EVALUATION OF THE TEOM METHOD FOR THE MEASUREMENT OF PARTICULATE MATTER FROM TEXAS CATTLE FEEDLOTS

A Thesis

by

STEWART JAMES SKLOSS

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2008

Major Subject: Biological and Agricultural Engineering

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Approved by:

Chair of Committee,	Calvin B. Parnell, Jr.
Committee Members,	Bryan W. Shaw
	Dennis L. O'Neal
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ABSTRACT

Evaluation of the TEOM Method for the Measurement of Particulate Matter from Texas Cattle Feedlots. (May 2008)

Stewart James Skloss, B. S., Texas A&M University

Chair of Advisory Committee: Dr. Calvin B. Parnell, Jr.

The Tapered Element Oscillating Microbalance (TEOM) sampler is an EPA approved Federal Equivalent Method Sampler for measuring PM_{10} concentrations. The Center for Agricultural Air Quality Engineering and Science (CAAQES) owns two Rupprecht and Patashnick (R&P) Series1400a monitors. The R&P Series 1400a monitor uses the TEOM method to measure particulate matter (PM) concentrations and was approved by EPA in 1990 as an automated equivalent method PM_{10} sampler. Since its approval, many state air pollution regulatory agencies (SAPRAs) have located R&P Series 1400a monitors at community-oriented monitoring sites. Some SAPRAs have even located TEOM samplers at the property line of major sources to determine if the source is meeting its permit requirements for PM_c emissions. This thesis presents the results of PM_{10} and TSP concentrations measured with TEOM and low-volume gravimetric samplers at two Texas cattle feedlots. The purpose of this research was to compare the performance of the R&P Series 1400a monitor to the low-volume gravimetric sampler when sampling PM from a feedlot. Furthermore, this research was

conducted to avoid the inappropriate regulation of cattle feedlots that may occur in the future as a consequence of the TEOM sampler being used to measure PM_c emissions.

The results of this research demonstrate that relationship between the R&P Series 1400a monitor and the low-volume gravimetric sampler is linear. In general, it was observed that the TEOM sampler measured higher PM_{10} and TSP concentrations than the low-volume gravimetric sampler when sampling downwind from a cattle feedlot. The opposite results were observed when sampling was conducted upwind from the feedlot. The collected data demonstrates that the concentration difference between the two sampling methods is linearly dependent with the concentration intensity for the upwind sampling locations. This trend was shown to be statistically significant. Another linear relationship was observed between the concentration difference and the particle size (mass median diameter and geometric standard deviation) of the sampled dust. Although this trend was not statistically significant, it is believed that additional downwind concentration measurements would validate this relationship.

DEDICATION

To

My Parents

For the love and support they have shown.

ACKNOWLEDGEMENTS

I would like to thank my committee chair, Dr. Calvin Parnell, Jr., for the enthusiasm and support he gave to this project. I would also like to thank my committee members, Dr. Bryan Shaw and Dr. Dennis O'Neal, for their guidance and support throughout the course of this research.

Thanks to the Cotton Chair, Texas AgriLife Research, and USDA-CSREES for making this research possible. Thanks also to Dr. Brent Auvermann at the Texas A&M Research and Extension Center in Amarillo for generously sharing TEOM and weather data with me.

Thanks to my colleagues in 324 Scoates Hall for their friendship, encouragement and advice. Thank you for making this time such a memorable experience.

Thanks to all the members of Parnell's Crew, especially those that went on feedyard sampling trips. Your dedication and hard work are greatly appreciated.

Finally, thanks to my sister for her loving care and excellent home-cooked meals. I am blessed to have a sister like her.

NOMENCLATURE

AED	Aerodynamic equivalent diameter
CAAQES	Center for Agricultural Air Quality Engineering and Science
ESD	Equivalent spherical diameter
FRM	Federal reference method
FEM	Federal equivalent method
GSD	Geometric standard deviation
$LVPM_{10}$	Low-volume PM_{10}
LVTSP	Low-volume TSP
MMD	Mass median diameter
NAAQS	National ambient air quality standards
PM	Particulate matter
$PM_{2.5}$	Particulate matter with an AED less than or equal to 2.5 μm
PM_{10}	Particulate matter with an AED less than or equal to 10 μm
PM_c	Particulate matter with an AED less than or equal to 10 μm but greater than 2.5 μm
PSD	Particle size distribution
SAPRA	State air pollution regulatory agency
TEOM	Tapered element oscillating microbalance
TSP	Total suspended particulate

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CHAPTER I

INTRODUCTION

At the center of the Clean Air Act is the National Ambient Air Quality Standards (NAAQS) program. The NAAQS established concentration limits for the following six criteria pollutants: sulfur dioxide (SO_2), nitrogen dioxide (NO_2), particulate matter (PM), carbon monoxide (CO), ozone (O_3), and lead (Pb) (CFR, 1999a). These six pollutants were selected for regulation because of the threat which they pose to the health of the public and the environment.

The PM NAAQS addresses two categories of particle pollution. The first category consists of particles with an aerodynamic equivalent diameter (AED) less than or equal to 2.5 µm ($PM_{2.5}$). Often, $PM_{2.5}$ is referred to as fine particle PM or "soot". In 2006, EPA modified the original $PM_{2.5}$ NAAQS by reducing the 24 h standard from 65 µg m^{-3} to 35 µg m^{-3} (98th percentile). The annual $PM_{2.5}$ standard was retained at 15 µg m^{-3} (arithmetic mean). The second category of particles regulated under the PM NAAQS are particles with an AED less than or equal to 10 µm but greater than 2.5 µm. This category is referred to as inhalable coarse particles (PM_c). The PM_c NAAQS uses particles with an AED less than or equal to 10 µm (PM_{10}) as an indicator of the PM_c concentration. The 2006 revisions retained the 24 h PM_{10} standard of 150 µg m^{-3} (99th percentile) for the PM_c NAAQS. EPA revoked the annual PM_{10} standard because available health evidence does not suggest a link between long term exposure to PM_{10}

This thesis follows the style of *Transactions of the ASABE*.

and health problems (CFR, 2006). Hence, there is no annual PM_c NAAQS.

EPA and state air pollution regulatory agencies (SAPRAs) use the NAAQS for two purposes. The primary purpose of the NAAQS is to determine whether an area is in attainment. Area designations are used to describe the quality of air for a particular geographic region and are based on the number of exceedances of the NAAQS. EPA guidelines require that federal reference method (FRM) or federal equivalent method (FEM) samplers be used to measure ambient $PM_{2.5}$ and PM_{10} concentrations for area designations. Furthermore guidance has been issued by EPA which lists criteria for locating samplers. When ambient $PM_{2.5}$ and PM_{10} concentrations are measured for regulatory purposes, EPA requires that the samplers be located at community-oriented monitoring sites. The location of these sites should estimate the pollutant level people encounter during their daily activities. In addition to approximating exposure, community-oriented monitoring sites must be located beyond the zone of influence of a single source. A sampler that is placed in a neighborhood adjacent to a source is considered to be a community-oriented monitoring site only if the location is at least 500 m from the property line of the source (Watson et al., 1997). The guidance issued by EPA specifically prohibits the monitoring of ambient $PM_{2.5}$ and PM_{10} concentrations at the property line for determinations of attainment and non-attainment.

The second use of the NAAQS is as a concentration not to be exceeded at the property line and beyond for permitting. Authorization for the second use of the NAAQS is not included in the Clean Air Act or the Code of Federal Regulations. In fact, the preamble to 40CFR Part 50 (2006) includes the following language which discourages the second use of the NAAQS:

"EPA notes that the NAAQS do not create emissions control obligations for individual sources or groups of sources. Measured or modeled concentrations exceeding the NAAQS off-property of agricultural sources should not be used to deny permits or require reductions of PM emissions. Even if an individual source (or sources) were shown to contribute to an exceedance of the 24 h PM_{10} standard at a community-oriented monitoring site, this should not necessarily result in regulation or required reductions of emissions from that agricultural source."

Despite this statement, some SAPRAs continue to rely on the second use of the NAAQS to regulate agricultural operations. In some states, the modeled or measured concentration limit used for permitting is at the nearest occupied residence. California is the only state that limits PM_{10} concentrations at the property line to concentrations less than 150 $\mu g\ m^{-3}$.

The Tapered Element Oscillating Microbalance (TEOM) sampler is an EPA designated equivalent method sampler for measuring PM_{10} concentrations. The Center for Agricultural Air Quality Engineering and Science (CAAQES) owns two Rupprecht and Patashnick (R&P) Series 1400a Ambient PM_{10} monitors (R&P Series 1400a TEOM Monitor, Rupprecht and Patashnick Co. Inc., Albany, NY). The R&P Series 1400a monitor uses the TEOM method to measure PM_{10} concentrations and was approved by EPA in 1990 as an equivalent method sampler (Federal Register, 1990). Since its approval, many SAPRAs have located R&P Series 1400a monitors at community-oriented monitoring sites. Some SAPRAs have even located TEOM samplers at the property line of major sources to determine if the source is meeting its permit requirements for PM_c emissions. The monitor can also be configured to measure total suspended particulate (TSP) or $PM_{2.5}$ concentrations; however, EPA has not approved the R&P Series 1400a monitor as an equivalent method for these configurations (Rupprecht and Patashnick, 2002).

Over the past fifteen years, many SAPRAs have implemented TEOM samplers to measure PM_{10} concentrations. The TEOM sampler has several important advantages over the FRM gravimetric sampler including automated operation, reduced maintenance, and continuous, real-time measurement of PM. Consequently, SAPRAs have lowered PM_{10} monitoring costs by replacing FRM gravimetric samplers with TEOM samplers. Similarly, due to the TEOM sampler's automated operation, SAPRAs have expanded their monitoring capabilities by installing more TEOM samplers at additional community-oriented monitoring sites.

Cattle feedlots are agricultural sources of PM. Although most SAPRAs do not require cattle feedlots to obtain operating permits, it is anticipated that this will change in the future. Furthermore, it is probable that the TEOM sampler will be used to regulate PM_c emissions from cattle feedlots. Previous research has shown that when collocated with a FRM sampler the TEOM sampler will frequently measure a different PM_{10} concentration. Due to the concentration differences observed between the TEOM method and the FRM method, it is important that research be conducted to avoid inappropriate regulation of cattle feedlots. In order to accurately evaluate the performance of the TEOM method the following objectives have been established for this research: (1) determine the relationship between concentrations measured by the TEOM sampler and the low-volume gravimetric sampler, and (2) characterize the influence that concentration intensity and particle size may have on the relationship between concentrations measured by the TEOM sampler and the low-volume gravimetric sampler.

CHAPTER II

LITERATURE REVIEW

Several sources have indicated that the TEOM sampler does not accurately measure PM_{10} concentrations. Allen et al. (1997) observed that the relationship between PM_{10} concentrations measured by the TEOM sampler and the FRM sampler varied widely depending upon location and season. The study reported reasonable agreement for urban areas during the winter, but found the sampling methods to be poorly correlated for rural monitoring sites and those locations with high PM_{10} concentrations. In general, it was observed that the TEOM sampler measured lower PM_{10} concentrations than the FRM sampler. Allen et al. (1997) suspected that the concentration difference between the methods was caused by the evaporation of semi-volatile particles from the sample flow stream of the TEOM sampler. While the authors were unable to validate their suspicion, it was suggested that the PM composition at those locations with large concentration differences was dominated by a sizeable fraction of semi-volatile compounds.

During February and March of 1997, Vega et al. (2003) collocated TEOM samplers with FRM samplers at five monitoring sites in Mexico City to measure PM_{10} concentrations. Significant concentration differences were observed between the sampling methods. Vega et al. (2003) found that the TEOM sampler measured higher PM_{10} concentrations than the FRM sampler. In fact, for many of the tests the PM_{10} concentrations reported by the TEOM sampler were twice as great as those reported by the FRM sampler. The authors noted that PM_{10} concentrations in excess of 500 μg m^{-3} were frequently measured at all of the monitoring sites as a possible explanation for the difference between the methods. A chemical analysis was performed on the collected particulate mass. The results of the analysis revealed that the mass fraction of semi-volatile compounds was small lending confidence to the FRM sampler. Vega et al. (2003) concluded that TEOM and FRM PM_{10} concentrations should not be used interchangeably.

Wanjura et al. (2008) conducted upwind and downwind TSP sampling at a Texas cattle feedlot using collocated TEOM and low-volume gravimetric samplers during the summer of 2003, spring of 2004, and spring of 2005. In general, it was observed that the TEOM sampler measured lower TSP concentrations than the low-volume gravimetric sampler. Wanjura et al. (2008) showed that the TEOM measurement error was independent of the TSP concentration measured by the low-volume gravimetric sampler. The authors performed a particle size distribution analysis using the particle mass collected on the low-volume TSP filter. Based on the results of the analysis, Wanjura et al. (pending) observed linear relationships between the TEOM measurement error and the mass median diameter (MMD) and the geometric standard deviation (GSD). The authors concluded that the TEOM sampler would report a higher TSP concentration than the low-volume gravimetric sampler when the MMD of the sampled PM is greater than 18.5 μm.

CHAPTER III

METHODS

EPA guidelines require that only FRM or FEM samplers be used to measure ambient PM_{10} concentrations for area designations. Before EPA approves a sampler as FEM, it is tested in a controlled particulate concentration chamber. The FRM PM_{10} sampler described in 40CFR Part 53 (CFR, 1999b) is designed to have a nominal cutpoint of 10 ± 0.5 µm with a slope of 1.5 ± 0.1 (Buser et al., 2001). A PM_{10} sampler is designated as FEM based on how closely its performance follows that of the FRM PM_{10} sampler.

TEOM Sampler Description

EPA approved the R&P Series 1400a monitor as a FEM sampler for measuring PM_{10} concentrations in 1990 (Federal Register, 1990). The R&P monitor uses the TEOM method to measure PM_{10} concentrations. The R&P Series 1400a monitor can also be configured to measure TSP or $PM_{2.5}$ concentrations; however, EPA has not approved the monitor as a FEM sampler for these configurations. Although the TEOM method is an intricate and complex design, the R&P monitor consists essentially of four main components: the size selective inlet, the TEOM sensor, the control unit, and the vacuum pump. Figure 1 shows the layout of the R&P Series 1400a monitor configured to measure TSP or PM_{10} concentrations.

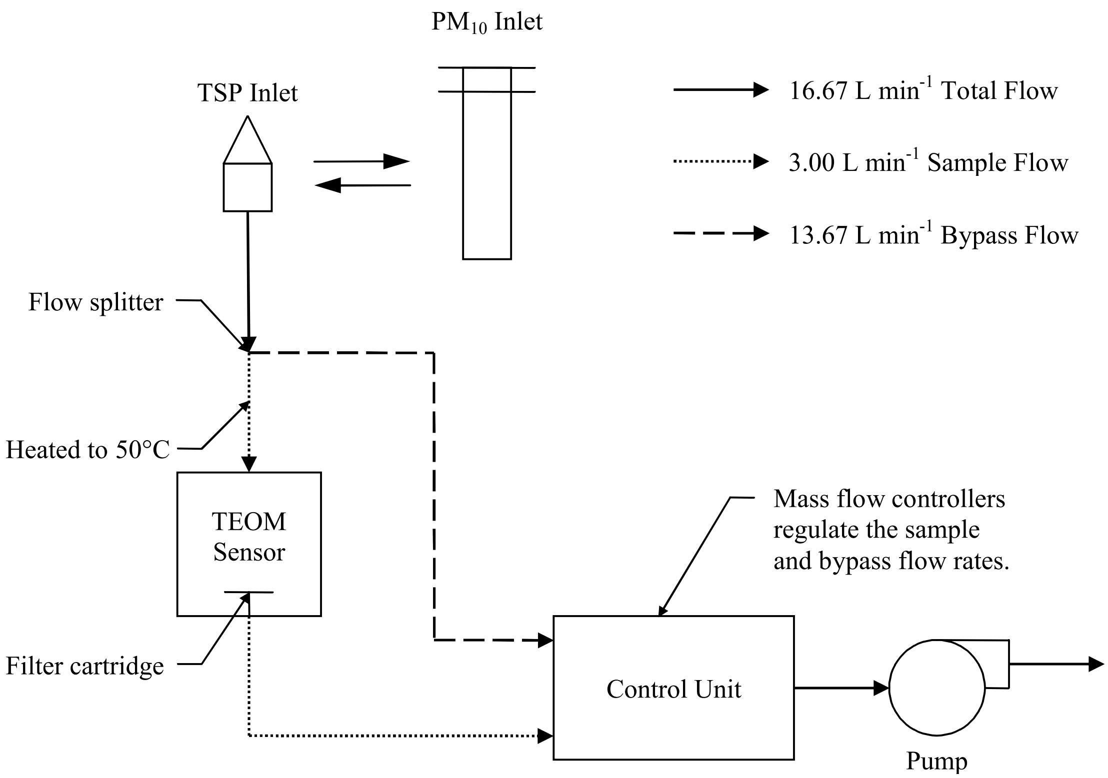

Figure 1. Schematic diagram of R&P Series 1400a monitor configured to measure TSP or PM_{10} concentrations.

In its standard configuration, the R&P Series 1400a monitor draws ambient air through the size selective inlet at a flow rate of 16.67 L min^{-1}. This flow rate is carefully maintained by the monitor to meet the design velocity of the size selective inlet. Once the air and those particles not separated by the inlet have entered the monitor, the air stream is isokinetically split into the sample flow and the bypass flow. Two mass flow controllers located in the control unit regulate the sample flow at 3.00 ± 0.2 L min^{-1} and the bypass flow at 13.67 ± 1 L min^{-1}. After the air stream is split, the sample flow is heated to 50°C. This is done to lessen the effect of the water vapor in the sample flow before it enters the TEOM sensor where the actual measurement of PM occurs. Since the bypass flow is not used by the R&P Series 1400a monitor for PM measurement purposes, it is exhausted outside through the bottom of the instrument (Rupprecht and Patashnick, 2002).

Immediately after entering the TEOM sensor, the sample flow impacts the replaceable filter cartridge, which is connected to the mass transducer by a hollow tapered element. As PM collects on the filter, the TEOM sensor measures the change in oscillation frequency of the hollow tapered element to determine the change in total mass of the replaceable filter cartridge. Together, the collected PM, replaceable filter cartridge, and hollow tapered element can be modeled as a spring-mass system (Rupprecht and Patashnick, 2002). Equation 1 is used to model the system.

$$F = \sqrt{\frac{K_0}{M}} \qquad (1)$$

where:

F = oscillation frequency (sec^{-1});

K_0 = spring rate ($N\ m^{-1}$); and

M = total mass of collected particulate matter, replaceable filter cartridge, and hollow tapered element (kg).

From equation 1, it can be observed that as the mass of PM collected on the filter increases, the oscillation frequency of the hollow tapered element decreases. This change is detected by the TEOM sensor which measures the oscillation frequency of the hollow tapered element every 2 s. Through algebraic manipulation, equation 1 can be modified into equation 2. Equation 2 uses the change in frequency measured over the 2 s sampling period to calculate the change in total mass of the system.

$$\Delta M = K_0\left(\frac{1}{F_1^2} - \frac{1}{F_2^2}\right) \tag{2}$$

where:

ΔM = change in total mass (kg), and

$F_{1,2}$ = initial (1) and final (2) measured oscillation frequency (sec^{-1}).

Since the mass of the replaceable filter cartridge and the hollow tapered element remain constant, any change in the total mass of the system is equal to the mass of PM collected on the filter. The measured PM concentration is calculated by dividing the mass of collected PM over the volume of air drawn across the filter. The 10 min mass concentration average is shown on the display of the R&P Series 1400a control unit. This concentration is continuously updated every 2 s. The PM concentration data storage interval is specified by the operator in the R&P Series 1400a control unit (Rupprecht and Patashnick, 2002).

Low-volume Gravimetric Sampler Description

The only other type of sampler that can be used for area designations is the FRM sampler. In 2005, Wanjura et al. designed and evaluated a low-volume sampler to measure TSP concentrations. The sampler was labeled as low-volume because it operates at a much lower sampling flow rate than the EPA high-volume TSP sampler.

The low-volume TSP sampler (LVTSP) designed by Wanjura et al. (2005) has a sampling flow rate of 16.67 L min^{-1} compared to the EPA high-volume TSP sampler which has a sampling flow rate of 1416.67 L min^{-1} (CFR, 1987). To accurately evaluate their design, the authors tested the LVTSP sampler against the EPA high-volume sampler in a controlled particulate concentration chamber. The TSP concentration data collected by Wanjura et al. (2005) demonstrated that the low-volume sampler maintained a more constant flow rate than the EPA high-volume sampler which resulted in more accurate TSP concentration measurements. Using the same low-volume gravimetric design, Wang et al. (2005) adapted the LVTSP sampler to measure PM_{10} concentrations. The only difference between the LVTSP sampler and the low-volume PM_{10} ($LVPM_{10}$) sampler is the size selective inlet. When configured as a FRM sampler, the $LVPM_{10}$ sampler is equipped with a PM_{10} size selective inlet (Wang et al., 2005).

Like the R&P Series 1400a monitor, the low-volume gravimetric sampler consists of four main components. These components are the size selective inlet, the filter holder, the orifice meter, and the vacuum pump and valve. Figure 2 shows the layout of the low-volume gravimetric sampler configured to measure TSP or PM_{10} concentrations. The low-volume gravimetric samplers used by CAAQES are identical to the LVTSP sampler designed and evaluated by Wanjura et al. (2005). When used to measure PM_{10} concentrations, the low-volume sampler is configured with a FRM PM_{10} size selective inlet. For both configurations, the low-volume gravimetric sampler draws ambient air through the size selective inlet at a flow rate of 16.67 L min^{-1}, the same flow rate maintained by R&P Series 1400a monitor.

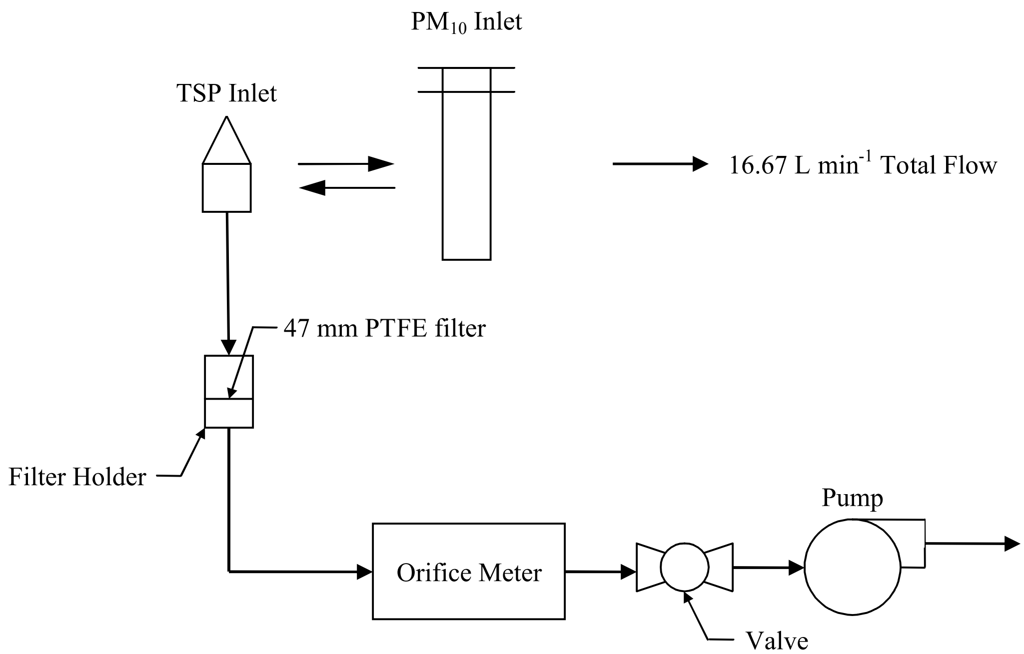

Figure 2. Schematic diagram of low-volume gravimetric sampler configured to measure TSP or PM_{10} concentrations.

