			
	NNW	0.000118	0.002760	0.001610			
F	N	0.001529	0.000460				
	NNE	0.001412	0.000690				
	NE	0.001765	0.000920				
	ENE	0.003882	0.001495				
	E	0.009058	0.003220				
	ESE	0.006587	0.005520				
	SE	0.006117	0.005980				
	SSE	0.004588	0.005405				
	S	0.005176	0.004830				
	SSW	0.003764	0.003220				
	SW	0.002588	0.001610				
	WSW	0.004117	0.001150				
	W	0.004235	0.001150				
	WNW	0.002706	0.002070				
	NW	0.002117	0.002070				
	NNW	0.001294	0.000805				

Table 5. Nichols Ranch PTD JFD, Classes A-C

Stability Class	Wind Direction	Wind Speed (mph) - Project-to-Date					
		< 3	4 - 7	8 - 12	13 - 18	19 - 24	> 24
A	N	0.000704	0.002373				
	NNE	0.000798	0.001590				
	NE	0.000822	0.001405				
	ENE	0.001503	0.001267				
	E	0.002278	0.001659				
	ESE	0.003076	0.002488				
	SE	0.002254	0.003041				
	SSE	0.002372	0.003064				
	S	0.002442	0.004193				
	SSW	0.002231	0.003548				
	SW	0.002818	0.003271				
	WSW	0.002512	0.003294				
	W	0.002137	0.004700				
	WNW	0.002019	0.004792				
	NW	0.001385	0.003594				
	NNW	0.001221	0.002672				
B	N	0.000047	0.002534	0.000276			
	NNE		0.001198	0.000161			
	NE	0.000070	0.000530	0.000092			
	ENE	0.000258	0.001014	0.000046			
	E	0.000822	0.001083	0.000069			
	ESE	0.000751	0.002073	0.000092			
	SE	0.000258	0.002742	0.000138			
	SSE	0.000164	0.002649	0.000253			
	S	0.000164	0.003064	0.000184			
	SSW	0.000235	0.002972	0.000184			
	SW	0.000188	0.002672	0.000299			
	WSW	0.000399	0.003064	0.000253			
	W	0.000423	0.002926	0.000207			
	WNW	0.000399	0.004239	0.000299			
	NW	0.000164	0.002926	0.000299			
	NNW	0.000094	0.002695	0.000392			
C	N	0.000023	0.000622	0.005115			
	NNE		0.000346	0.002004			
	NE	0.000047	0.000369	0.001682			
	ENE	0.000235	0.000461	0.000806			
	E	0.001315	0.001544	0.000875			
	ESE	0.000423	0.001497	0.002511			
	SE	0.000070	0.001083	0.002626			
	SSE	0.000047	0.000852	0.002327			
	S	0.000047	0.001060	0.002949			
	SSW	0.000070	0.001083	0.005368			
	SW	0.000188	0.001198	0.004631			
	WSW	0.000258	0.001313	0.003893			
	W	0.000376	0.001705	0.004884			
	WNW	0.000141	0.002396	0.003824			
	NW	0.000070	0.001590	0.004147			
	NNW	0.000047	0.001083	0.005322			

Table 6. Nichols Ranch PTD JFD, Classes D-F

Stability Class	Wind Direction	Wind Speed (mph) - Project-to-Date					
		< 3	4 - 7	8 - 12	13 - 18	19 - 24	> 24
D	N	0.000282	0.004562	0.016611	0.016887	0.005138	0.001428
	NNE	0.000094	0.002096	0.006497	0.005299	0.000806	0.000184
	NE	0.000094	0.002189	0.006382	0.005621	0.000553	0.000023
	ENE	0.002066	0.009584	0.004608	0.002419	0.000253	
	E	0.006762	0.043197	0.011865	0.004585	0.000760	0.000069
	ESE	0.000798	0.009123	0.017532	0.017048	0.005322	0.001428
	SE	0.000188	0.003156	0.005921	0.007902	0.002580	0.000622
	SSE	0.000117	0.002649	0.003709	0.001705	0.000461	0.000092
	S	0.000047	0.004285	0.007165	0.003571	0.000714	0.000046
	SSW	0.000141	0.006474	0.019652	0.025135	0.010275	0.003087
	SW	0.000164	0.002903	0.012325	0.024029	0.017256	0.007994
	WSW	0.000446	0.002511	0.005875	0.009930	0.003940	0.001935
	W	0.000939	0.005045	0.005667	0.007994	0.003456	0.001567
	WNW	0.000704	0.009100	0.006819	0.003202	0.001221	0.000207
	NW	0.000470	0.007856	0.011289	0.007695	0.002488	0.001221
	NNW	0.000164	0.007050	0.020251	0.026148	0.012924	0.003893
E	N	0.000235	0.001912	0.000829			
	NNE	0.000141	0.001152	0.001313			
	NE	0.000141	0.001359	0.001613			
	ENE	0.002254	0.008801	0.001083			
	E	0.004696	0.050454	0.010966			
	ESE	0.001550	0.006704	0.005207			
	SE	0.000610	0.002719	0.000461			
	SSE	0.000517	0.002788	0.000184			
	S	0.000423	0.003548	0.000276			
	SSW	0.000423	0.002189	0.000530			
	SW	0.000446	0.001175	0.000253			
	WSW	0.001080	0.001497	0.000507			
	W	0.000986	0.002212	0.000622			
	WNW	0.001033	0.004331	0.001244			
	NW	0.000775	0.003479	0.001428			
	NNW	0.000423	0.002603	0.001682			
F	N	0.001620	0.000968				
	NNE	0.001198	0.001037				
	NE	0.001714	0.000875				
	ENE	0.003804	0.002073				
	E	0.008923	0.004907				
	ESE	0.007819	0.005022				
	SE	0.005354	0.005667				
	SSE	0.004344	0.004769				
	S	0.003968	0.004631				
	SSW	0.003264	0.002580				
	SW	0.002724	0.001636				
	WSW	0.003546	0.001336				
	W	0.003780	0.001981				
	WNW	0.003381	0.001958				
	NW	0.002465	0.002027				
	NNW	0.001691	0.001428				

Representativeness of On-Site Baseline Year Monitoring

The accumulation of five years of on-site, hourly wind data enables a comparison between the baseline monitoring year and the subsequent four-year period. The purpose of this comparison is to demonstrate that the baseline wind data used for air quality monitoring and dispersion modeling are typical of the longer term. While five years do not constitute a formal long-term demonstration (which Regulatory Guide 3.63 recommends be made at an off-site location), the following discussion suggests a trend of only slight variations from year to year.

Figure 8 compares wind speed frequency distributions between the baseline year and the subsequent four years of monitoring. The hourly data for each distribution fall into one of 7 wind speed categories ranging from calm to greater than 24 mph (see Tables 3 through 6). Figure 9 illustrates the linear association between the baseline and 4-year wind speed frequencies graphed in Figure 8. In keeping with convention, the less certain variable (short-term frequency) is assigned to the vertical (dependent) axis and the better-supported, longer-term frequency is assigned to the horizontal (independent) axis. The graph illustrates the degree to which the baseline-year frequencies match the 4-year frequencies. The R^2 value of 0.99 confirms a very strong linear relationship, and the slope of 0.99 indicates substantial equivalence between short and long-term wind speed frequencies at Nichols Ranch. A p-value of zero establishes a near-100% confidence level that this relationship is statistically significant.

Figure 10 compares wind direction frequency distributions between the baseline year and the subsequent four years of monitoring. The hourly data for each distribution fall into one of 17 wind direction categories, including calm winds and 16 cardinal wind direction sectors (see Tables 3 through 6). Figure 11 illustrates the linear association between the baseline and longer-term wind direction frequencies as graphed in Figure 10, with the same choice of dependent and independent variables as for the wind speed frequency comparison. The graph illustrates the degree to which the baseline-year frequencies match the 4-year frequencies. The R^2 value of 0.94 confirms a strong linear relationship, and the slope of 0.99 indicates substantial equivalence between short and longer-term frequencies at Nichols Ranch. A p-value of zero leaves little doubt that this relationship is statistically significant.