The volumetric flow rate of the low-volume gravimetric sampler is regulated manually using the valve located between the pump and the orifice meter. The flow rate is maintained by adjusting the pressure drop measured across the orifice meter to the value that corresponds to a volumetric flow rate of 16.67 L min^{-1}. Equation 3 is used to calculate the sampling flow rate of the low-volume gravimetric sampler.

$$Q = 1.252 \times 10^4 K D_o^2 \sqrt{\frac{\Delta P}{\rho_{air}}} \quad (3)$$

where:

Q = volumetric flow rate (m^3 h^{-1}),

K = orifice meter constant (dimensionless),

D_o = orifice diameter (m),

ΔP = pressure difference (mm H_2O), and

ρ_{air} = air density (kg m^{-3}).

Since the calculation of the sampling flow rate requires air density as a variable, a weather station is erected at the sampling location to record atmospheric pressure, temperature, and relative humidity. The average air density can be determined for the test duration with these properties. Equation 4 is used to calculate air density.

$$\rho_{air} = \frac{P_a - P_w}{0.0028(T + 273)} + \frac{P_w}{0.0046(T + 273)} \tag{4}$$

where:

P_a = atmospheric pressure (atm),

P_w = water vapor pressure (atm), and

T = temperature (°C).

The PM that is not captured by the size selective inlet is collected on a 47 mm diameter polytetrafluoroethylene (PTFE) filter (2 µm pore size Zefluor Membrane Filter, Pall Corp., East Hills, NY) located in the filter holder. The filter is weighed before sampling and after sampling on a Mettler – Toledo AG245 balance (AG245, Mettler Toledo, Greifensee, Switzerland) (range: 0-41 g, accuracy: ±0.01 mg) to establish the pre-weight and post weight, respectively. The length of the test duration is also recorded. Equation 5 is used to calculate the mass concentration measured by the low-volume gravimetric sampler.

$$C = \frac{\Delta M}{Qt} \tag{5}$$

where:

C = mass concentration (μg m^{-3}),

ΔM = change in total filter mass (μg),

Q = volumetric air flow rate (m^3 h^{-1}), and

t = test duration (h).

After the mass concentration measured by the LVTSP sampler has been calculated, a particle size distribution (PSD) analysis is performed on the filter. The results of the PSD analysis are used to determine the MMD and GSD of the sampled PM. In order to remove the particles from the filter for analysis by the Coulter Multisizer3 (Beckman – Coulter, Coulter Multisizer3, Miami, FL), the filter is placed in a lithium chloride, methanol solution and subjected to a 5 min ultrasonic bath. The Coulter Multisizer3 is capable of measuring particles 2 to 60 μm in diameter. The results of the PSD analysis are evaluated according to the protocol described by Simpson et al. (2003).

Sampling Methodology

PM sampling was conducted at Feedyard C during the spring of 2006 and at Feedyards C and E during the summer of 2007. Both feedyards are located in the Texas Panhandle. The concentration data collected for this research was measured using collocated monitoring sites. Stationed at each collocated monitoring site was a R&P

Series 1400a monitor and a low-volume gravimetric sampler. Both types of samplers were operated using the same configuration (TSP or PM_{10}).

In the spring of 2006, a 4 day sampling trip was conducted at Feedyard C. Feedyard C is a large feedlot with approximately 45,000 head of cattle on feed at any one time. Two collocated monitoring sites were established along the north property line of the feedlot to measure downwind TSP and PM_{10} concentrations. One collocated monitoring site was established along the south property line of the feedlot to measure upwind TSP concentrations. In the summer of 2007, a 5 day sampling trip was conducted at Feedyard C. One collocated monitoring site was established along the south property line of the feedlot to measure upwind PM_{10} concentrations. The location of each monitoring site is shown in Figure 3.

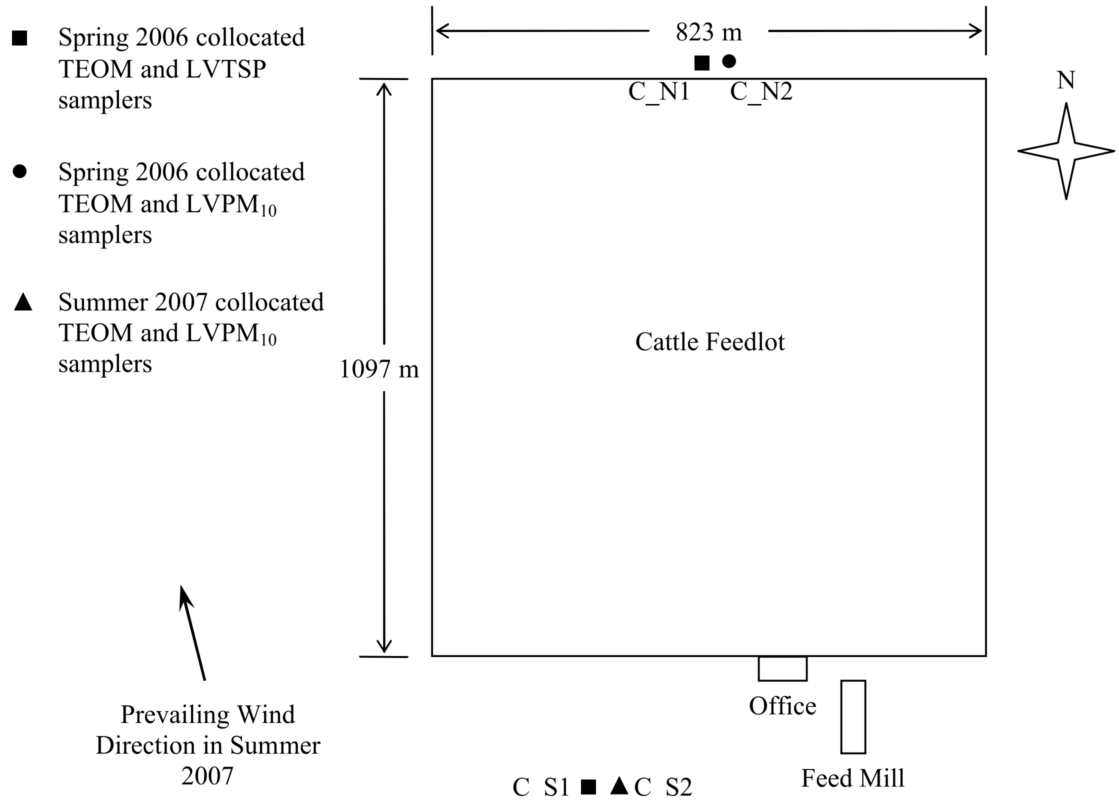

Figure 3. Diagram of Feedyard C showing the location of the collocated TEOM and low-volume gravimetric samplers during the spring of 2006 and the summer of 2007.

The weather during the 4 day sampling trip to Feedyard C in the spring of 2006 consisted of warm days and cool nights. The weather station was erected along the north property line near the collocated monitoring sites to measure and record atmospheric pressure, temperature, relative humidity, wind speed, and wind direction. The average daytime and nighttime temperatures were 24.6°C and 13.1°C, respectively. No rainfall was recorded during the trip. Wind direction was variable. The average wind speed was 2.34 m s^{-1}, with calm winds observed 11% of the time. The average duration of the daytime and nighttime sampling tests were 3 h and 9 h, respectively. Due to the dry condition of the cattle pens, high TSP and PM_{10} concentrations were observed for both the TEOM and low-volume gravimetric samplers at the upwind and downwind monitoring sites. All three of the R&P Series 1400a monitors had a mass concentration data storage interval of 1 min. Construction was being done on the highway to the south of the feedlot causing irregular yet thick windblown dust. It is believed that this construction affected the concentration measurements at the C_S1 monitoring site.

The weather during the 5 day sampling trip to Feedyard C in the summer of 2007 consisted of warm days and nights. The weather station was erected along the north property line to avoid hindering the operation of the feedlot. The same weather data was recorded as the previous year. The average daytime and nighttime temperatures were 26.4°C and 19.8°C, respectively. Although no rainfall was recorded during the trip, heavy rains were reported the week before sampling. The prevailing wind direction was from the south, southeast. The average wind speed was 2.75 m s^{-1}, with calm winds observed only 3% of the time. The average duration of the daytime and nighttime sampling tests were 3 h and 6 h, respectively. Measured PM_{10} concentrations were low due to the wet pen conditions and the fact that the monitoring site was located upwind of the cattle feedlot. The single R&P Series 1400a monitor used at Feedyard C had a mass concentration data storage interval of 1 min.

In the summer of 2007, a 4 day sampling trip was conducted at Feedyard E. Feedyard E is a medium feedlot with approximately 30,000 head of cattle on feed at any one time. One collocated monitoring site was established along the south property line of the feedlot to measure upwind TSP concentrations. The location of the monitoring site is shown is Figure 4.

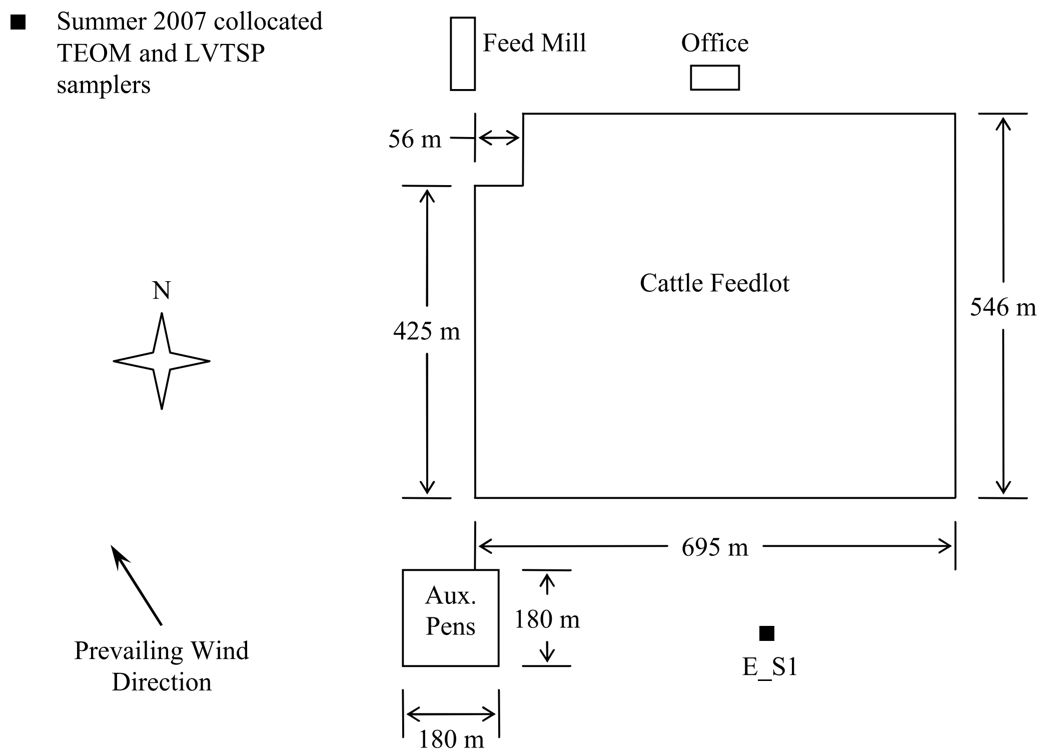

Figure 4. Diagram of Feedyard E showing the location of the collocated TEOM and low-volume gravimetric samplers during the summer of 2007.

The weather during the 4 day sampling trip to Feedyard E in the summer of 2007 consisted of warm days and nights. The weather station was erected along the south property line. The same weather data was recorded at Feedyard E as was recorded at

Feedyard C during the summer of 2006. The average daytime and nighttime temperatures were 28.2°C and 19.2°C, respectively. Heavy rainfall was recorded on day 3 when a strong front blew through the area. The prevailing wind direction was from the southeast; however, strong north winds were recorded before the arrival of the front. The average wind speed was 3.79 m s^{-1}, with calm winds observed only 2% of the time. The duration of the daytime and nighttime sampling tests varied greatly due to the rainfall event. Measured TSP concentrations were low due to the wet pen conditions and the fact that the monitoring site was located upwind of the cattle feedlot. The single R&P Series 1400a monitor used at Feedyard C had a mass concentration data storage interval of 1 min.

CHAPTER IV

RESULTS AND DISCUSSION

Perhaps the most important difference between the TEOM method and the FRM method is the frequency at which PM concentrations are reported. The R&P Series 1400a monitor measures PM concentrations continuously in real-time. In fact, the R&P monitor is capable of measuring and recording PM concentrations as frequently as every 2 s. For the purposes of this research, the R&P Series 1400a monitor was programmed to record PM concentrations on a 1 min interval. This data storage interval was selected because it allows the R&P monitor to run continuously for a 5 day sampling period without exceeding the memory capacity of the control unit. Figure 5 shows the PM_{10} concentrations measured by the TEOM sampler at the C_N2 monitoring site.

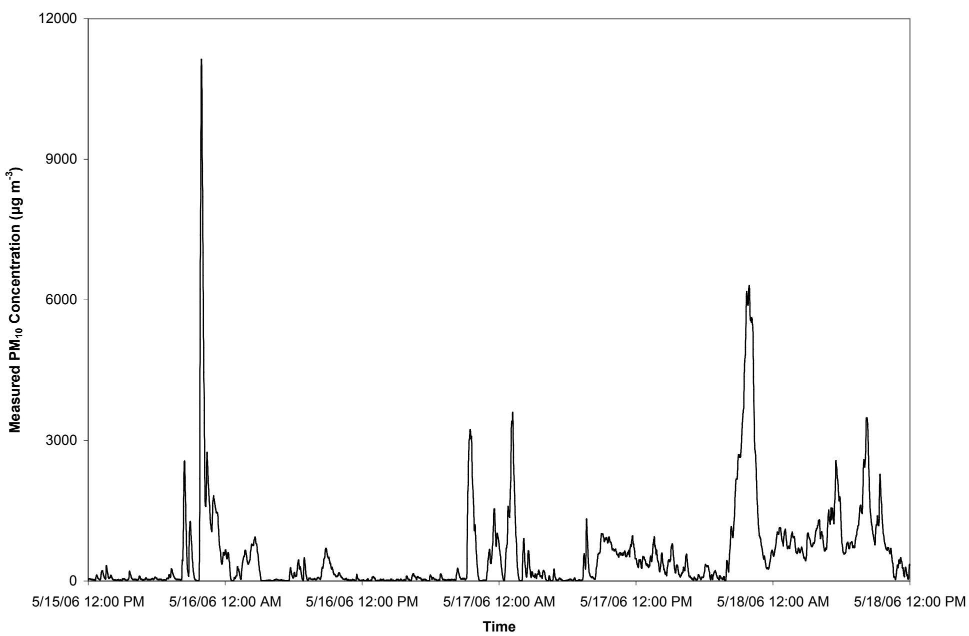

Figure 5. Real-time PM_{10} concentrations measured by the TEOM sampler at the C_N2 monitoring site.

The capability of the TEOM sampler to measure PM concentrations continuously in real-time differs greatly with the low-volume gravimetric sampler. The low-volume gravimetric sampler is essentially a time integrated sampling method. As a consequence of this difference, the concentration data measured by the TEOM sampler was averaged for each low-volume sampling test. The difference between the sampling methods can be seen in Figure 6.

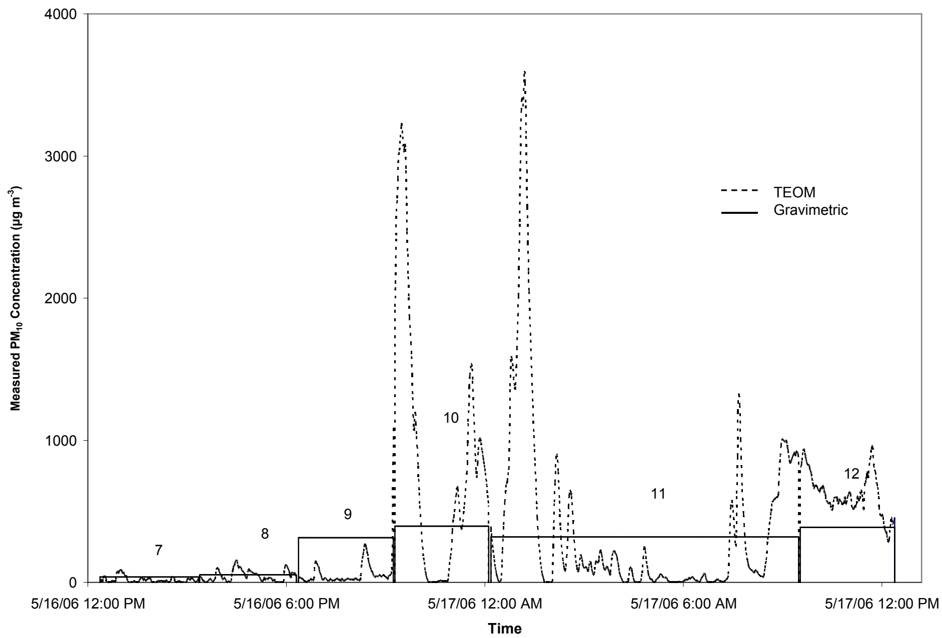

Figure 6. PM_{10} concentrations measured by the TEOM sampler and the low-volume gravimetric sampler at the C_N2 monitoring site for tests 7-12.

The performance of the R&P Series 1400a monitor was evaluated by comparing the average TEOM concentrations to the low-volume gravimetric sampler concentrations. Figures 7-11 show the PM concentrations measured by the TEOM and low-volume gravimetric samplers at all of the collocated monitoring sites.

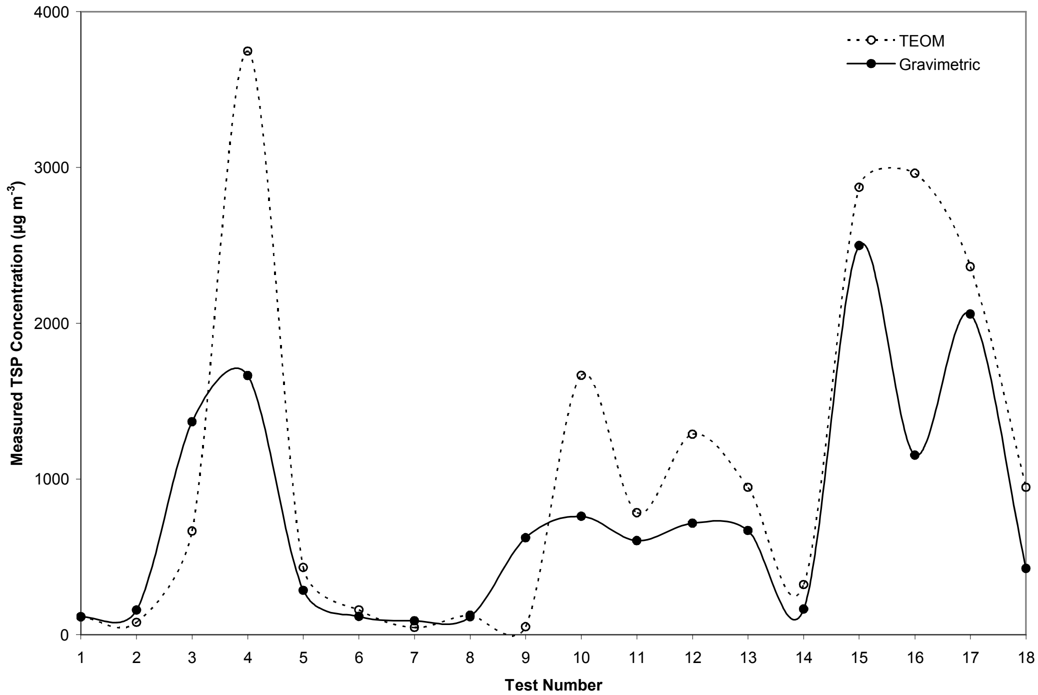

Figure 7. TSP concentrations measured at the C_N1 monitoring site.

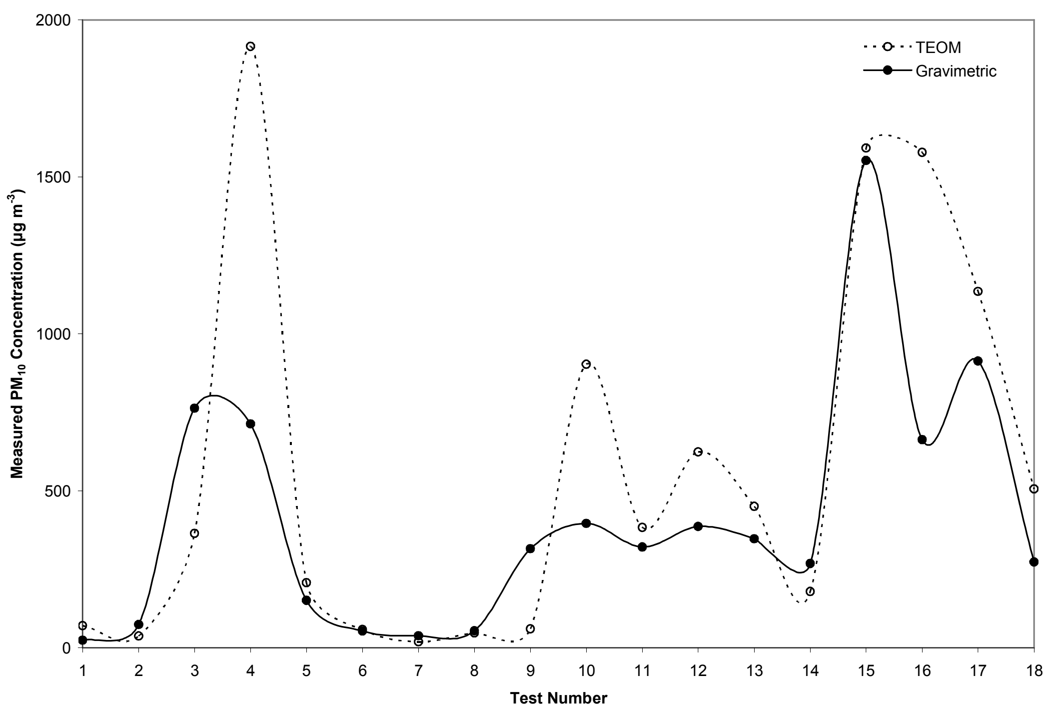

Figure 8. PM_{10} concentrations measured at the C_N2 monitoring site.