The MILDOS model accepts meteorological inputs in the form of joint wind speed, wind direction and stability class frequency distributions, also known as STAR distributions. An important subset of the STAR distribution is the two-way wind classification, which categorizes hourly wind data by both speed and direction. Joint wind speed and direction distributions are amenable to linear regression or correlation. Analyzing these two-way distributions can strengthen the case for longer-term representativeness of baseline wind data. The joint analysis offers a more rigorous comparison than individual speed and direction analyses. This comparison also offers the best quantitative measure of the similarity between the associated wind roses (see Figure 6).

Figure 12 shows the linear relationship between baseline-year and subsequent 4-year joint frequencies at Nichols Ranch. The hourly data for each distribution fall into one of 97 categories. The graph illustrates the degree to which the baseline-year joint frequencies match the 4-year frequencies. The R^2 value of 0.95 confirms a strong linear relationship, and the slope of 0.98 indicates substantial equivalence between short and long-term frequencies. A p-value of zero leaves little doubt that this relationship is statistically significant.

Linear regression also isolates the sources of variation among category frequencies. When multiplied by 100, R^2 signifies the percent of the variation from a mean frequency that is common to both the baseline-year and the 4-year distributions. In Figure 12, for example, 95% of the baseline-year variation can be predicted based on measured 4-year frequencies, while only 5% is attributed to random, year-to-year fluctuations and/or measurement error.

In conclusion, the comparative wind roses, frequency distribution graphs, and regression analyses offer no evidence that monitored wind data from the baseline year do not represent longer-term wind patterns at Nichols Ranch.