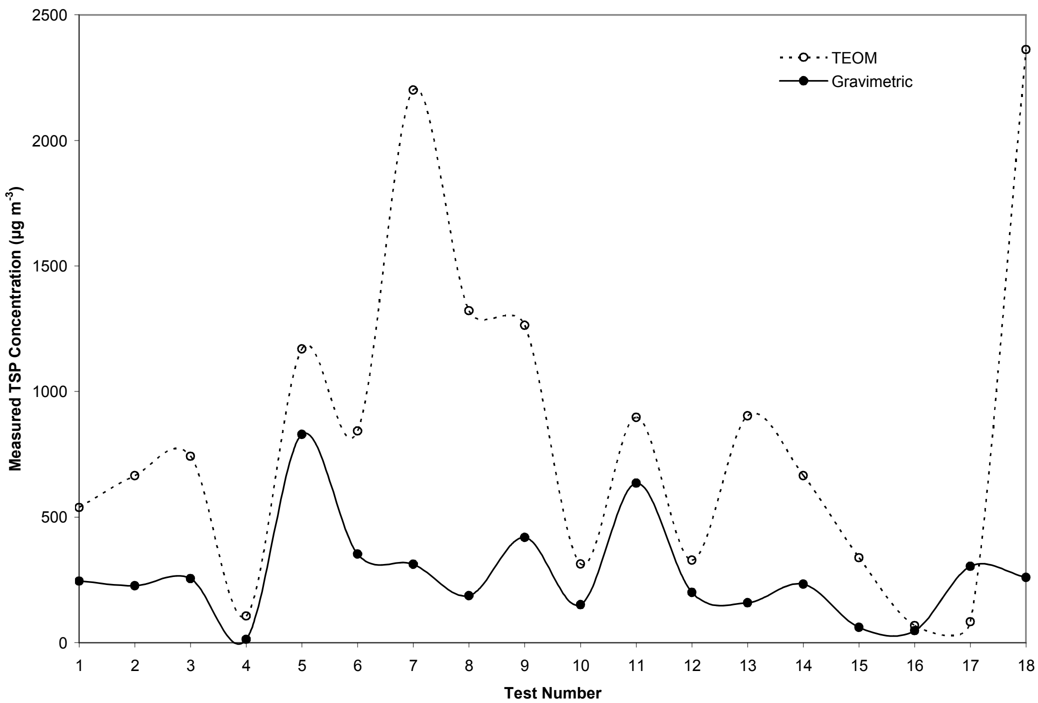

Figure 9. TSP concentrations measured at the C_S1 monitoring site.

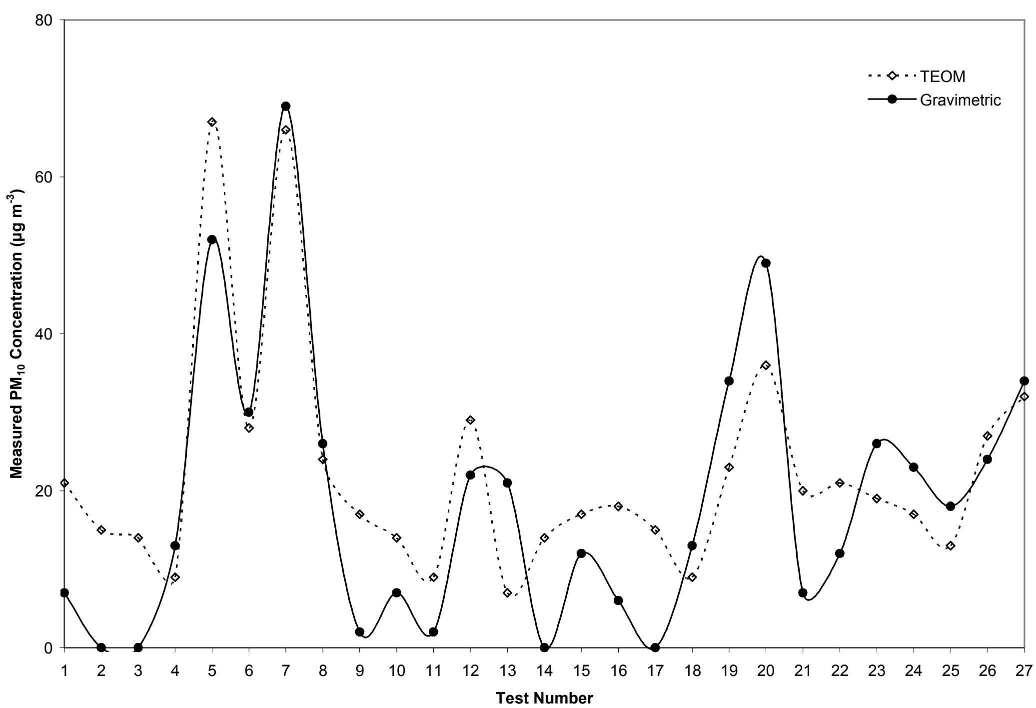

Figure 10. PM_{10} concentrations measured at the C_S2 monitoring site.

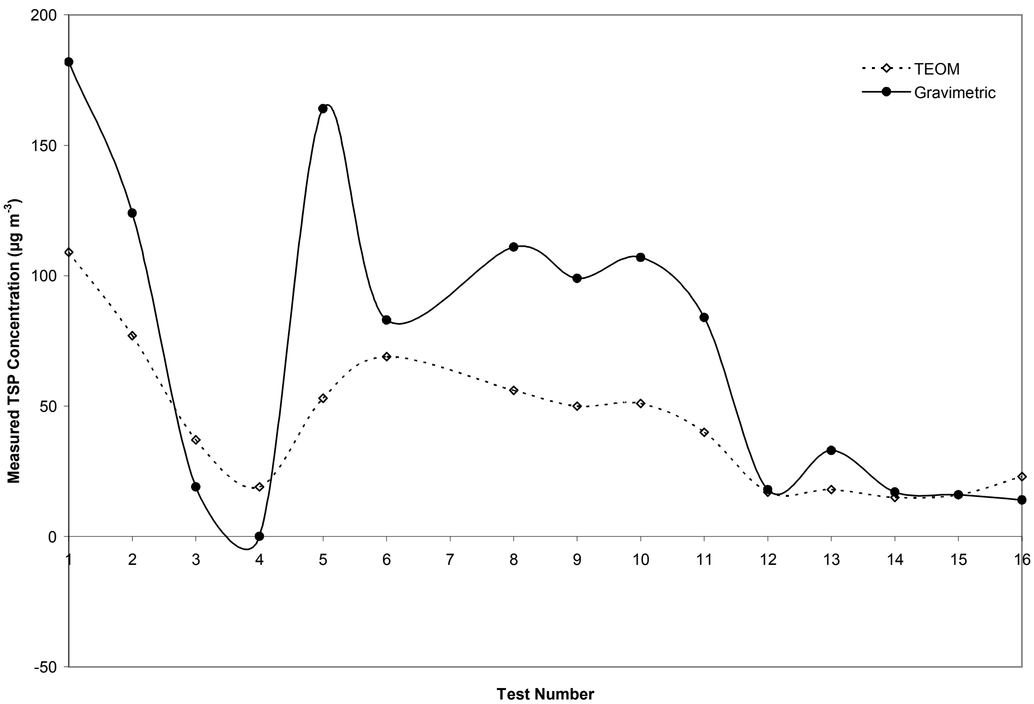

Figure 11. TSP concentrations measured at the E_S1 monitoring site.

The TSP and PM_{10} concentrations measured at Feedyard C during the spring of 2006 were unusually high for all of the monitoring sites. The large increase in PM emissions from the cattle pens is attributed to a lack of rain. Furthermore, it is believed that the highway construction downwind from the feedlot caused the TSP concentrations measured at the CS_1 monitoring site to increase.

The cattle pen conditions at Feedyards C and E were very different in 2007. Wet pens caused the PM concentrations measured at the C_S2 and E_S1 monitoring sites to be low. In fact, on day 3 of the sampling trip to Feedyard E, 7.6 cm of rain was recorded. The TSP concentrations measured at E_S1 decreased noticeably after the rainfall event. This difference can be seen in Figure 11 for tests 11-16.

The relationship between the TEOM sampler and the low-volume gravimetric sampler was determined by generating a plot of the average TEOM concentration versus the collocated low-volume gravimetric concentration for each monitoring site. Based upon previous research (Allen et al., 1997; Vega et al., 2003; Wanjura et al., 2008), it was hypothesized that the plot of the TEOM concentration versus the gravimetric concentration would be linear and that a linear regression analysis could therefore be used to evaluate the relationship between the sampling methods. Figures 12-16 show the plots of the TEOM concentrations versus the collocated low-volume gravimetric concentration for all of the monitoring sites.

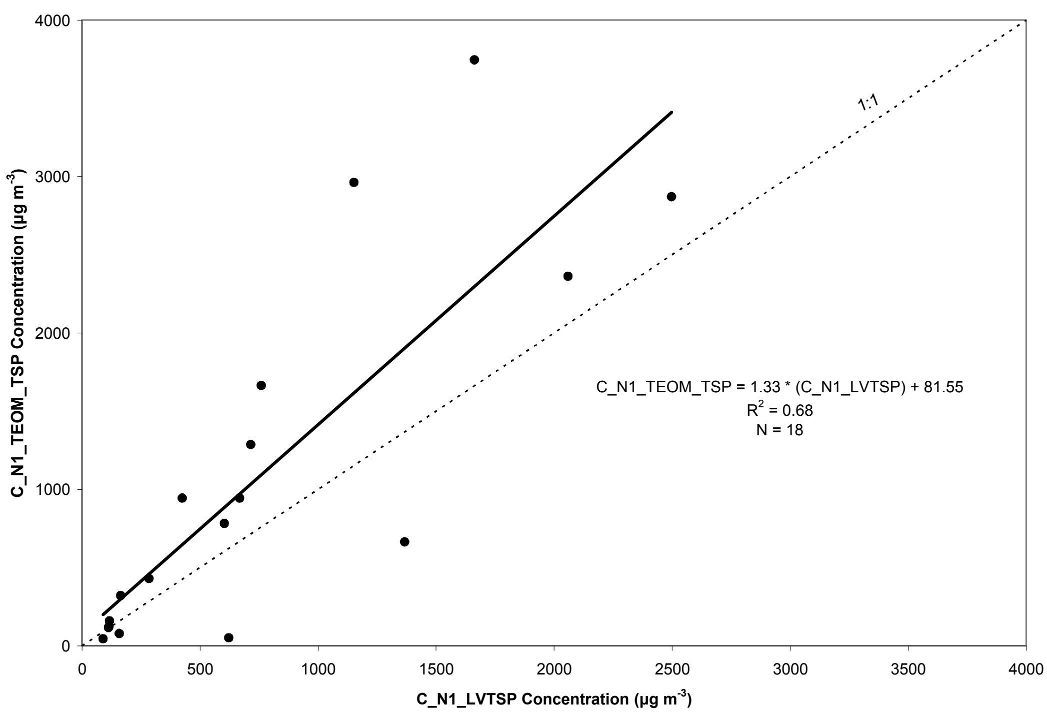

Figure 12. TEOM TSP concentrations versus LVTSP concentrations for the C_N1 monitoring site.

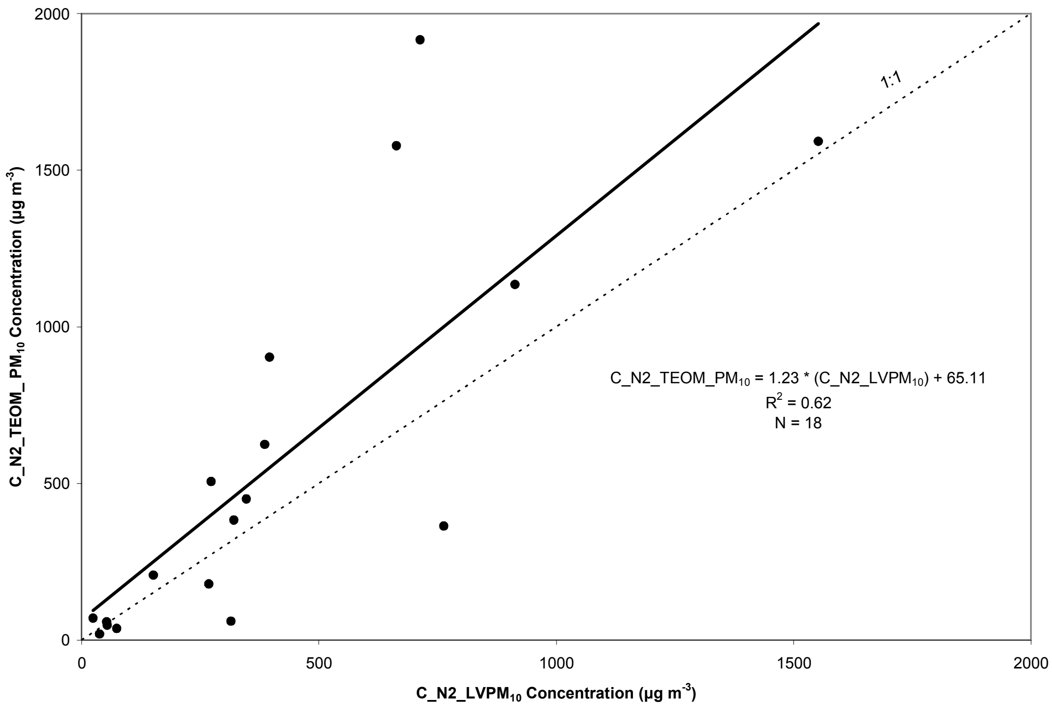

Figure 13. TEOM PM_{10} concentrations versus $LVPM_{10}$ concentrations for the C_N2 monitoring site.

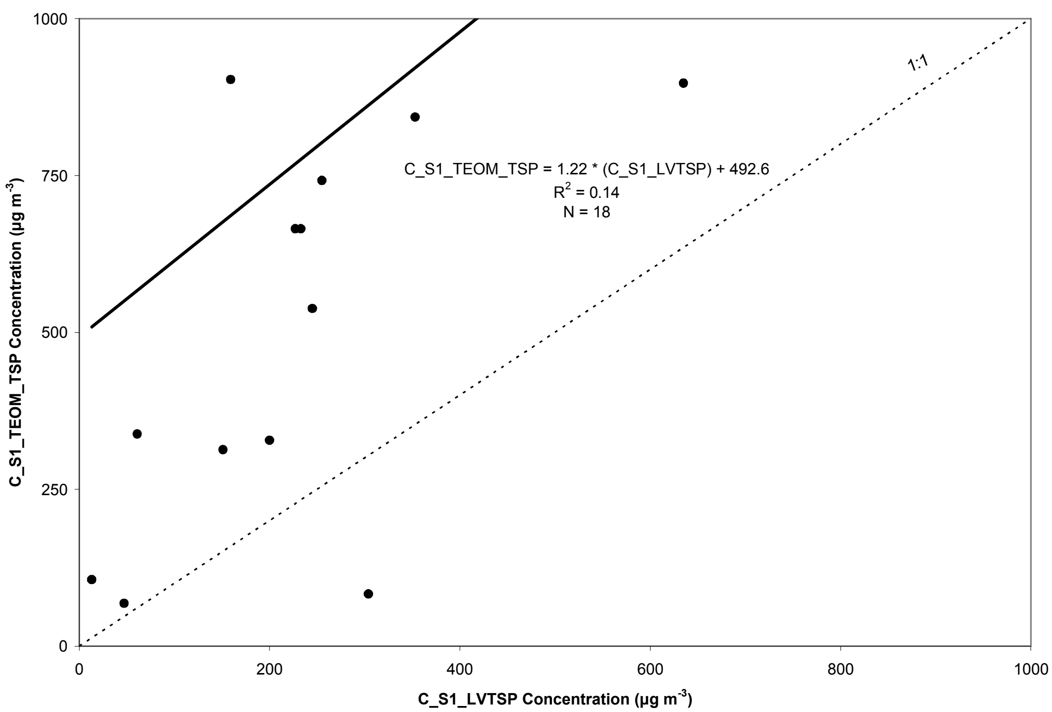

Figure 14. TEOM TSP concentrations versus LVTSP concentrations for the C_S1 monitoring site.

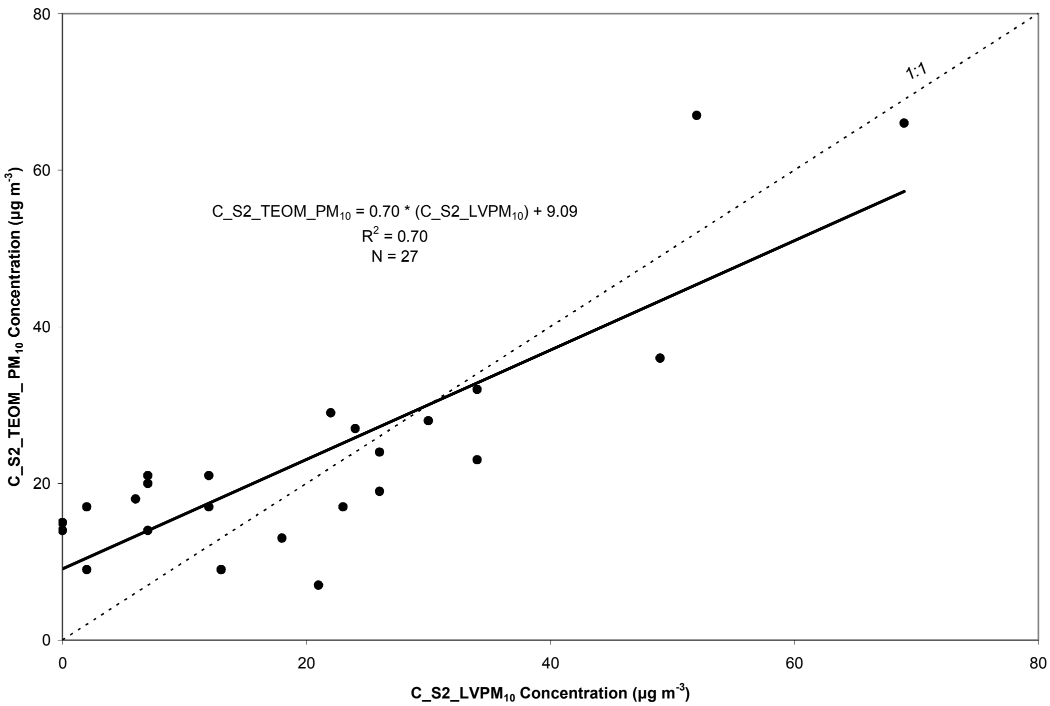

Figure 15. TEOM PM_{10} concentrations versus $LVPM_{10}$ concentrations for the C_S2 monitoring site.

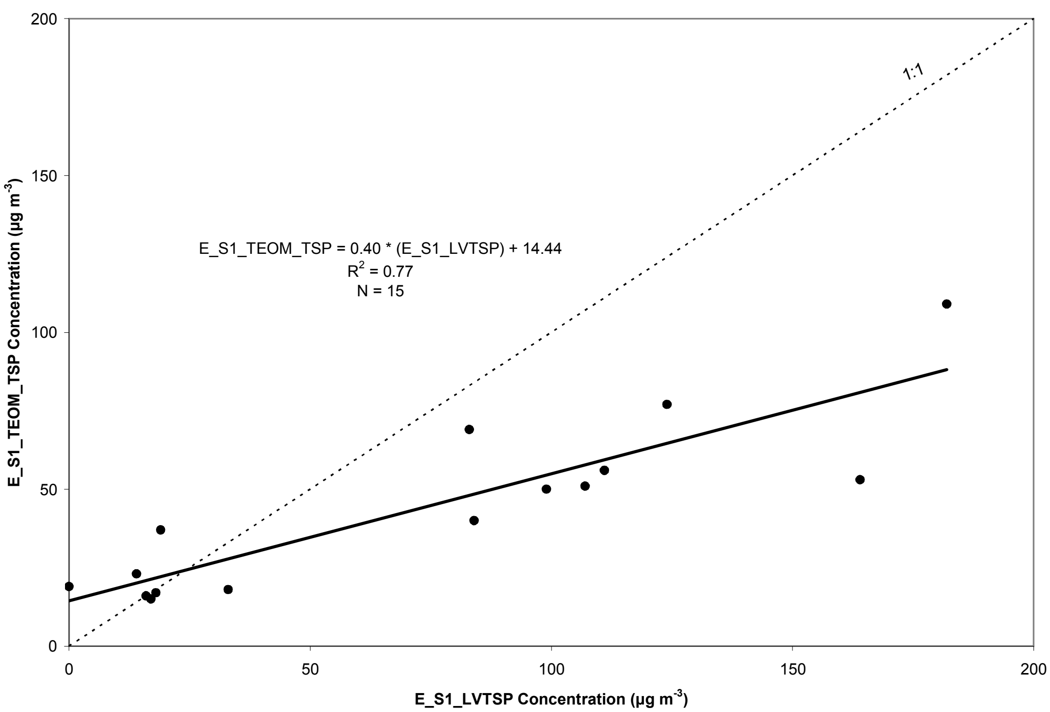

Figure 16. TEOM TSP concentrations versus LVTSP concentrations for the E_S1 monitoring site.

The results of the linear regression analysis are shown in Table 1. The correlation was good for all of the monitoring sites except C_S1. This was likely due to the irregular PM loading caused by the highway construction downwind from the site.

Table 1. Linear regression analysis results of the TEOM concentration versus the collocated low-volume gravimetric concentration for all of the monitoring sites.

			Regression Equation Coefficients		95% Confidence Interval for Slope		
Location	Size	R^2	Constant	Slope	Lower Limit	Upper Limit	Slope P-value
C_N1	TSP	0.68	81.55	1.33	0.85	1.81	2.31E-05
C_N2	PM_{10}	0.62	65.11	1.23	0.72	1.73	9.77E-05
C_S1	TSP	0.14	492.6	1.22	-0.41	2.84	1.31E-01
C_S2	PM_{10}	0.70	9.09	0.70	0.51	0.89	5.32E-08
E_S1	TSP	0.77	14.44	0.40	0.27	0.54	1.72E-05

The P-values in Table 1 test the null hypothesis that the corresponding slope is equal to zero. The null hypothesis is rejected for all of the monitoring sites except C_S1 because the P-values are not significant at the 0.05 level ($\alpha = 0.05$). This same conclusion can be reached by observing the 95% confidence interval for the slope of each monitoring site. The results clearly demonstrate that the relationship between the TEOM sampler and the low-volume gravimetric sampler is linear. Furthermore, the results for the C_N1 and C_N2 monitoring sites show that the R&P Series 1400a monitor frequently measures higher PM_{10} and TSP concentrations than the low-volume gravimetric sampler when sampling downwind. The opposite results were observed for the upwind monitoring sites, C_S2 and E_S1.

Previous research has indicated that concentration intensity (Vega et al., 2003) and particle size (Wanjura et al., 2008) affect the relationship between the TEOM sampler and the gravimetric sampler. Concentration intensity simply refers to the magnitude of the PM concentration measurement. Particle size is described by the MMD and GSD of the sampled PM. Since the average MMD of PM from Texas cattle feedlots is 16-18 μm (Sweeten et al., 1998) and the TSP concentrations measured downwind from a feedlot frequently exceeds 500 μg m^{-3} (Wanjura et al., 2008), it was hypothesized that concentration intensity and particle size would both influence the relationship between the TEOM sampler and the low-volume gravimetric sampler.

The influence which concentration intensity and particle size have on the relationship between PM concentrations measured by the TEOM sampler and the low-volume gravimetric sampler was determined using the concentration difference between the sampling methods. Equation 6 was used to calculate the concentration difference.

$$C_D = C_T - C_G \qquad (6)$$

where:

C_D = concentration difference (μg m^{-3}),

C_G = concentration measured by the low-volume gravimetric sampler (μg m^{-3}), and

C_T = concentration measured by the TEOM sampler (μg m^{-3}).

Figures 17-21 show the concentration difference for all of the monitoring sites.