Figure 8. Nichols Ranch Wind Speed Comparison

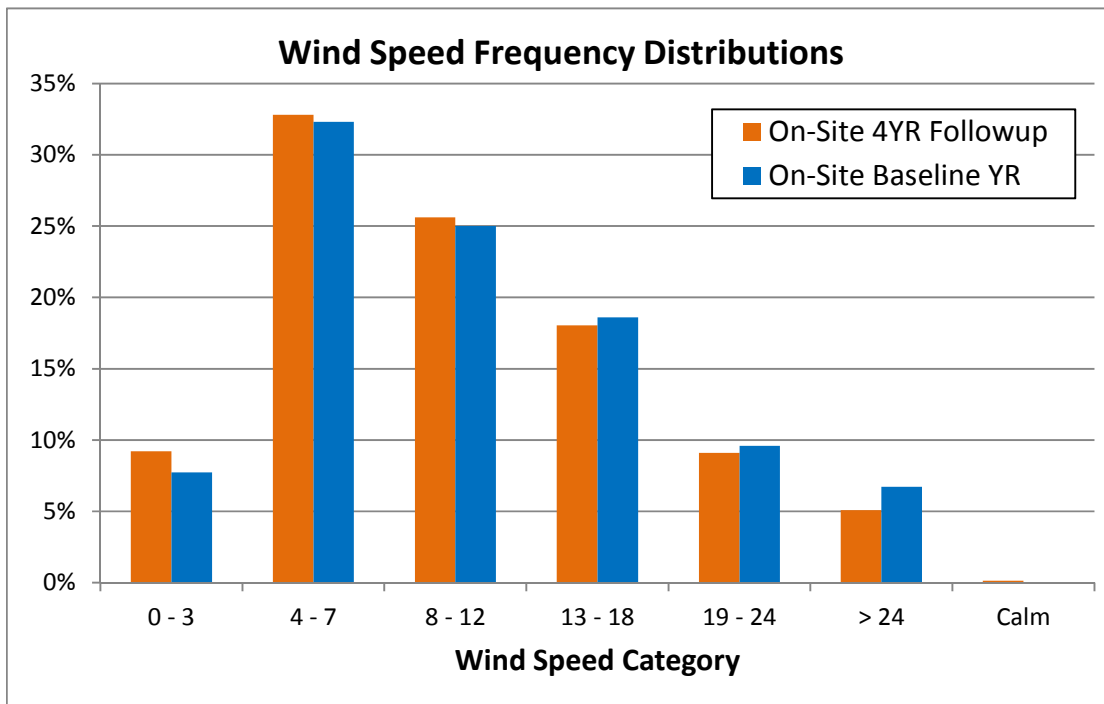


Figure 9. Nichols Ranch Wind Speed Correlation

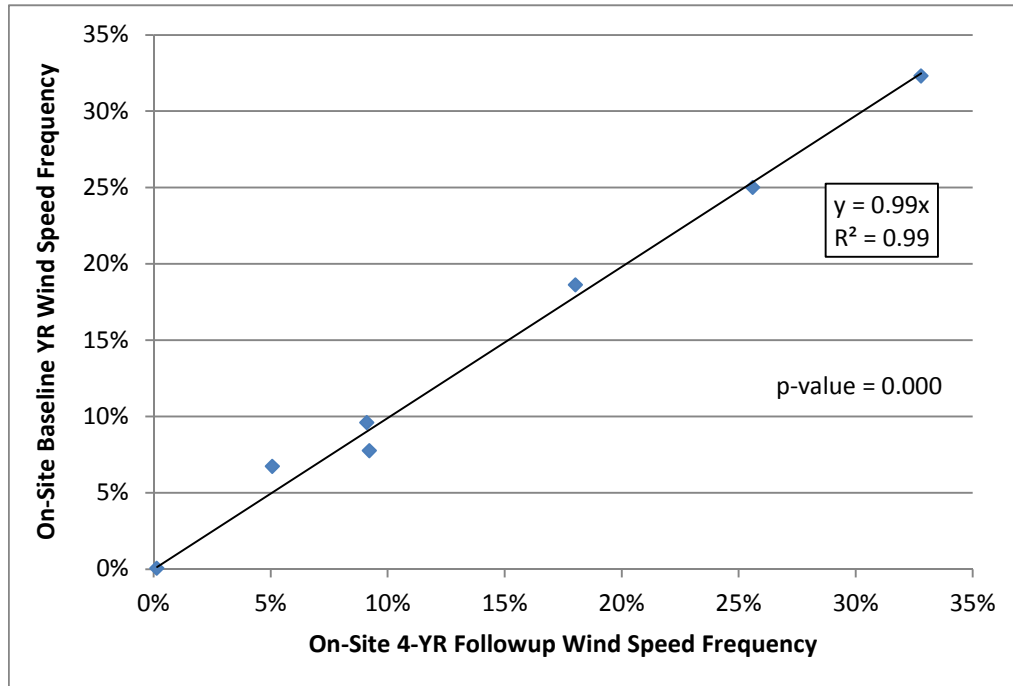


Figure 10. Nichols Ranch Wind Direction Comparison