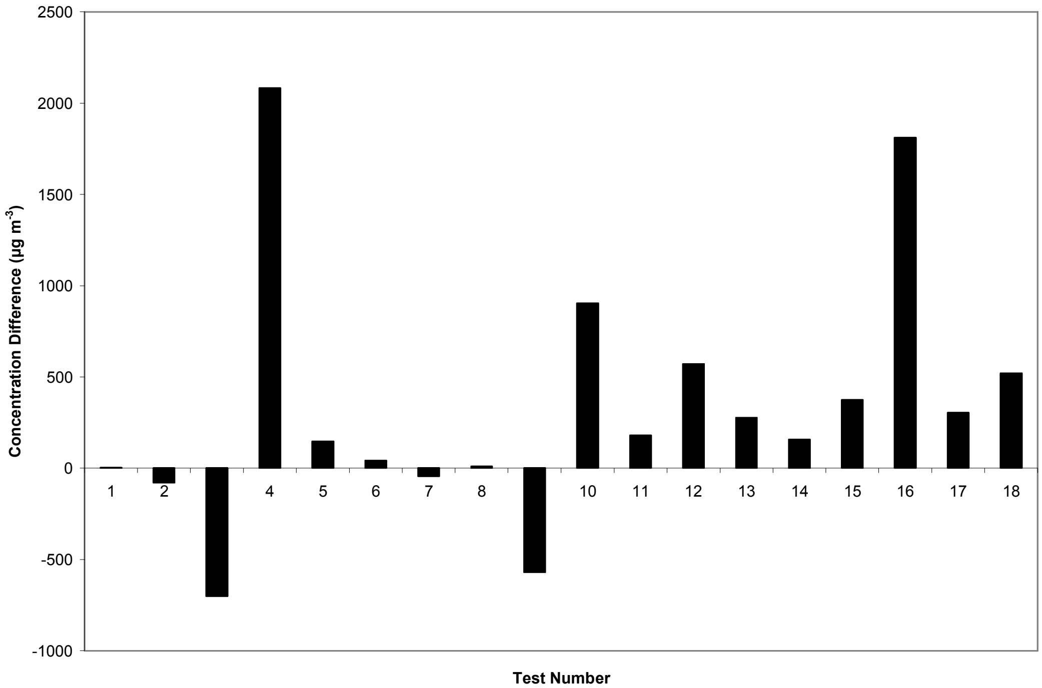

Figure 17. TSP concentration difference between the TEOM and LVTSP samplers at the C_N1 monitoring site.

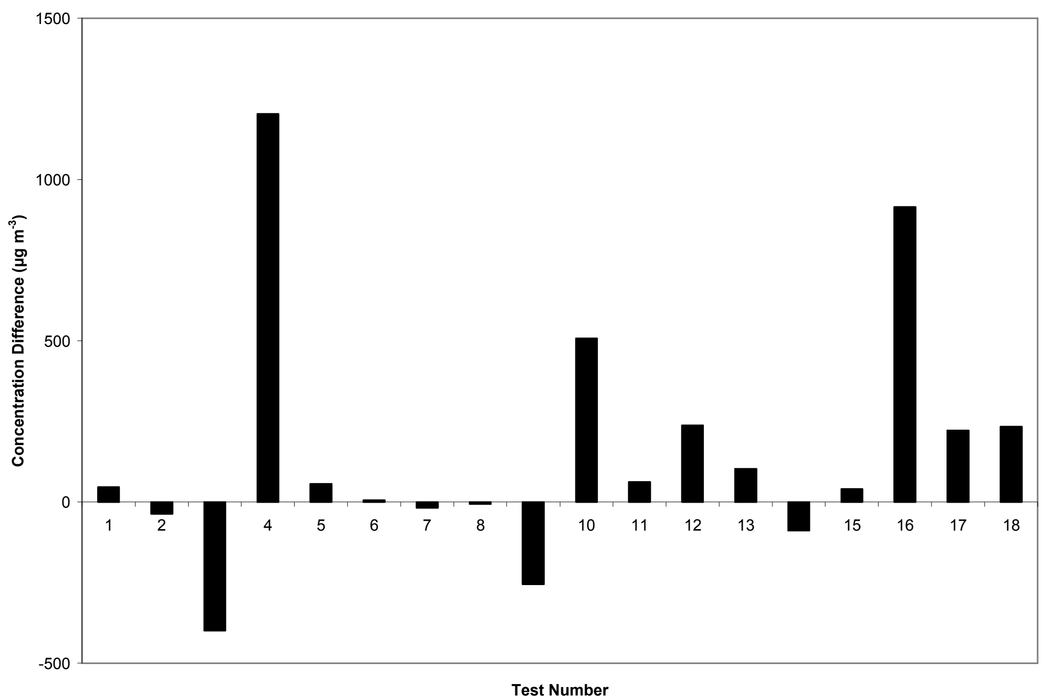

Figure 18. PM_{10} concentration difference between the TEOM and $LVPM_{10}$ samplers at the C_N2 monitoring site.

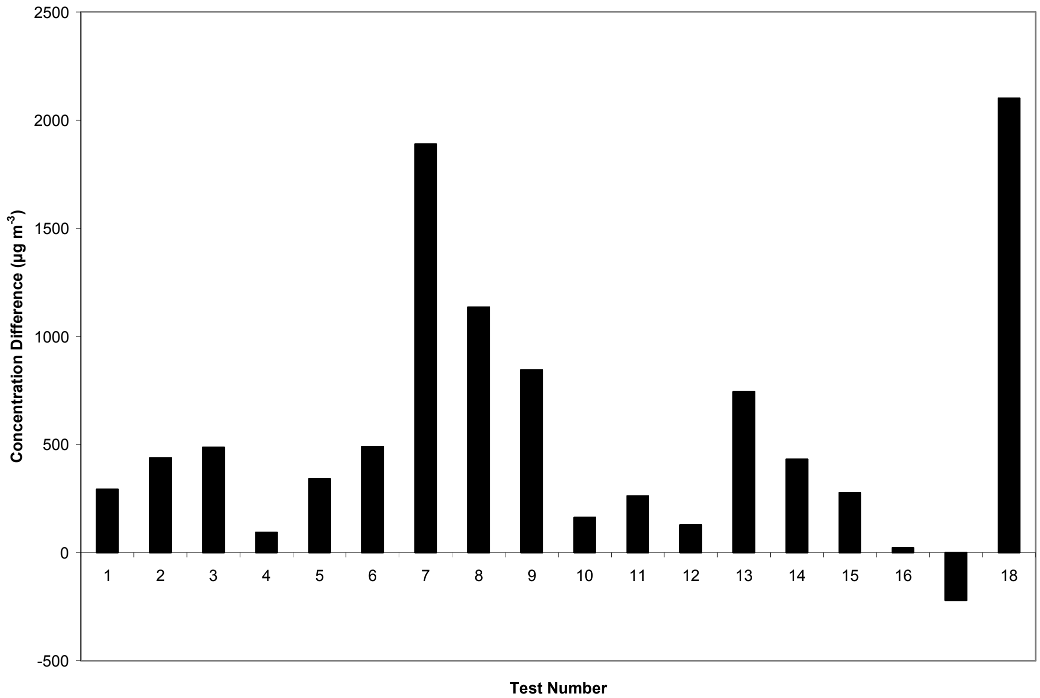

Figure 19. TSP concentration difference between the TEOM and LVTSP samplers at the C_S1 monitoring site.

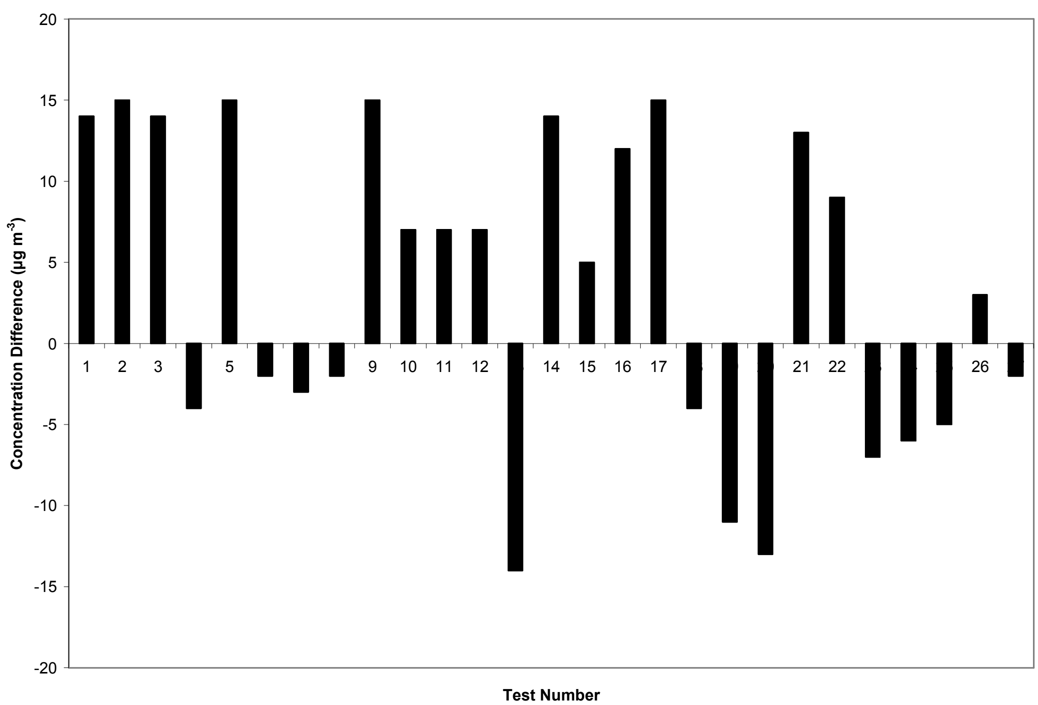

Figure 20. PM_{10} concentration difference between the TEOM and $LVPM_{10}$ samplers at the C_S2 monitoring site.

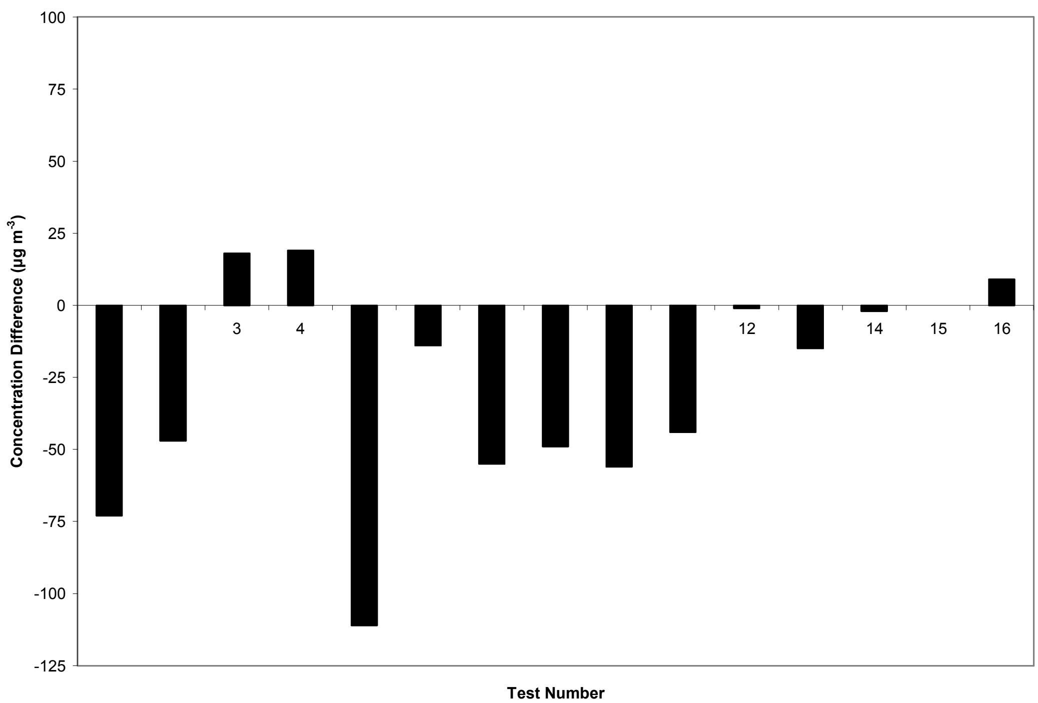

Figure 21. TSP concentration difference between the TEOM and LVTSP samplers at the E_S1 monitoring site.

The largest concentration difference between the TEOM sampler and the low-volume gravimetric sampler was observed at the C_S1 monitoring site. The concentration differences for the C_S2 and E_S1 upwind monitoring sites were small compared to the concentration differences calculated for the C_N1 and C_N2 downwind monitoring sites.

The relationship between the concentration difference and concentration intensity was determined by generating a plot of the concentration difference versus concentration intensity and performing a linear regression analysis for each monitoring site. The low-volume gravimetric sampler concentrations were used for concentration intensity. Figure

22 shows the plot of the concentration difference versus the concentration intensity for the E_S1 monitoring site.

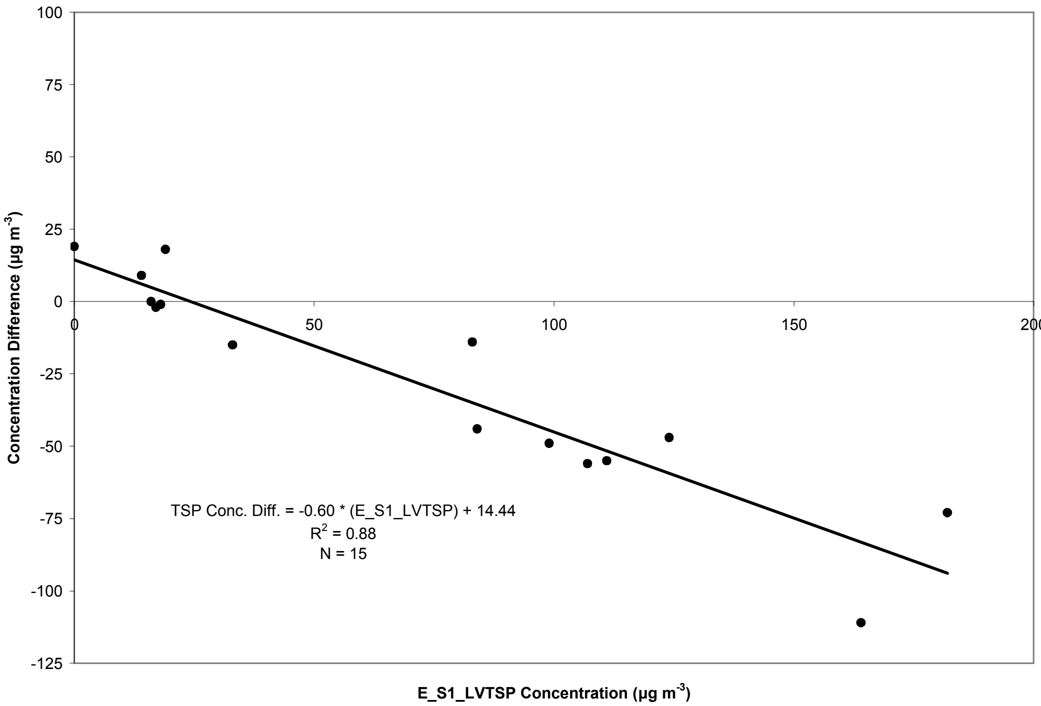

Figure 22. TSP concentration difference versus LVTSP concentrations for the E_S1 monitoring site.

The results of the linear regression analysis are shown in Table 2. The correlation was poor for the C_N1 and C_N2, and C_S1 monitoring sites; however, a strong correlation was observed for the E_S1 monitoring site. The coefficient of determination (R^2) for the C_S2 monitoring was lower than the E_S1 site because the data was considerably more scattered.

Table 2. Linear regression analysis results of the concentration difference versus the concentration intensity for all of the monitoring sites.

			Regression Equation Coefficients		95% Confidence Interval for Slope		
Location	Size	R^2	Constant	Slope	Lower Limit	Upper Limit	Slope P-value
C_N1	TSP	0.12	81.55	0.33	-0.15	0.81	1.61E-01
C_N2	PM_{10}	0.05	65.11	0.23	-0.28	0.73	3.57E-01
C_S1	TSP	0.00	492.6	0.22	-1.41	1.84	7.82E-01
C_S2	PM_{10}	0.30	9.09	-0.30	-0.49	-0.11	2.93E-03
E_S1	TSP	0.88	14.44	-0.60	-0.73	-0.46	2.48E-07

The P-values and 95% confidence intervals indicate the null hypothesis can only be rejected for the C_S2 and E_S1 monitoring sites. The results for the upwind monitoring sites demonstrate that the relationship between the concentration difference and the concentration intensity can be described as linear. Furthermore, the results show that the low-volume gravimetric sampler will measure a greater concentration than the TEOM sampler as the PM concentration of the upwind monitoring site increases. The results also show that the concentration difference between the TEOM sampler and the low-volume gravimetric sampler is independent of the concentration intensity for the downwind monitoring sites.

The relationship between the concentration difference and particle size was also evaluated using linear regression. In order to accurately evaluate the influence of particle size, linear regression analyses were performed for the concentration difference versus MMD, as well as, the concentration difference versus GSD. Only data from the C_N1, C_N2, and C_S1 collocated monitoring sites was used in the analyses. Figures 23-25 show the plots of the concentration difference versus the MMD for the C_N1, C_N2, and C_S1 monitoring sites.

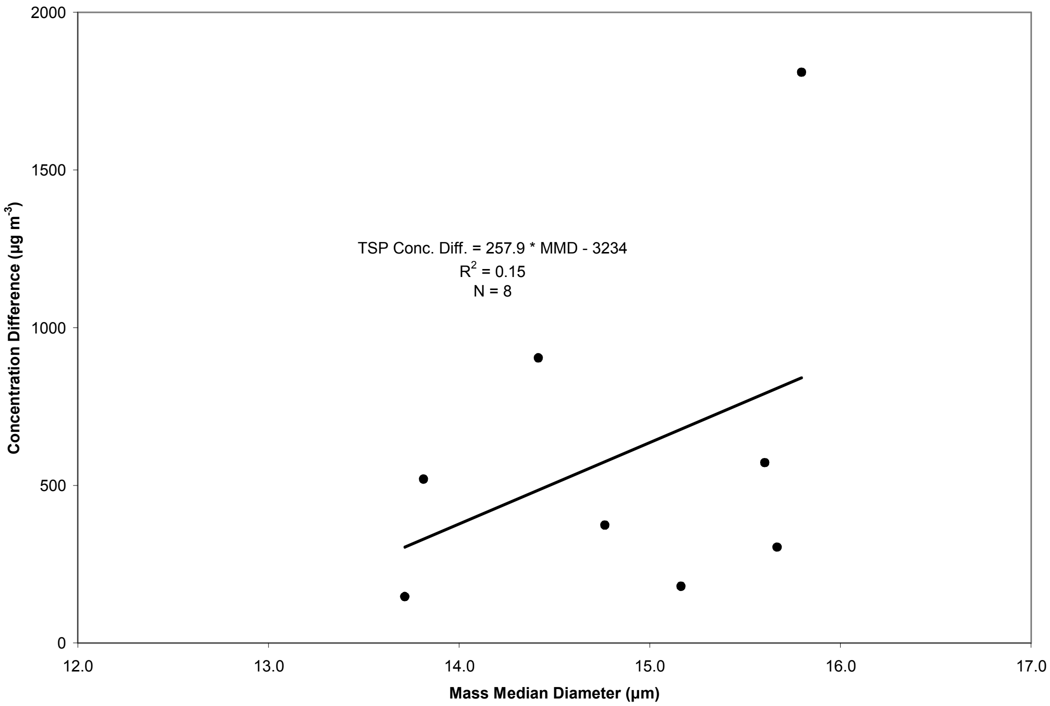

Figure 23. TSP concentration difference versus MMD for the C_N1 monitoring site.

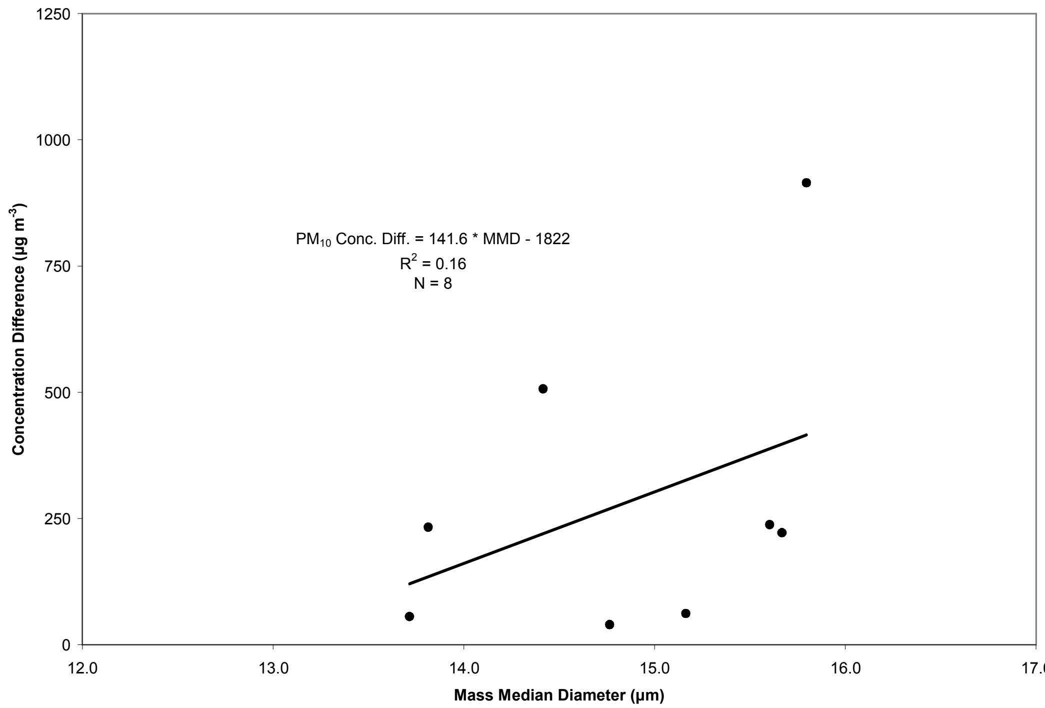

Figure 24. PM_{10} concentration difference versus MMD for the C_N2 monitoring site.

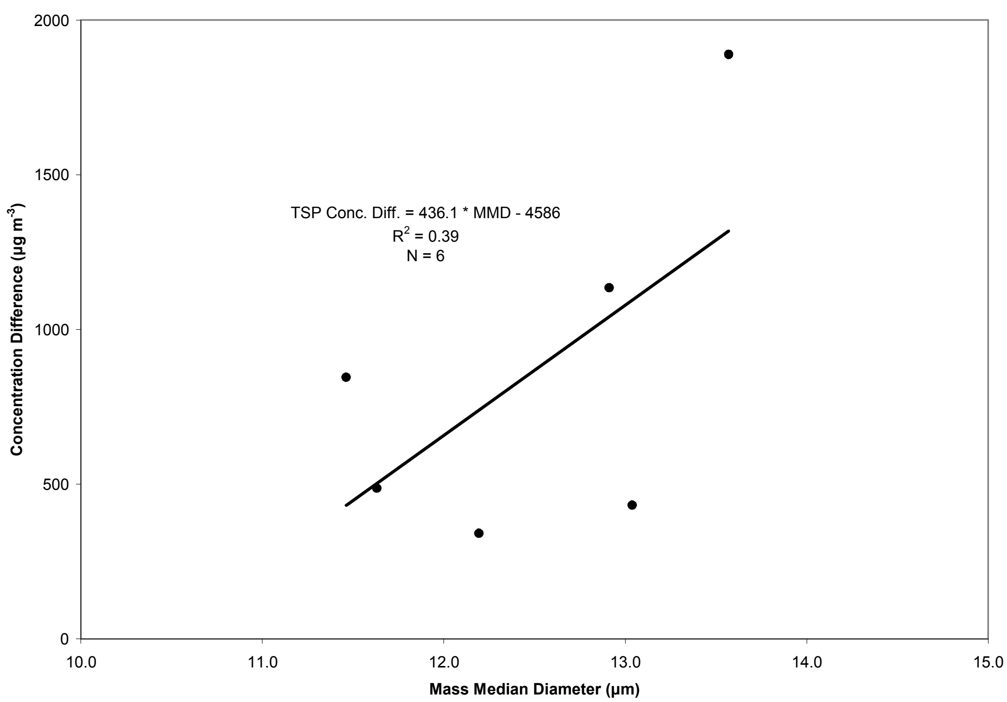

Figure 25. TSP concentration difference versus MMD for the C_S1 monitoring site.

The results of the linear regression analysis are shown in Table 3. The correlation was poor for the all of the monitoring sites; however, a positive linear relationship is observed between the concentration difference and the MMD.

Table 3. Linear regression analysis results of the concentration difference versus the MMD for the C_N1, C_N2, and C_S1 monitoring sites.

			Regression Equation Coefficients		95% Confidence Interval for Slope		
Location	Size	R^2	Constant	Slope	Lower Limit	Upper Limit	Slope P-value
C_N1	TSP	0.15	-3234	257.9	-348.8	864.5	0.338
C_N2	PM_{10}	0.16	-1822	141.6	-188.0	471.3	0.334
C_S1	TSP	0.39	-4586	436.4	-324.9	1198	0.187

The P-values and 95% confidence intervals indicate the null hypothesis cannot be rejected for any of the monitoring sites. Although the correlation is not statistically significant, it is believed that if more data were available then it could be demonstrated that the concentration difference between the TEOM sampler and low-volume gravimetric sampler is linearly dependent on the MMD of the sampled PM.

Figures 26-28 show the plots of the concentration difference versus the GSD for the C_N1, C_N2, and C_S1 monitoring sites.

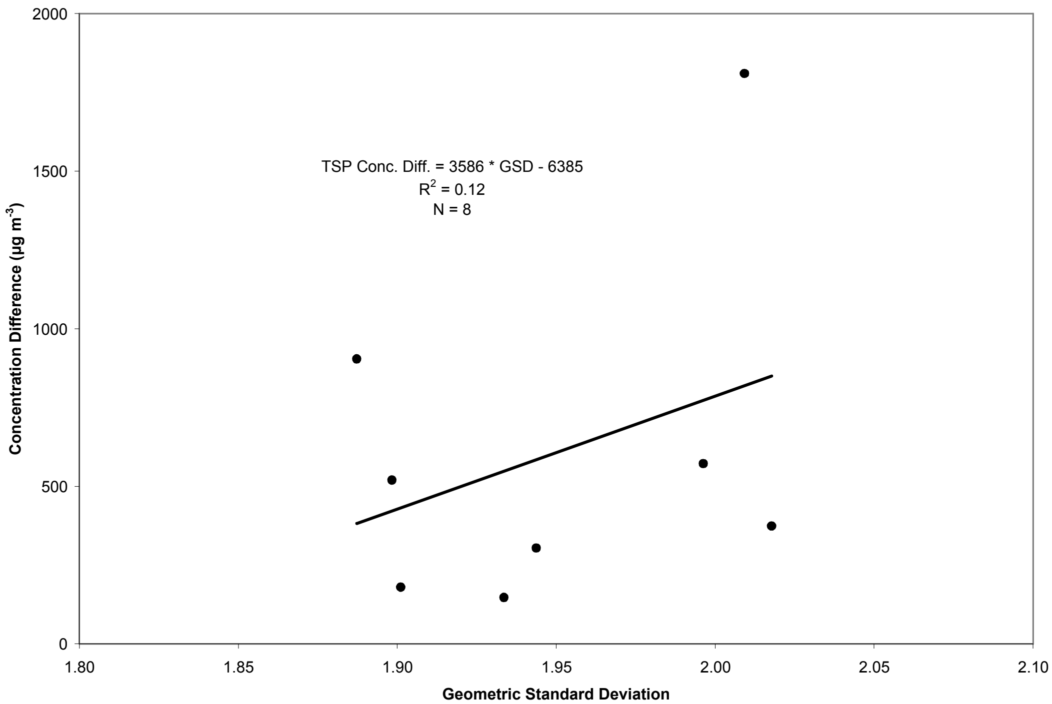

Figure 26. TSP concentration difference versus GSD for the C_N1 monitoring site.

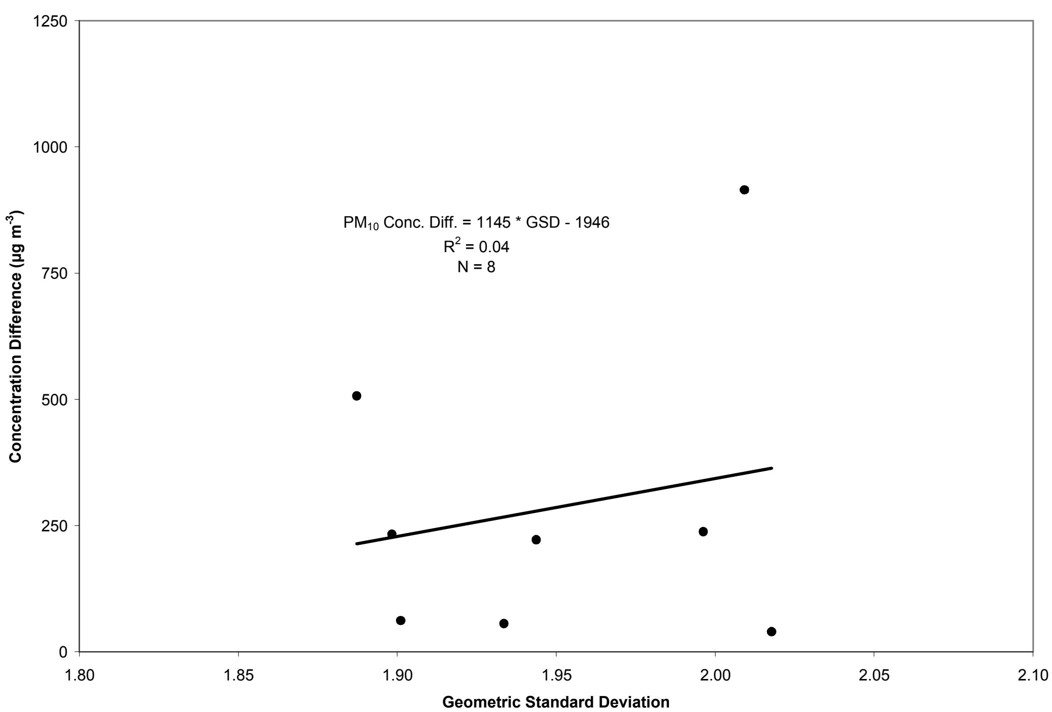

Figure 27. PM_{10} concentration difference versus GSD for the C_N2 monitoring site.

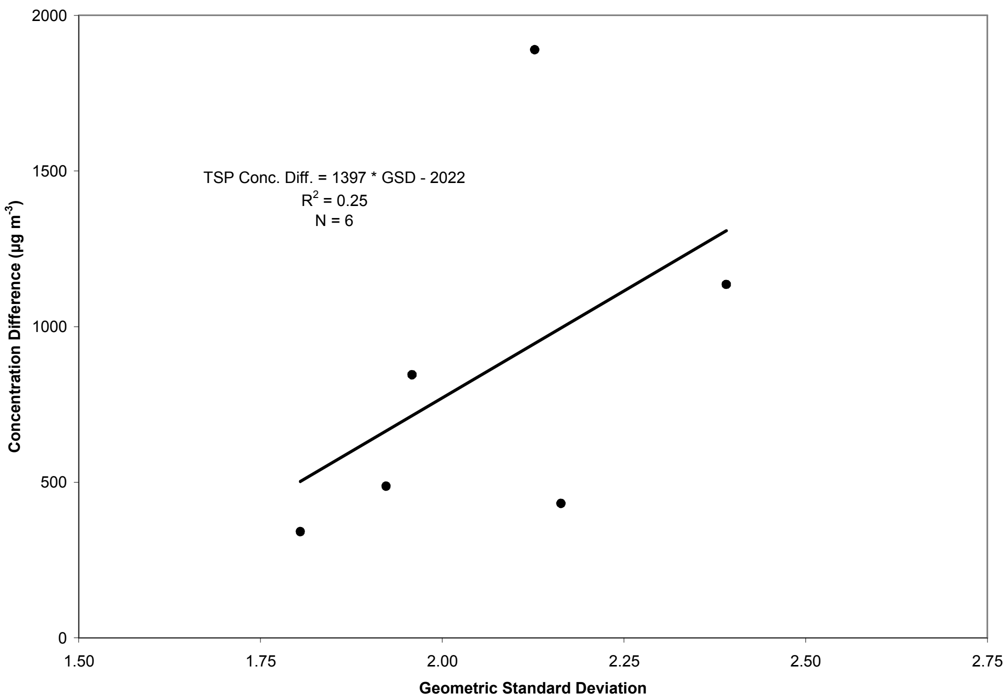

Figure 28. TSP concentration difference versus GSD for the C_S1 monitoring site.

The results of the linear regression analysis are shown in Table 4. The correlation was poor for the all of the monitoring sites; however, a positive linear relationship is observed between the concentration difference and the GSD.

Table 4. Linear regression analysis results of the concentration difference versus the GSD for the C_N1, C_N2, and C_S1 monitoring sites.

			Regression Equation Coefficients		95% Confidence Interval for Slope		
Location	Size	R^2	Constant	Slope	Lower Limit	Upper Limit	Slope P-value
C_N1	TSP	0.12	-6385	3586	-6096	13267	0.400
C_N2	PM_{10}	0.04	-1948	1145	-4355	6646	0.629
C_S1	TSP	0.25	-2022	1397	-1964	4757	0.313

The P-values and 95% confidence intervals indicate the null hypothesis cannot be rejected for any of the monitoring sites. Although the correlation is not statistically significant, it is believed that if more data were available then it could be demonstrated that the concentration difference between the TEOM sampler and low-volume gravimetric sampler is linearly dependent on the GSD of the sampled PM.

CHAPTER IV

CONCLUSIONS

The conclusions that can be made from the data collected for this research project are shown below.

- The results demonstrate that there is a positive linear relationship between the PM_{10} and TSP concentrations measured by the TEOM and low-volume gravimetric samplers.
- At the downwind collocated monitoring sites, it was observed that the TEOM sampler measured higher PM_{10} and TSP concentrations than the low-volume gravimetric sampler. This trend was shown to be statistically significant for the C_N1 and C_N2 monitoring sites.
- At most of the upwind collocated monitoring sites, it was observed that the TEOM sampler measured lower PM_{10} and TSP concentrations than the low-volume gravimetric sampler. This trend was shown to be statistically significant for the C_S2 and E_S1 monitoring sites. This trend was not observed for the C_S1 monitoring site. It is believed that the highway construction downwind of the C_S1 site severely affected the concentration measurements.
- At the downwind collocated monitoring sites, the results demonstrate that the concentration difference between the TEOM and low-volume gravimetric sampler is not linearly dependent with concentration intensity.

- At most of the upwind collocated monitoring sites, the results demonstrate that the concentration difference between the TEOM and low-volume gravimetric sampler is linearly dependent with concentration intensity. This trend was shown to be statistically significant for the C_S2 and E_S1 monitoring sites.
- The results indicate that there is a linear trend between the concentration difference and the MMD and GSD of the sampled PM; however, this correlation was not statistically significant. It is believed that additional downwind concentration measurements would validate this relationship.

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APPENDIX A

FIELD SAMPLER WORKSHEETS

Field Sampler Worksheet

Location: Feedyard C

Date: May 2006

Station: C_N1 (LVTSP)

Date	Test #	Fan #	Filter #	Time On	ΔP (in. H_2O)	Time Off	ΔP (in. H_2O)
5/15/06	1	11	2905	12:51	0.68	15:54	0.65
5/15/06	2	11	2918	15:56	0.68	18:29	0.50
5/15/06	3	11	2932	18:33	0.69	21:30	0.40
5/15/06	4	11	2940	21:33	0.70	0:31	0.68
5/16/06	5	11	2954	0:35	0.70	9:20	0.69
5/16/06	6	11	2965	9:23	0.69	12:19	0.68
5/16/06	7	11	2979	12:22	0.69	15:21	0.68
5/16/06	8	11	2992	15:23	0.66	18:18	0.64
5/16/06	9	11	3005	18:21	0.66	21:14	0.64
5/16/06	10	11	3015	21:17	0.66	0:07	0.65
5/16/06	11	11	3027	0:11	0.66	9:29	0.63
5/17/06	12	11	3041	9:32	0.68	12:23	0.67
5/17/06	13	11	3051	12:25	0.65	15:19	0.66
5/17/06	14	11	3063	15:20	0.65	18:22	0.63
5/17/06	15	11	3080	18:25	0.65	21:57	0.61
5/17/06	16	11	3088	22:00	0.68	0:17	0.66
5/18/06	17	11	3102	0:19	0.68	9:22	0.67
5/18/06	18	11	3115	9:24	0.68	12:21	0.66

Field Sampler Worksheet

Location: Feedyard C

Date: May 2006

Station: C_N2 ($LVPM_{10}$)

Date	Test #	Fan #	Filter #	Time On	ΔP (in. H_2O)	Time Off	ΔP (in. H_2O)
5/15/06	1	3	2908	12:51	0.82	15:54	0.80
5/15/06	2	3	2924	15:56	0.82	18:29	0.80
5/15/06	3	3	2931	18:33	0.83	21:30	0.78
5/15/06	4	3	2945	21:33	0.84	0:31	0.85
5/16/06	5	3	2960	0:35	0.84	9:20	0.84
5/16/06	6	3	2972	9:23	0.83	12:19	0.80
5/16/06	7	3	2985	12:22	0.83	15:21	0.81
5/16/06	8	3	2998	15:23	0.80	18:18	0.81
5/16/06	9	3	3011	18:22	0.80	21:14	0.81
5/16/06	10	3	3021	21:17	0.80	0:07	0.81
5/16/06	11	3	3033	0:11	0.80	9:29	0.75
5/17/06	12	3	3045	9:32	0.82	12:23	0.78
5/17/06	13	3	3061	12:25	0.79	15:19	0.81
5/17/06	14	3	3069	15:20	0.79	18:22	0.80
5/17/06	15	3	3085	18:25	0.79	21:57	0.71
5/17/06	16	3	3093	22:00	0.82	0:17	0.78
5/18/06	17	3	3108	0:19	0.82	9:22	0.74
5/18/06	18	3	3118	9:24	0.80	12:21	0.80

Field Sampler Worksheet

Location: Feedyard C

Date: May 2006

Station: C_S1 (LVTSP)

Date	Test #	Fan #	Filter #	Time On	ΔP (in. H_2O)	Time Off	ΔP (in. H_2O)
5/15/06	1	7	2902	12:25	0.75	15:30	0.75
5/15/06	2	7	2915	15:34	0.75	18:04	0.72
5/15/06	3	7	2949	18:07	0.76	21:06	0.75
5/15/06	4	7	2937	21:14	0.77	0:00	0.75
5/16/06	5	7	2951	0:05	0.77	8:55	0.79
5/16/06	6	7	2963	9:00	0.76	11:59	0.78
5/16/06	7	7	2976	12:01	0.76	15:00	0.75
5/16/06	8	7	2989	15:03	0.74	18:00	0.73
5/16/06	9	7	3003	18:02	0.74	21:00	0.70
5/16/06	10	7	3013	21:03	0.74	23:57	0.72
5/16/06	11	7	3025	23:59	0.74	9:02	0.75
5/17/06	12	7	3037	9:08	0.75	11:56	0.75
5/17/06	13	7	3050	12:01	0.75	15:00	0.75
5/17/06	14	7	3064	15:04	0.73	18:05	0.71
5/17/06	15	7	3076	18:08	0.73	21:36	0.75
5/17/06	16	7	3090	21:41	0.75	0:00	0.74
5/18/06	17	7	3099	0:03	0.75	8:59	0.77
5/18/06	18	7	3114	9:02	0.74	12:09	0.75

Field Sampler Worksheet

Location: Feedyard C

Date: July 2007

Station: C_S2 ($LVPM_{10}$)

Date	Test #	Fan #	Filter #	Time On	ΔP (in. H_2O)	Time Off	ΔP (in. H_2O)
7/13/07	1	25	4077	12:30	1.15	15:17	1.05
7/13/07	2	25	4096	15:22	1.15	17:56	1.15
7/13/07	3	25	4084	18:06	1.50	21:04	1.47
7/13/07	4	25	4089	21:07	1.50	6:26	1.47
7/14/07	5	25	4097	6:29	1.52	9:09	1.50
7/14/07	6	25	4092	9:13	1.50	12:02	1.48
7/14/07	7	25	4117	12:06	1.50	15:00	1.47
7/14/07	8	25	4123	15:03	1.46	18:00	1.44
7/14/07	9	25	4111	18:04	1.46	21:22	1.42
7/14/07	10	25	4115	21:25	1.50	0:02	1.46
7/15/07	11	25	4113	0:05	1.52	6:27	1.51
7/15/07	12	25	4101	6:30	1.50	9:32	1.53
7/15/07	13	25	4105	9:35	1.50	12:21	1.50
7/15/07	14	25	4130	12:24	1.50	15:21	1.48
7/15/07	15	25	4145	15:24	1.48	18:00	1.48
7/15/07	16	25	4134	18:03	1.50	21:20	1.49
7/15/07	17	25	4136	21:23	1.50	0:00	1.50
7/16/07	18	25	4129	0:03	1.52	6:13	1.56
7/16/07	19	25	4170	6:17	1.52	9:20	1.55
7/16/07	20	25	4172	9:23	1.50	11:58	1.50
7/16/07	21	25	4148	12:02	1.50	15:35	1.50
7/16/07	22	25	4175	15:38	1.48	18:02	1.47
7/16/07	23	25	4176	18:05	1.50	21:02	1.50

Field Sampler Worksheet

Location: Feedyard C

Date: July 2007

Station: C_S2 ($LVPM_{10}$)

Date	Test #	Fan #	Filter #	Time On	ΔP (in. H_2O)	Time Off	ΔP (in. H_2O)
7/16/07	24	25	4182	21:06	1.50	0:00	1.50
7/17/07	25	25	4150	0:03	1.50	6:14	1.48
7/17/07	26	25	4162	6:18	1.50	9:44	1.50
7/17/07	27	25	4160	9:48	1.50	12:00	1.45

Field Sampler Worksheet

Location: Feedyard E

Date: July 2007

Station: E_S1 (LVTSP)

Date	Test #	Fan #	Filter #	Time On	ΔP (in. H_2O)	Time Off	ΔP (in. H_2O)
7/9/07	1	31	2730	12:41	1.17	17:10	1.05
7/9/07	2	31	2780	17:13	1.17	21:17	1.19
7/9/07	3	31	2794	21:18	1.17	2:08	1.17
7/10/07	4	31	2754	2:11	1.17	6:48	1.18
7/10/07	5	31	3475	6:50	1.17	10:09	1.17
7/10/07	6	31	3488	10:10	1.17	12:52	1.16
7/10/07	7	31	2766	12:54	1.17	15:31	1.16
7/10/07	8	31	3511	15:33	1.17	18:35	1.21
7/10/07	9	31	3535	18:37	1.17	21:49	1.11
7/10/07	10	31	3839	21:50	1.17	0:55	1.17
7/11/07	11	31	3833	0:58	1.17	9:54	1.15
7/11/07	12	31	3891	9:57	1.17	15:12	1.16
7/11/07	13	31	3911	15:13	1.17	21:13	1.15
7/11/07	14	31	3926	21:16	1.17	6:42	1.14
7/12/07	15	31	3957	6:45	1.14	12:34	1.11
7/12/07	16	31	3953	12:36	1.14	15:18	1.15

APPENDIX B

MEASURED PARTICULATE MATTER CONCENTRATIONS

Measured Particulate Matter Concentrations

Location: Feedyard C

Date: May 2006

Station: C_N1

Date	Test #	LVTSP Conc. (μg m^{-3})	TEOM TSP Conc. (μg m^{-3})
5/15/06	1	113	116
5/15/06	2	158	79
5/15/06	3	1367	665
5/15/06	4	1663	3746
5/16/06	5	284	431
5/16/06	6	117	159
5/16/06	7	89	45
5/16/06	8	114	124
5/16/06	9	622	51
5/16/06	10	760	1664
5/16/06	11	603	783
5/17/06	12	715	1287
5/17/06	13	668	945
5/17/06	14	164	321
5/17/06	15	2498	2872
5/17/06	16	1152	2962
5/18/06	17	2059	2363
5/18/06	18	425	945

Measured Particulate Matter Concentrations

Location: Feedyard C

Date: May 2006

Station: C_N2

Date	Test #	$LVPM_{10}$ Conc. ($\mu g\ m^{-3}$)	TEOM PM_{10} Conc. ($\mu g\ m^{-3}$)
5/15/06	1	24	70
5/15/06	2	74	37
5/15/06	3	763	364
5/15/06	4	713	1916
5/16/06	5	151	207
5/16/06	6	53	58
5/16/06	7	38	19
5/16/06	8	54	47
5/16/06	9	315	60
5/16/06	10	396	903
5/16/06	11	321	383
5/17/06	12	386	624
5/17/06	13	347	450
5/17/06	14	268	179
5/17/06	15	1552	1592
5/17/06	16	663	1578
5/18/06	17	913	1135
5/18/06	18	273	506

Measured Particulate Matter Concentrations

Location: Feedyard C

Date: May 2006

Station: C_S1

Date	Test #	LVTSP Conc. (μg m^{-3})	TEOM TSP Conc. (μg m^{-3})
5/15/06	1	245	538
5/15/06	2	227	665
5/15/06	3	255	742
5/15/06	4	13	106
5/16/06	5	829	1170
5/16/06	6	353	843
5/16/06	7	312	2201
5/16/06	8	187	1322
5/16/06	9	419	1264
5/16/06	10	151	313
5/16/06	11	635	897
5/17/06	12	200	328
5/17/06	13	159	903
5/17/06	14	233	665
5/17/06	15	61	338
5/17/06	16	47	68
5/18/06	17	304	83
5/18/06	18	260	2362

Measured Particulate Matter Concentrations

Location: Feedyard C

Date: July 2007

Station: C_S2

Date	Test #	$LVPM_{10}$ Conc. ($\mu g\ m^{-3}$)	TEOM PM_{10} Conc. ($\mu g\ m^{-3}$)
7/13/07	1	7	21
7/13/07	2	0	15
7/13/07	3	0	14
7/13/07	4	13	9
7/14/07	5	52	67
7/14/07	6	30	28
7/14/07	7	69	66
7/14/07	8	26	24
7/14/07	9	2	17
7/14/07	10	7	14
7/15/07	11	2	9
7/15/07	12	22	29
7/15/07	13	21	7
7/15/07	14	0	14
7/15/07	15	12	17
7/15/07	16	6	18
7/15/07	17	0	15
7/16/07	18	13	9
7/16/07	19	34	23
7/16/07	20	49	36
7/16/07	21	7	20
7/16/07	22	12	21
7/16/07	23	26	19

Measured Particulate Matter Concentrations

Location: Feedyard C

Date: July 2007

Station: C_S2

Date	Test #	$LVPM_{10}$ Conc. ($\mu g\ m^{-3}$)	TEOM PM_{10} Conc. ($\mu g\ m^{-3}$)
7/16/07	24	23	17
7/17/07	25	18	13
7/17/07	26	24	27
7/17/07	27	34	32

Measured Particulate Matter Concentrations

Location: Feedyard E

Date: July 2007

Station: E_S1

Date	Test #	LVTSP Conc. (μg m^{-3})	TEOM TSP Conc. (μg m^{-3})
7/9/07	1	182	109
7/9/07	2	124	77
7/9/07	3	19	37
7/10/07	4	0	19
7/10/07	5	164	53
7/10/07	6	83	69
7/10/07	7	619	–
7/10/07	8	111	56
7/10/07	9	99	50
7/10/07	10	107	51
7/11/07	11	84	40
7/11/07	12	18	17
7/11/07	13	33	18
7/11/07	14	17	15
7/12/07	15	16	16
7/12/07	16	14	23

APPENDIX C

PARTICLE SIZE DISTRIBUTION ANALYSIS

Particle Size Distribution Analysis

Location: Feedyard C

Date: May 2006

Station: C_N1 (LVTSP)

Date	Test #	ESD (µm)	MMD (µm)[a],[b]	GSD
5/15/06	1	–	–	–
5/15/06	2	–	–	–
5/15/06	3	10.9	16.1	1.96
5/15/06	4	9.8	14.6	1.90
5/16/06	5	9.2	13.7	1.93
5/16/06	6	–	–	–
5/16/06	7	–	–	–
5/16/06	8	–	–	–
5/16/06	9	9.8	14.5	1.91
5/16/06	10	9.7	14.4	1.89
5/16/06	11	10.2	15.2	1.90
5/17/06	12	10.5	15.6	2.00
5/17/06	13	11.5	17.1	2.03
5/17/06	14	–	–	–
5/17/06	15	10.0	14.8	2.02
5/17/06	16	10.7	15.8	2.01
5/18/06	17	10.6	15.7	1.94
5/18/06	18	9.3	13.8	1.90

[a] Mass median diameter reported as the AED.
[b] Particle density is 2.2 g cm^{-3}.