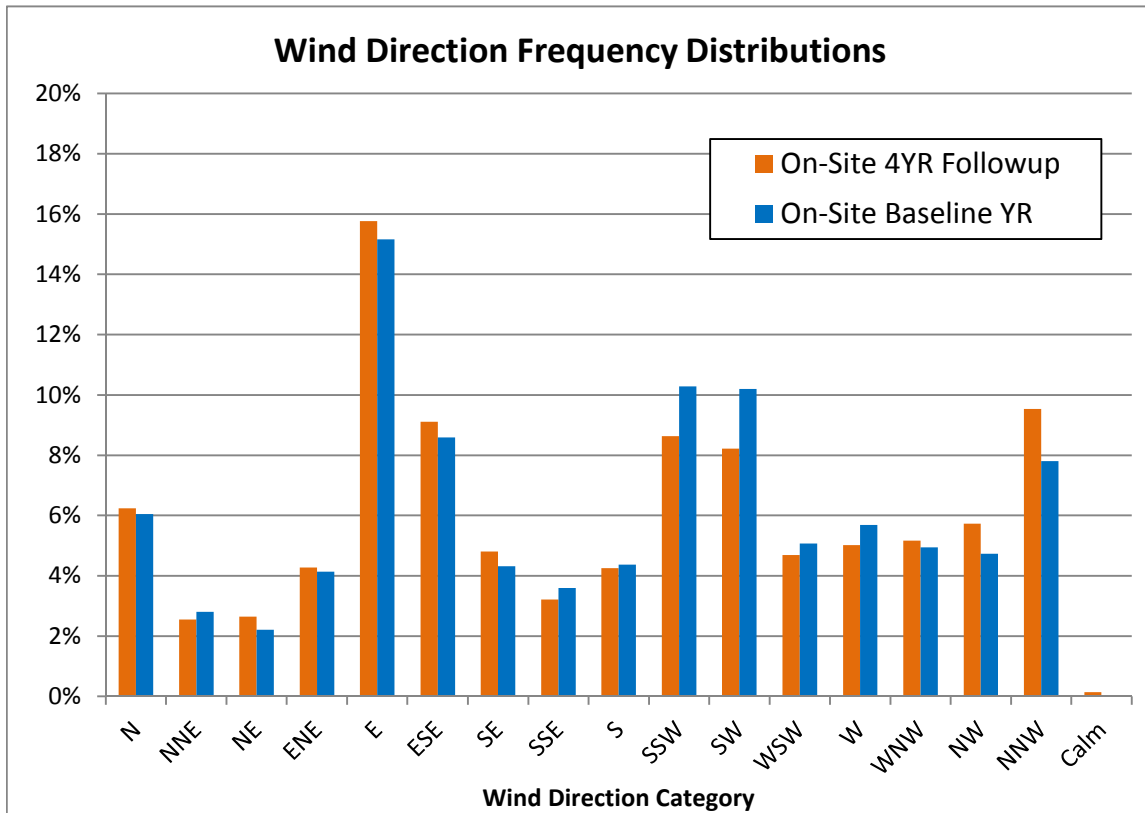


Figure 11. Nichols Ranch Wind Direction Correlation

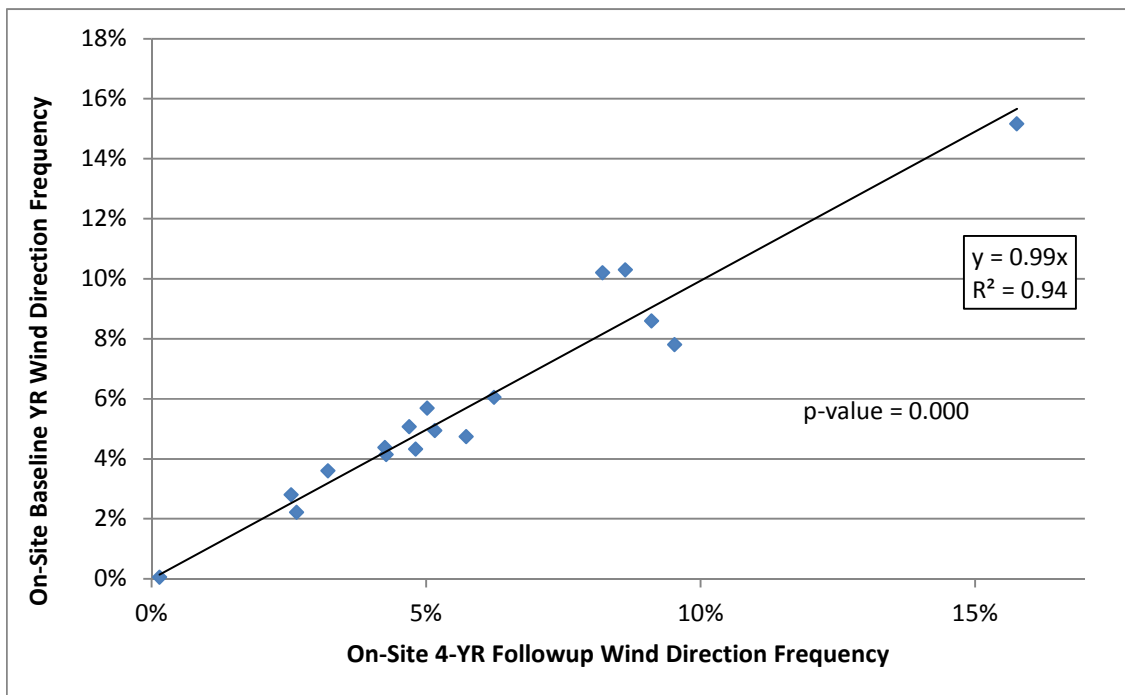


Figure 12. Nichols Ranch Joint Wind Speed and Direction Correlation