Particle Size Distribution Analysis

Location: Feedyard C

Date: May 2006

Station: C_S1 (LVTSP)

Date	Test #	ESD (μm)	MMD (μm)[a],[b]	GSD
5/15/06	1	10.3	15.3	2.08
5/15/06	2	10.3	15.2	2.09
5/15/06	3	7.8	11.6	1.92
5/15/06	4	3.6	–	–
5/16/06	5	8.2	12.2	1.80
5/16/06	6	10.4	15.5	2.08
5/16/06	7	9.1	13.6	2.13
5/16/06	8	8.7	12.9	2.39
5/16/06	9	7.7	11.5	1.96
5/16/06	10	8.8	13.0	2.08
5/16/06	11	9.2	13.6	1.90
5/17/06	12	–	–	–
5/17/06	13	10.3	15.2	2.25
5/17/06	14	8.8	13.0	2.16
5/17/06	15	10.9	16.1	2.08
5/17/06	16	11.9	17.6	2.98
5/18/06	17	–	–	–
5/18/06	18	–	–	–

[a] Mass median diameter reported as the AED.
[b] Particle density is 2.2 g cm^{-3}.

APPENDIX D

WEATHER DATA

Weather Data

Location: Feedyard C

Date: May 2006

Date	Test #	P_{atm} (psia)	T (°F)	RH (%)	ρ_{ma} (lb ft^{-3})
5/15/06	1	12.99	70.0	28.1	0.0661
5/15/06	2	13.01	73.0	23.8	0.0658
5/15/06	3	13.02	69.0	25.1	0.0664
5/15/06	4	13.05	59.0	39.3	0.0678
5/16/06	5	13.04	49.0	55.3	0.0690
5/16/06	6	13.02	72.0	32.5	0.0659
5/16/06	7	13.00	78.0	13.7	0.0652
5/16/06	8	12.97	80.0	12.3	0.0648
5/16/06	9	12.96	75.0	15.6	0.0654
5/16/06	10	12.98	61.0	29.4	0.0672
5/16/06	11	12.98	50.0	45.6	0.0686
5/17/06	12	12.98	74.0	21.5	0.0655
5/17/06	13	12.96	81.0	15.7	0.0646
5/17/06	14	12.92	84.0	11.2	0.0641
5/17/06	15	12.92	79.0	15.5	0.0646
5/17/06	16	12.94	66.0	33.4	0.0663
5/18/06	17	12.94	61.0	40.3	0.0669
5/18/06	18	12.93	81.0	20.4	0.0644

Weather Data

Location: Feedyard C

Date: July 2007

Date	Test #	P_{atm} (psia)	T (°F)	RH (%)	ρ_{ma} (lb ft^{-3})
7/13/07	1	13.01	70.0	87.2	0.0658
7/13/07	2	13.00	73.4	73.7	0.0653
7/13/07	3	12.98	73.6	69.2	0.0652
7/13/07	4	12.99	61.2	92.4	0.0669
7/14/07	5	12.99	63.3	91.4	0.0666
7/14/07	6	12.98	78.9	56.2	0.0646
7/14/07	7	12.97	86.8	34.1	0.0637
7/14/07	8	12.95	88.9	27.9	0.0634
7/14/07	9	12.94	85.7	34.0	0.0637
7/14/07	10	12.95	74.1	62.7	0.0651
7/15/07	11	12.97	65.3	80.5	0.0662
7/15/07	12	12.98	65.9	79.7	0.0662
7/15/07	13	12.96	84.1	38.5	0.0640
7/15/07	14	12.95	89.5	28.6	0.0633
7/15/07	15	12.94	90.2	31.6	0.0631
7/15/07	16	12.93	85.7	40.3	0.0636
7/15/07	17	12.95	75.3	62.8	0.0649
7/16/07	18	12.96	67.5	79.0	0.0659
7/16/07	19	12.96	67.7	78.1	0.0659
7/16/07	20	12.96	78.1	57.4	0.0646
7/16/07	21	12.95	85.2	44.6	0.0637
7/16/07	22	12.93	89.0	36.6	0.0632
7/16/07	23	12.92	86.1	38.9	0.0635

Weather Data

Location: Feedyard C

Date: July 2007

Date	Test #	P_{atm} (psia)	T (°F)	RH (%)	ρ_{ma} (lb ft^{-3})
7/16/07	24	12.94	74.9	57.9	0.0649
7/17/07	25	12.96	69.3	72.2	0.0657
7/17/07	26	12.96	68.1	74.7	0.0659
7/17/07	27	12.96	79.6	53.2	0.0644

Weather Data

Location: Feedyard E

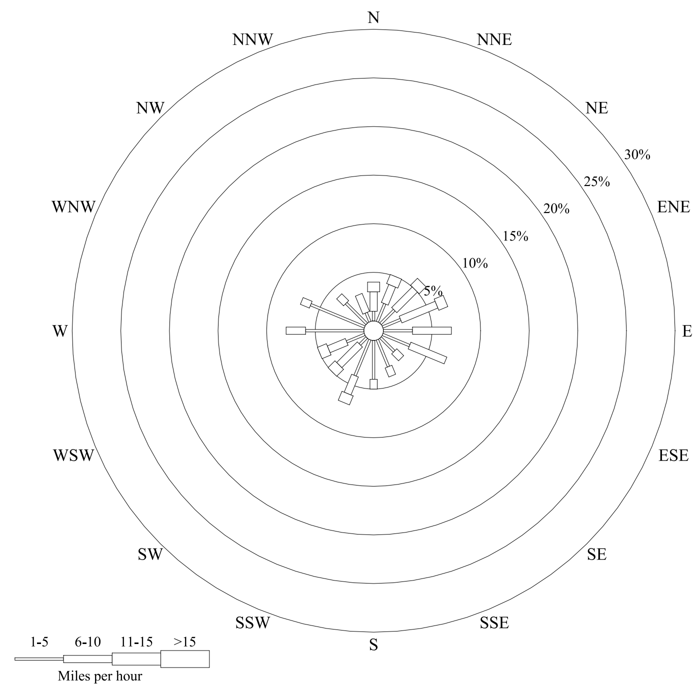
Date: July 2007

Date	Test #	P_{atm} (psia)	T (°F)	RH (%)	ρ_{ma} (lb ft^{-3})
7/9/07	1	12.76	89.9	30.7	0.0623
7/9/07	2	12.76	83.6	42.4	0.0630
7/9/07	3	12.79	67.4	74.6	0.0650
7/10/07	4	12.78	61.1	86.9	0.0659
7/10/07	5	12.80	67.4	74.8	0.0651
7/10/07	6	12.80	86.1	34.4	0.0630
7/10/07	7	12.80	92.1	26.5	0.0623
7/10/07	8	12.79	92.8	29.0	0.0622
7/10/07	9	12.80	87.1	39.0	0.0628
7/10/07	10	12.85	78.3	57.0	0.0640
7/11/07	11	12.88	65.2	88.2	0.0658
7/11/07	12	12.88	77.3	62.8	0.0642
7/11/07	13	12.84	82.1	55.3	0.0634
7/11/07	14	12.86	68.6	85.9	0.0652
7/12/07	15	12.85	74.3	70.8	0.0644
7/12/07	16	12.83	83.0	52.6	0.0633

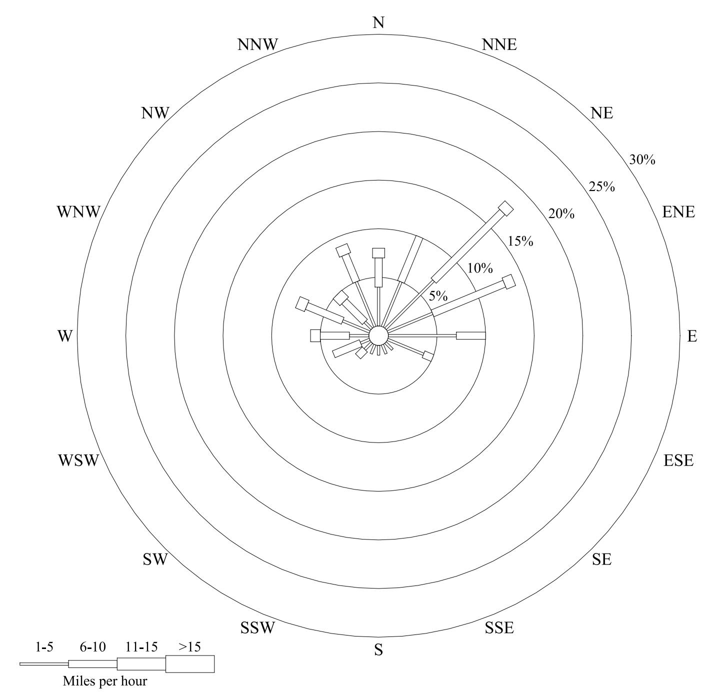
APPENDIX E

WIND SPEED AND DIRECTION

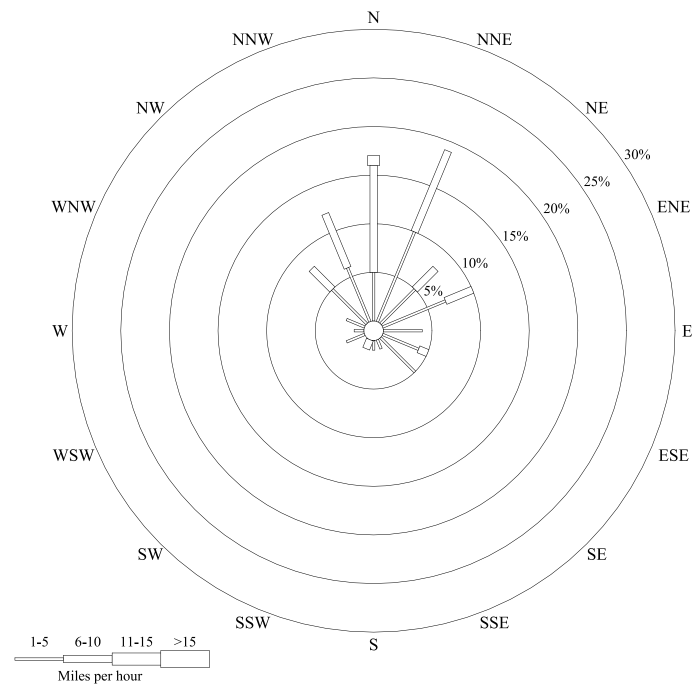
Location:	Feedyard C
Year:	2006
Station:	North TSP
Test Number:	All Tests
Start Date:	5/15/06
Start Time:	12:51 P.M.
End Date:	5/18/06
End Time:	12:21 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	5.23 mi/h
Calm Winds:	11%
Comments:	



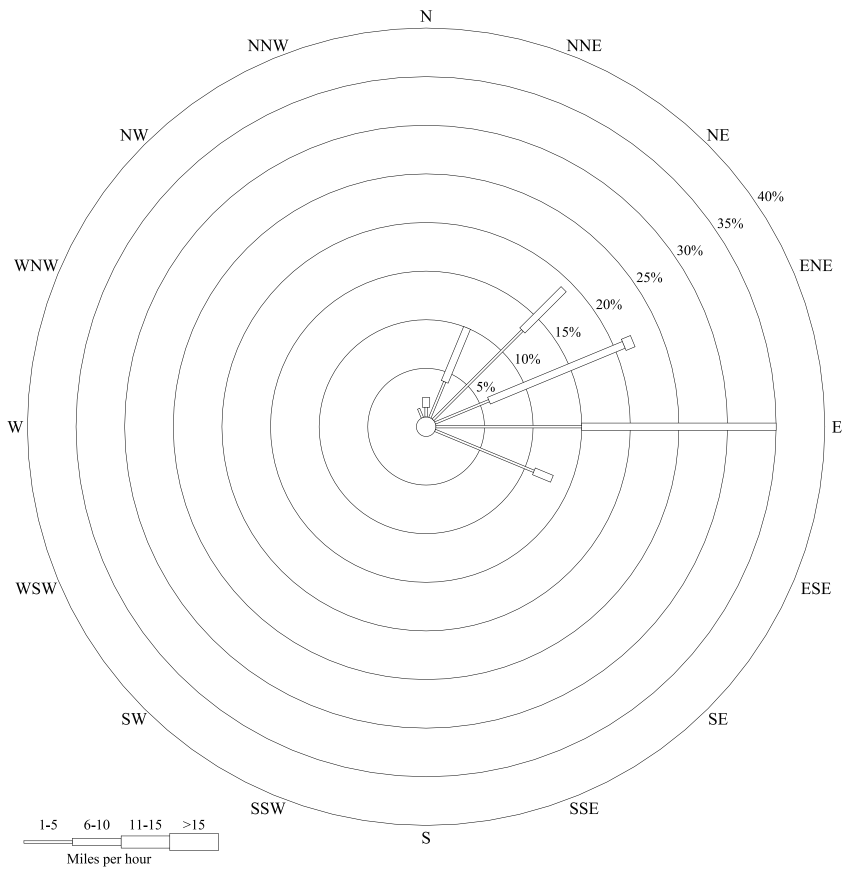
Location:	Feedyard C
Year:	2006
Station:	North TSP
Test Number:	1
Start Date:	5/15/06
Start Time:	12:51 P.M.
End Date:	5/15/06
End Time:	3:54 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	5.46 mi/h
Calm Winds:	6%
Comments:	



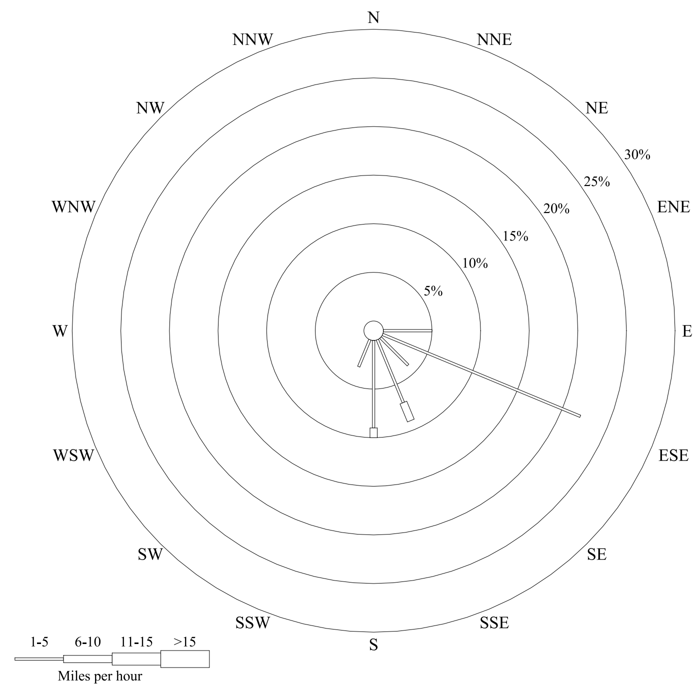
Location:	Feedyard C
Year:	2006
Station:	North TSP
Test Number:	2
Start Date:	5/15/06
Start Time:	3:56 P.M.
End Date:	5/15/06
End Time:	6:29 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	4.53 mi/h
Calm Winds:	5%
Comments:	



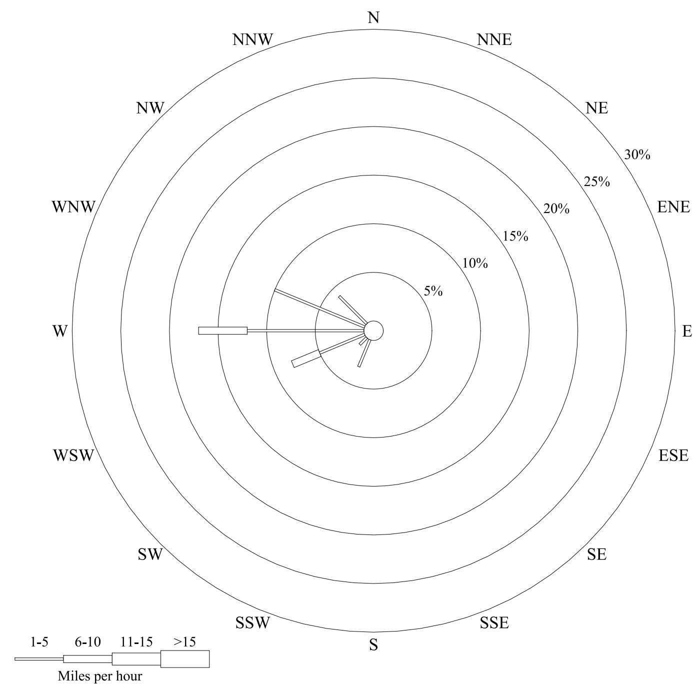
Location:	Feedyard C
Year:	2006
Station:	North TSP
Test Number:	3
Start Date:	5/15/06
Start Time:	6:33 P.M.
End Date:	5/15/06
End Time:	9:30 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	5.64 mi/h
Calm Winds:	1%
Comments:	



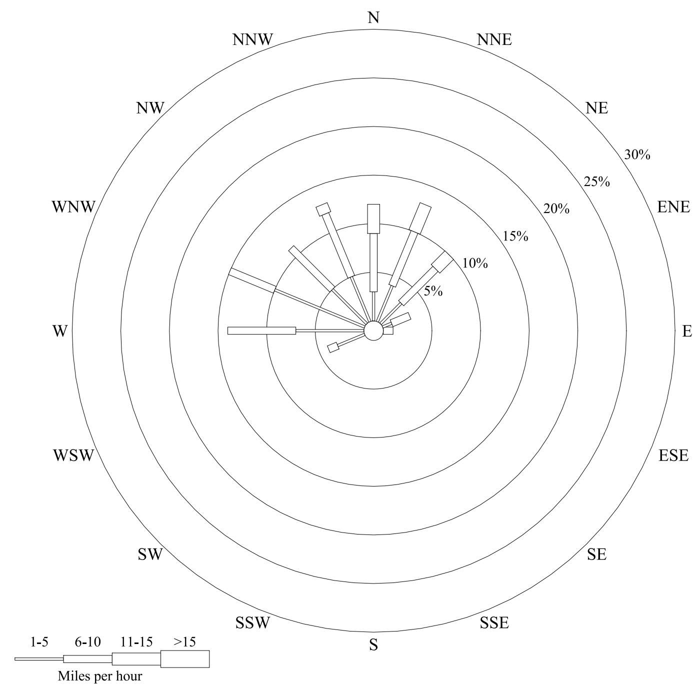
Location:	Feedyard C
Year:	2006
Station:	North TSP
Test Number:	4
Start Date:	5/15/06
Start Time:	9:33 P.M.
End Date:	5/16/06
End Time:	12:31 A.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	2.10 mi/h
Calm Winds:	46%
Comments:	



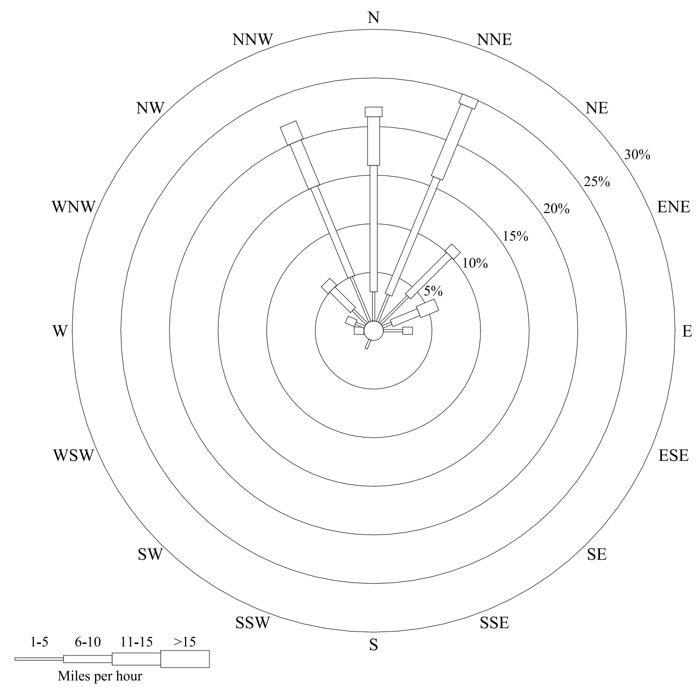
Location:	Feedyard C
Year:	2006
Station:	North TSP
Test Number:	5
Start Date:	5/16/06
Start Time:	12:35 A.M.
End Date:	5/16/06
End Time:	9:20 A.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	1.70 mi/h
Calm Winds:	58%
Comments:	



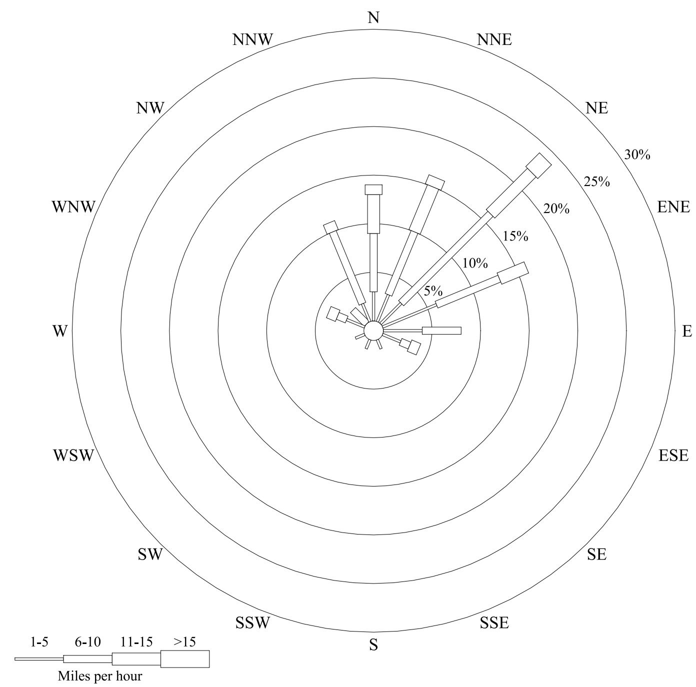
Location:	Feedyard C
Year:	2006
Station:	North TSP
Test Number:	6
Start Date:	5/16/06
Start Time:	9:23 A.M.
End Date:	5/16/06
End Time:	12:19 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	5.98 mi/h
Calm Winds:	4%
Comments:	



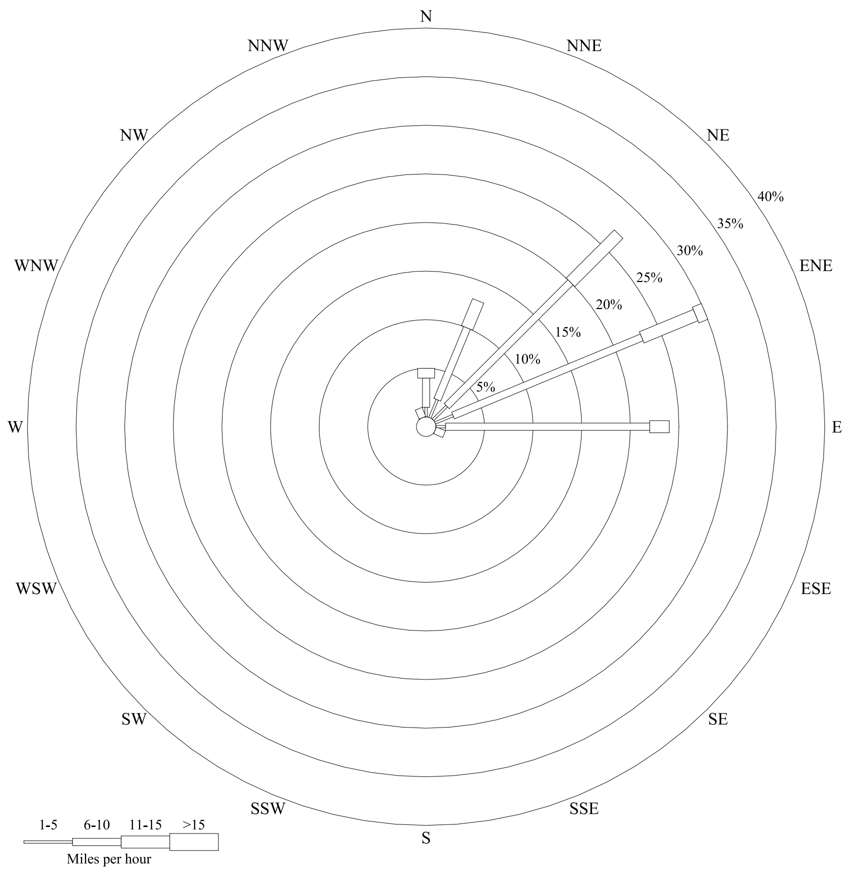
Location:	Feedyard C
Year:	2006
Station:	North TSP
Test Number:	7
Start Date:	5/16/06
Start Time:	12:22 P.M.
End Date:	5/16/06
End Time:	3:21 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	8.22 mi/h
Calm Winds:	2%
Comments:	



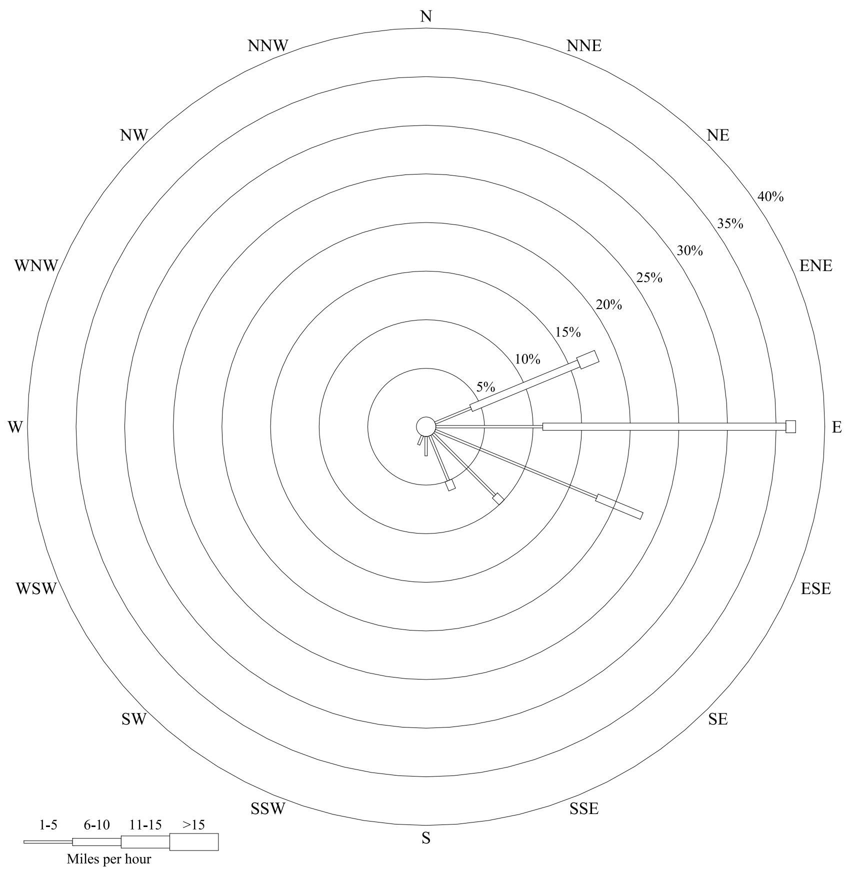
Location:	Feedyard C
Year:	2006
Station:	North TSP
Test Number:	8
Start Date:	5/16/06
Start Time:	3:23 P.M.
End Date:	5/16/06
End Time:	6:18 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	7.98 mi/h
Calm Winds:	2%
Comments:	



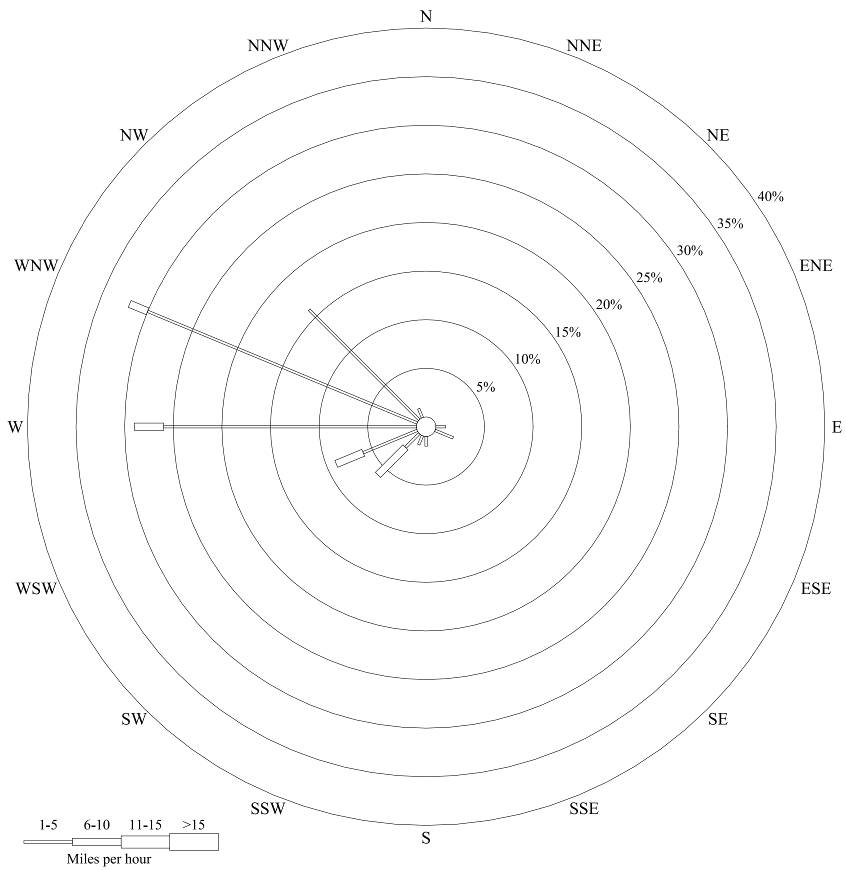
Location:	Feedyard C
Year:	2006
Station:	North TSP
Test Number:	9
Start Date:	5/16/06
Start Time:	6:22 P.M.
End Date:	5/16/06
End Time:	9:14 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	8.59 mi/h
Calm Winds:	0%
Comments:	



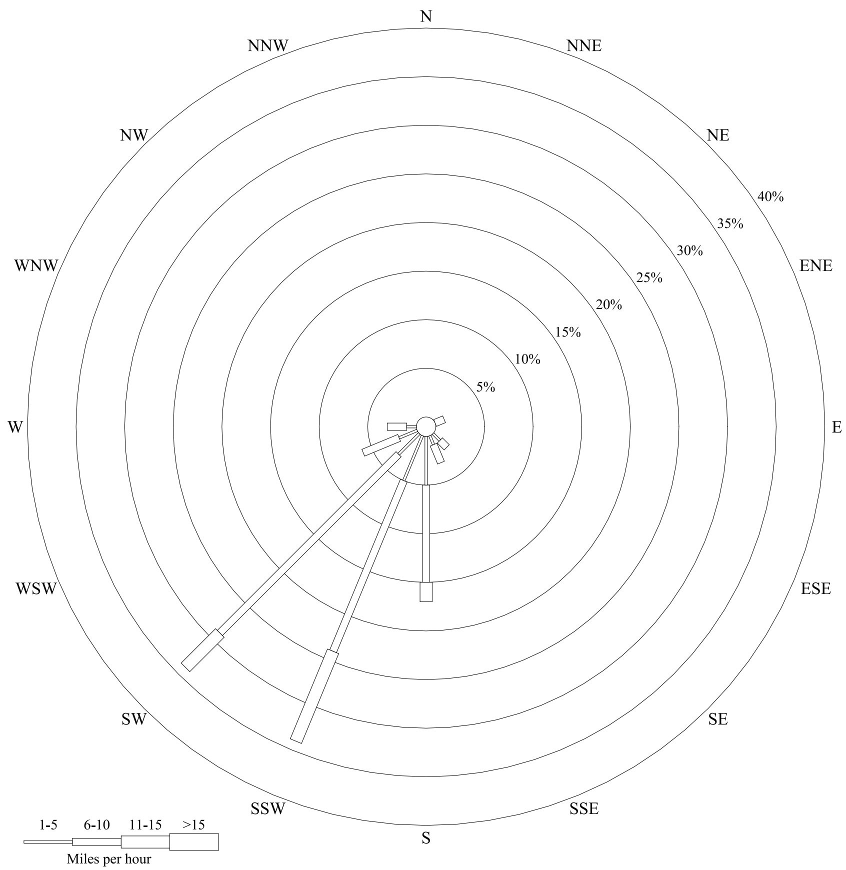
Location:	Feedyard C
Year:	2006
Station:	North TSP
Test Number:	10
Start Date:	5/16/06
Start Time:	9:17 P.M.
End Date:	5/17/06
End Time:	12:07 A.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	5.18 mi/h
Calm Winds:	4%
Comments:	



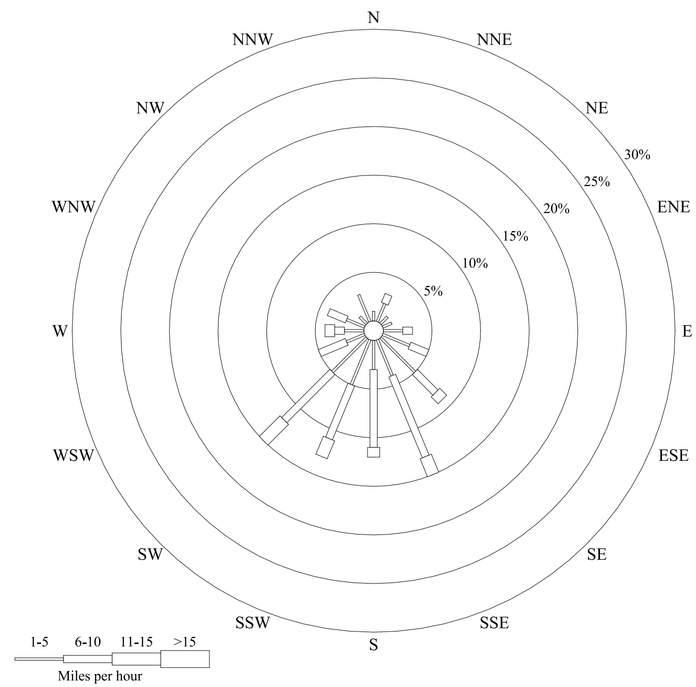
Location:	Feedyard C
Year:	2006
Station:	North TSP
Test Number:	11
Start Date:	5/17/06
Start Time:	12:11 A.M.
End Date:	5/17/06
End Time:	9:29 A.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	3.89 mi/h
Calm Winds:	1%
Comments:	



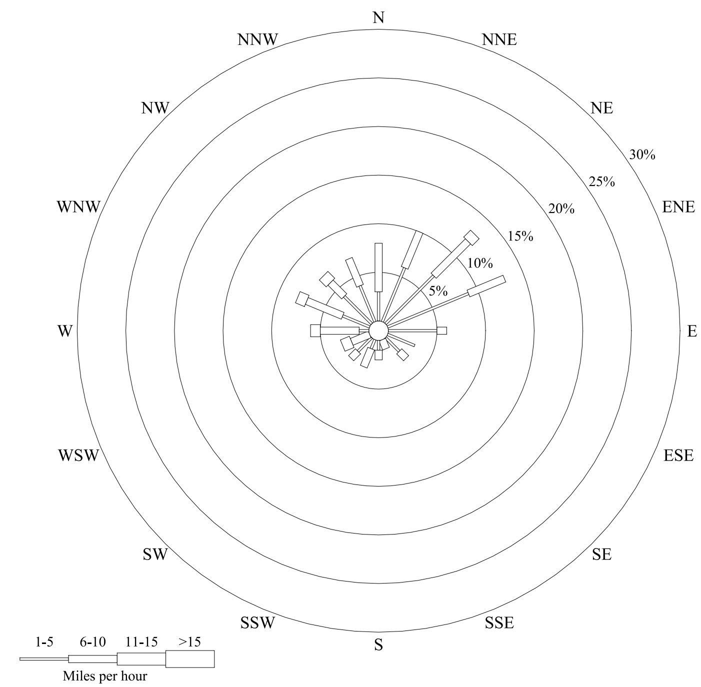
Location:	Feedyard C
Year:	2006
Station:	North TSP
Test Number:	12
Start Date:	5/17/06
Start Time:	9:32 A.M.
End Date:	5/17/06
End Time:	12:23 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	7.89 mi/h
Calm Winds:	1%
Comments:	



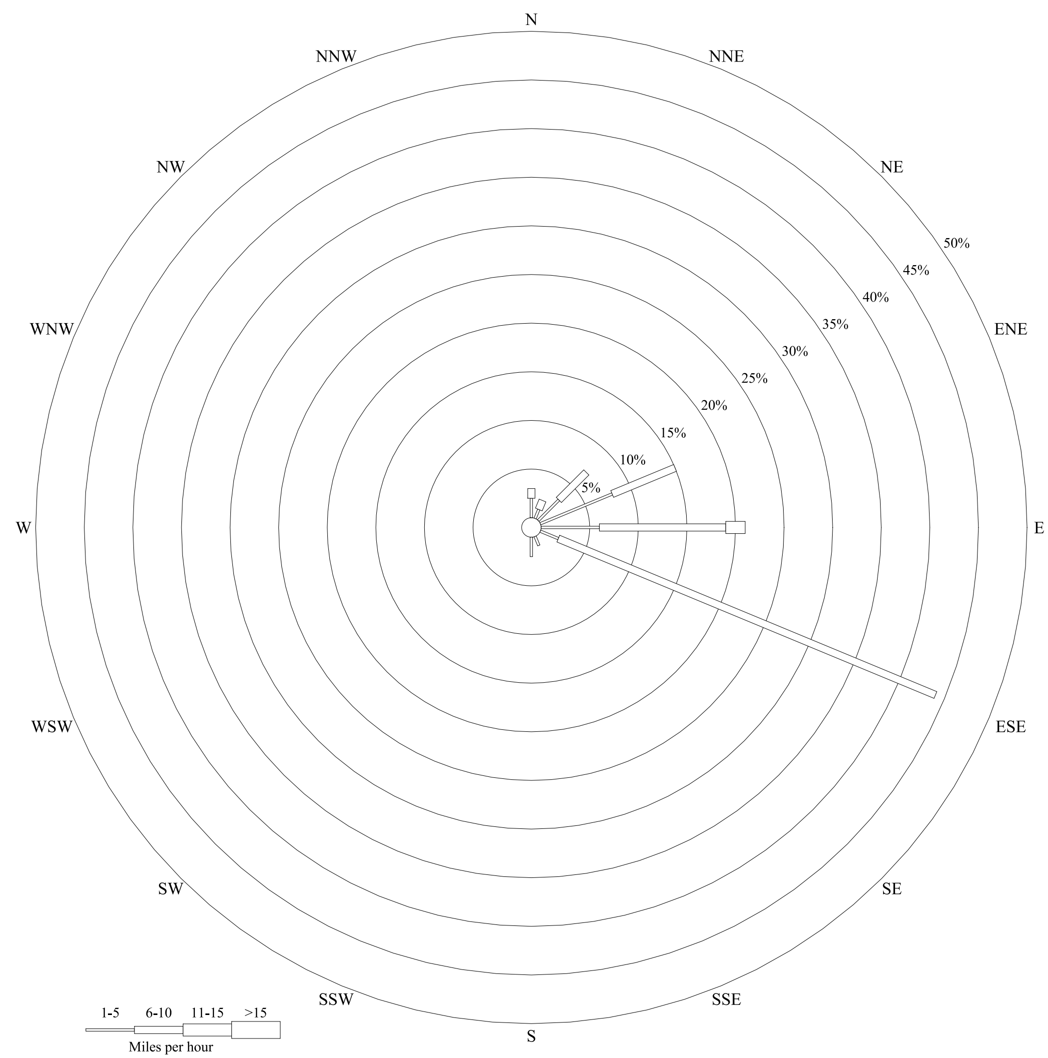
Location:	Feedyard C
Year:	2006
Station:	North TSP
Test Number:	13
Start Date:	5/17/06
Start Time:	12:25 P.M.
End Date:	5/17/06
End Time:	3:19 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	5.84 mi/h
Calm Winds:	9%
Comments:	



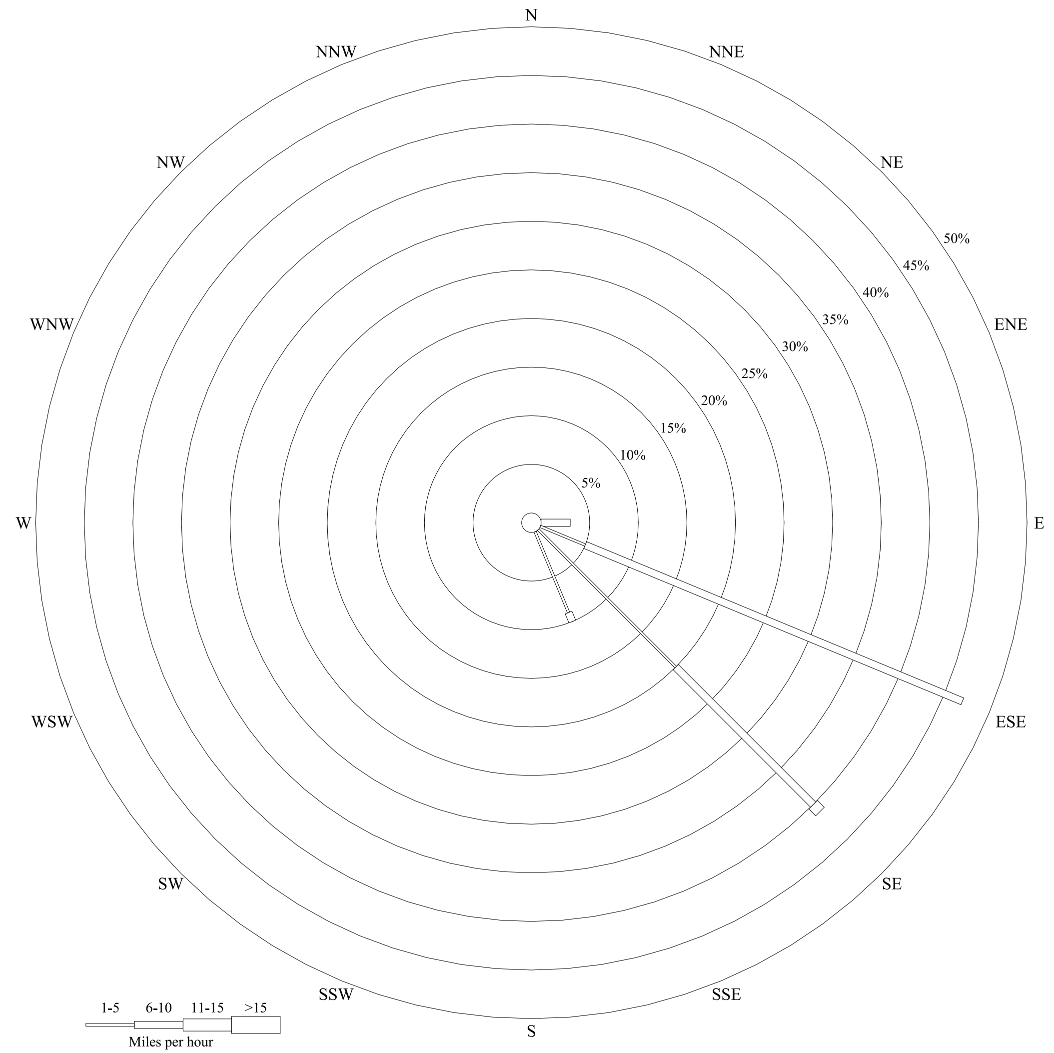
Location:	Feedyard C
Year:	2006
Station:	North TSP
Test Number:	14
Start Date:	5/17/06
Start Time:	3:20 P.M.
End Date:	5/17/06
End Time:	6:22 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	5.09 mi/h
Calm Winds:	5%
Comments:	



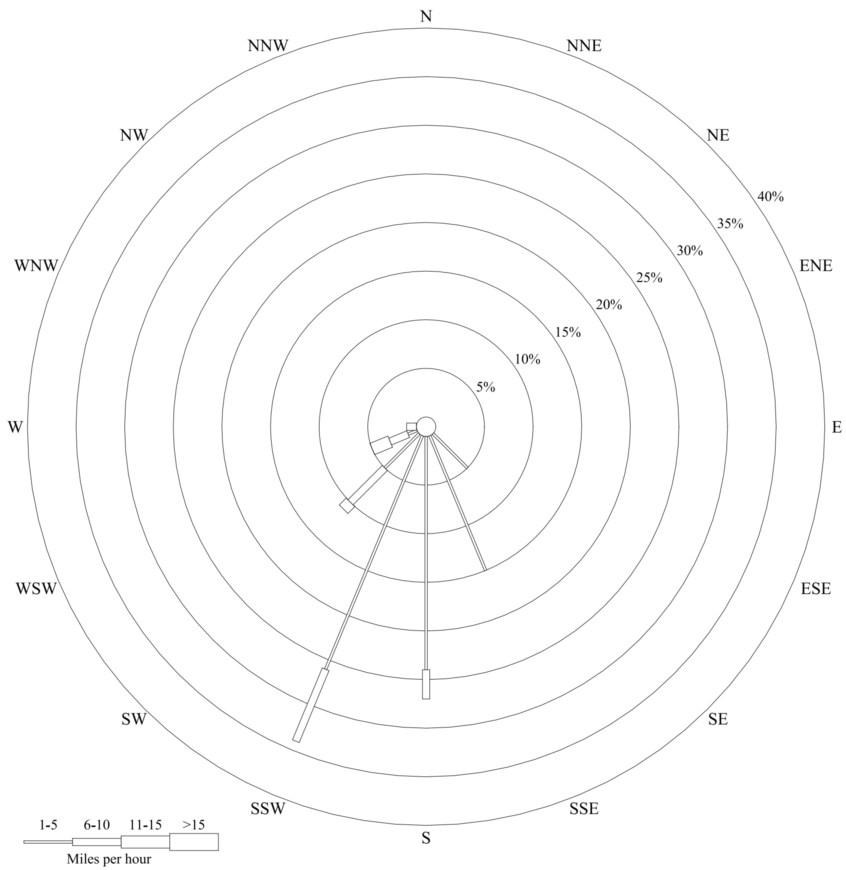
Location:	Feedyard C
Year:	2006
Station:	North TSP
Test Number:	15
Start Date:	5/17/06
Start Time:	6:25 P.M.
End Date:	5/17/06
End Time:	9:57 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	6.65 mi/h
Calm Winds:	1%
Comments:	



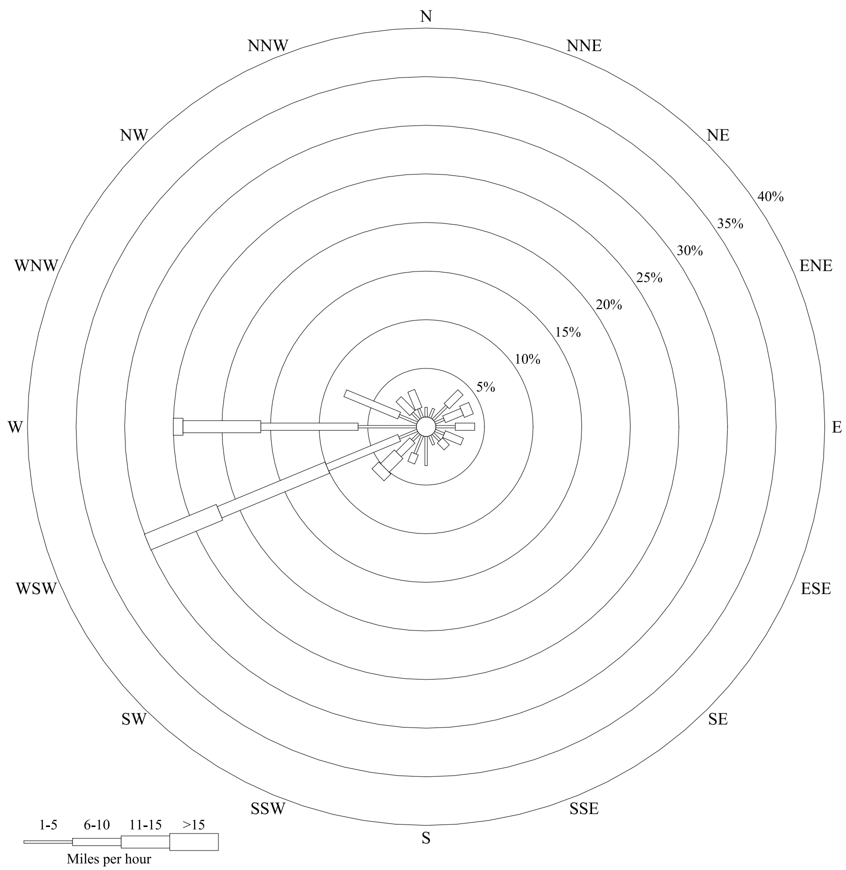
Location:	Feedyard C
Year:	2006
Station:	North TSP
Test Number:	16
Start Date:	5/17/06
Start Time:	10:00 P.M.
End Date:	5/18/06
End Time:	12:17 A.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	6.32 mi/h
Calm Winds:	0%
Comments:	



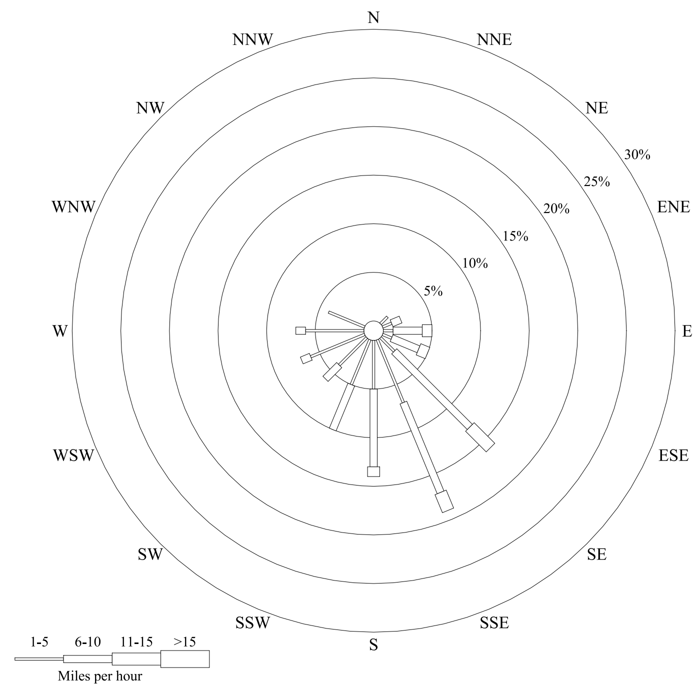
Location:	Feedyard C
Year:	2006
Station:	North TSP
Test Number:	17
Start Date:	5/18/06
Start Time:	12:19 A.M.
End Date:	5/18/06
End Time:	9:22 A.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	4.88 mi/h
Calm Winds:	1%
Comments:	



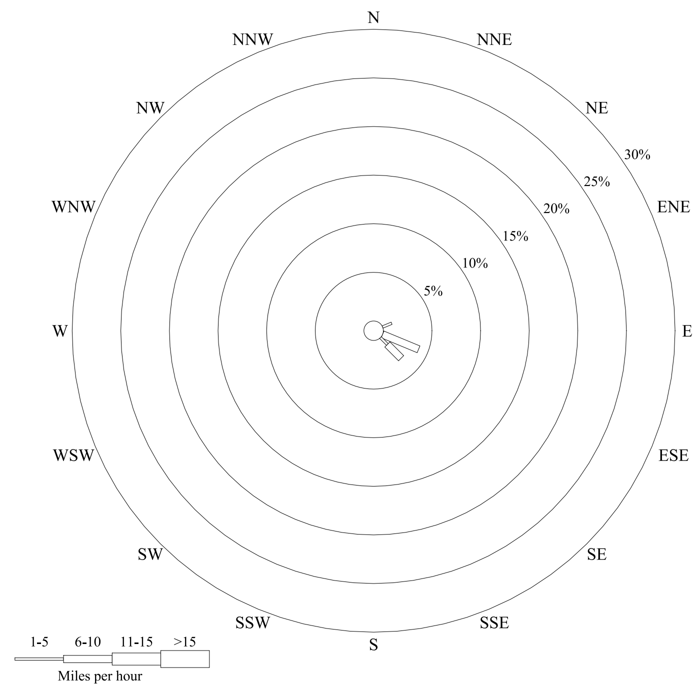
Location:	Feedyard C
Year:	2006
Station:	North TSP
Test Number:	18
Start Date:	5/18/06
Start Time:	9:24 A.M.
End Date:	5/18/06
End Time:	12:21 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	8.40 mi/h
Calm Winds:	2%
Comments:	



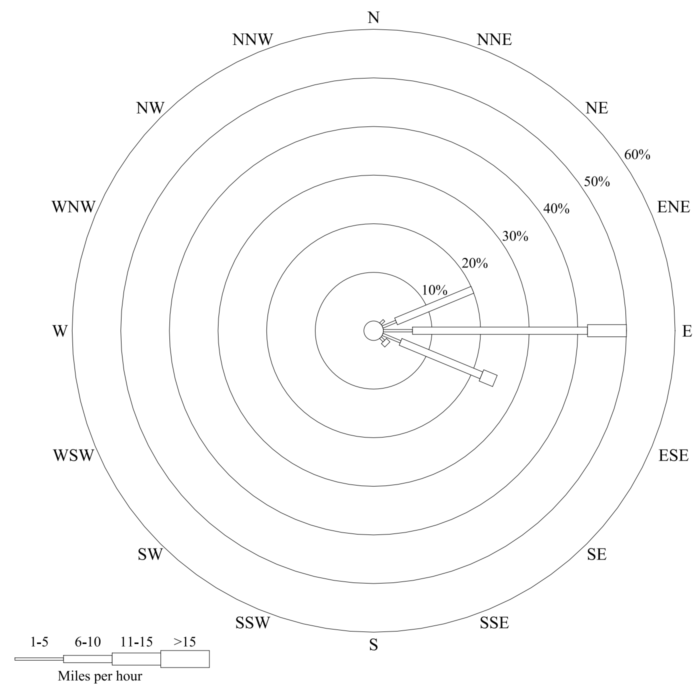
Location:	Feedyard C
Year:	2007
Station:	North TSP
Test Number:	All Tests
Start Date:	7/13/07
Start Time:	12:22 P.M.
End Date:	7/17/07
End Time:	12:28 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	6.16 mi/h
Calm Winds:	3%
Comments:	



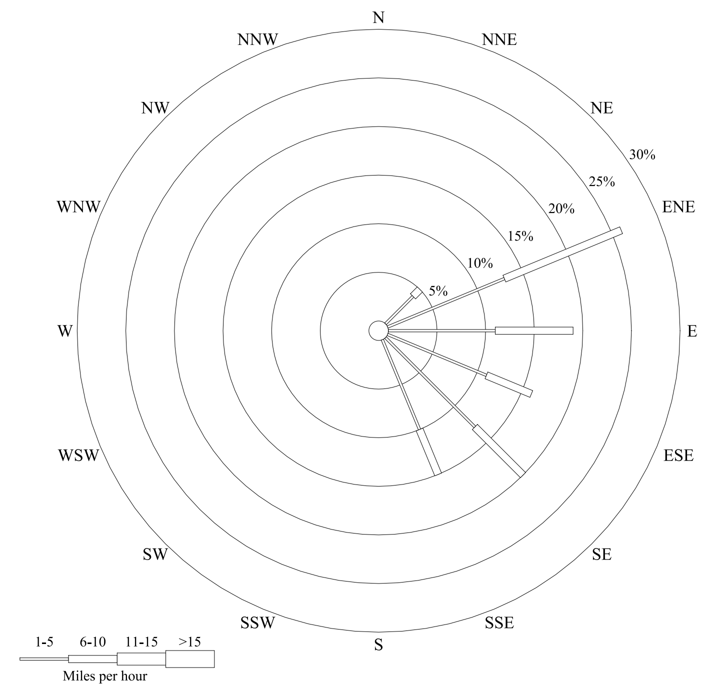
Location:	Feedyard C
Year:	2007
Station:	North TSP
Test Number:	1
Start Date:	7/13/07
Start Time:	12:22 P.M.
End Date:	7/13/07
End Time:	2:58 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	0.52 mi/h
Calm Winds:	94%
Comments:	



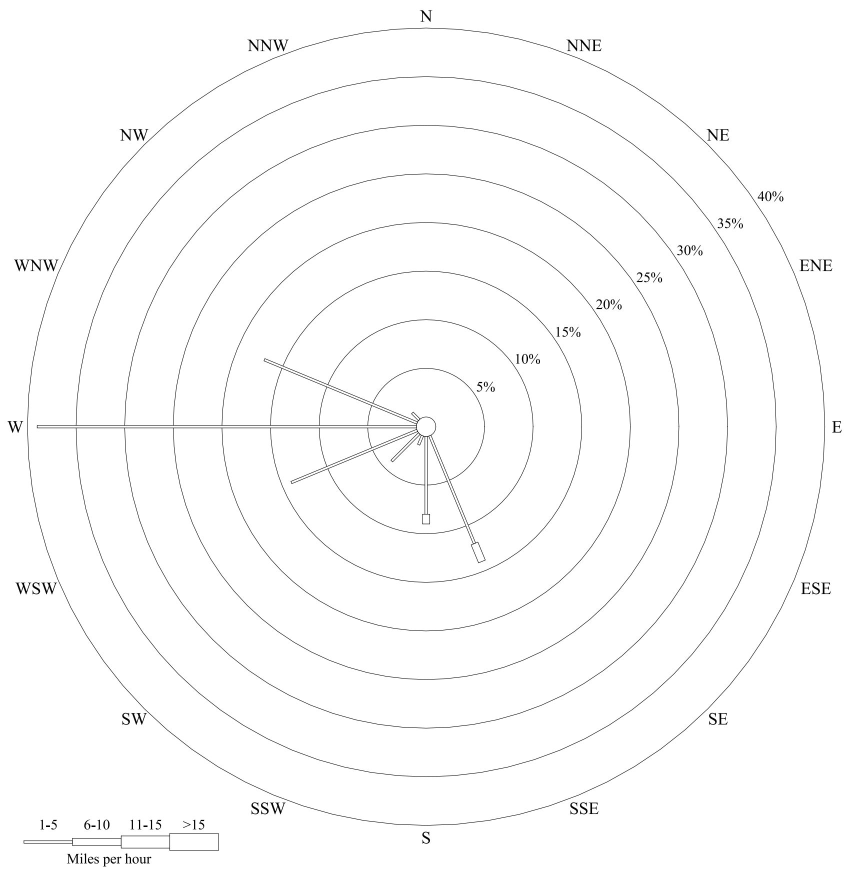
Location:	Feedyard C
Year:	2007
Station:	North TSP
Test Number:	2
Start Date:	7/13/07
Start Time:	3:02 P.M.
End Date:	7/13/07
End Time:	6:28 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	7.97 mi/h
Calm Winds:	0%
Comments:	



Location:	Feedyard C
Year:	2007
Station:	North TSP
Test Number:	3
Start Date:	7/13/07
Start Time:	6:32 P.M.
End Date:	7/13/07
End Time:	9:19 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	5.26 mi/h
Calm Winds:	0%
Comments:	

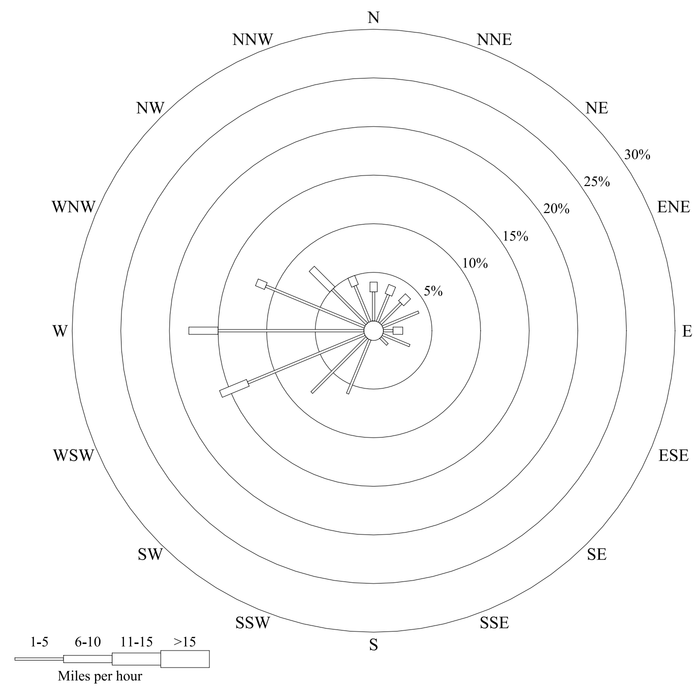


Location:	Feedyard C
Year:	2007
Station:	North TSP
Test Number:	4
Start Date:	7/13/07
Start Time:	9:23 P.M.
End Date:	7/14/07
End Time:	6:38 A.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	3.74 mi/h
Calm Winds:	0%
Comments:	

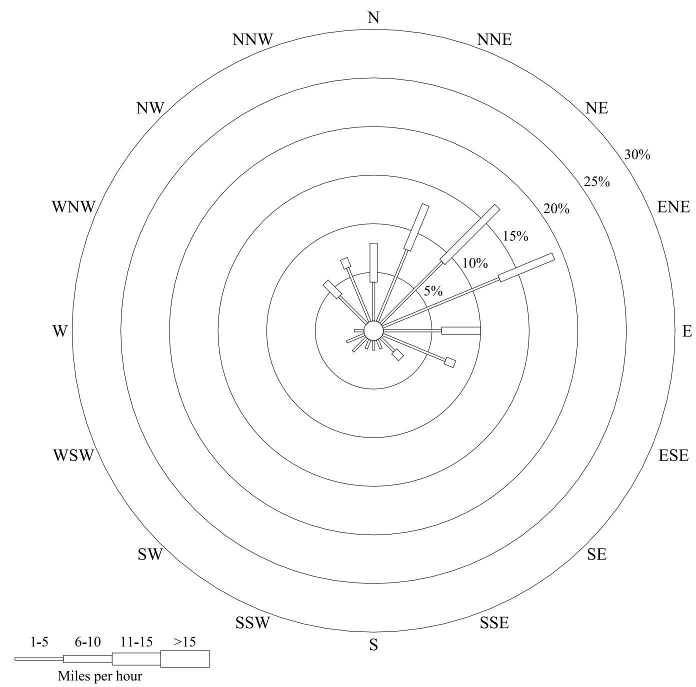


Location:	Feedyard C
Year:	2007
Station:	North TSP
Test Number:	5
Start Date:	7/14/07
Start Time:	6:41 A.M.
End Date:	7/14/07
End Time:	9:29 A.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	4.58 mi/h
Calm Winds:	0%
Comments:	

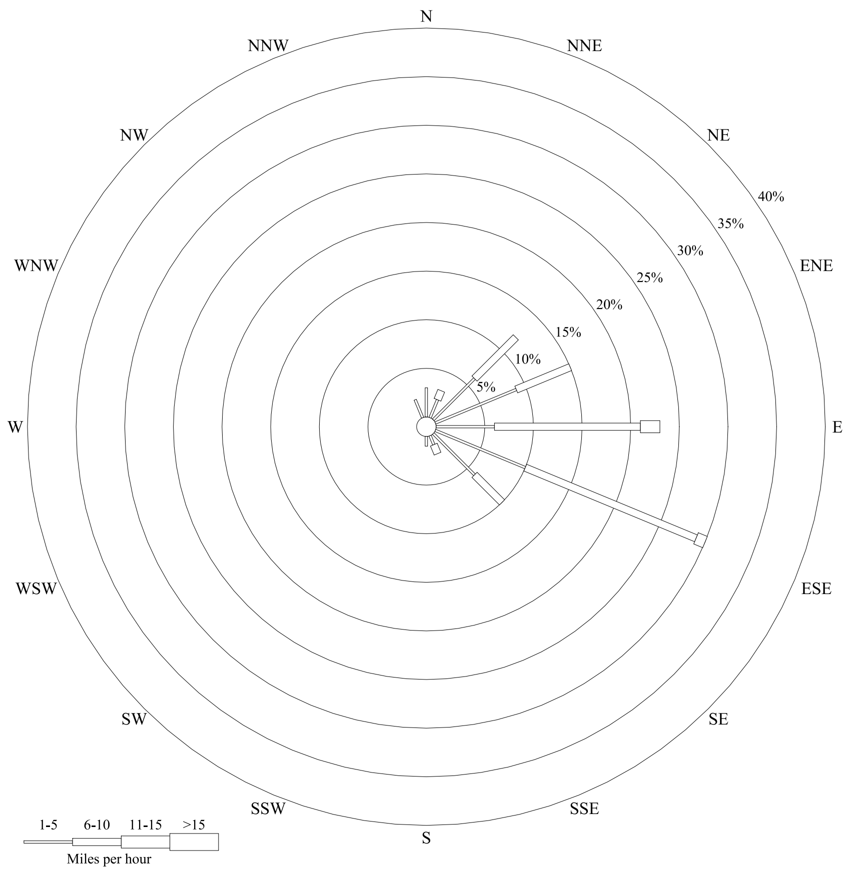
Location:	Feedyard C
Year:	2007
Station:	North TSP
Test Number:	6
Start Date:	7/14/07
Start Time:	9:37 A.M.
End Date:	7/14/07
End Time:	12:11 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	3.71 mi/h
Calm Winds:	9%
Comments:	



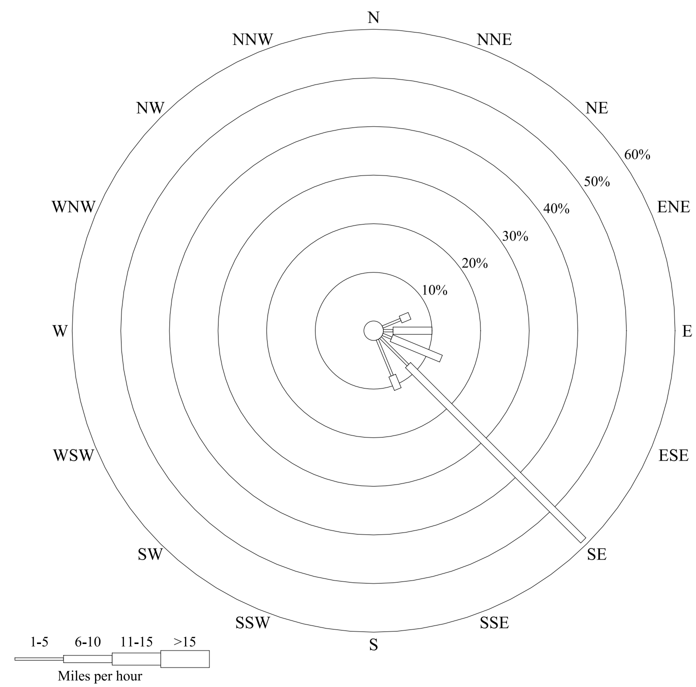
Location:	Feedyard C
Year:	2007
Station:	North TSP
Test Number:	7
Start Date:	7/14/07
Start Time:	12:16 P.M.
End Date:	7/14/07
End Time:	3:19 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	4.56 mi/h
Calm Winds:	5%
Comments:	



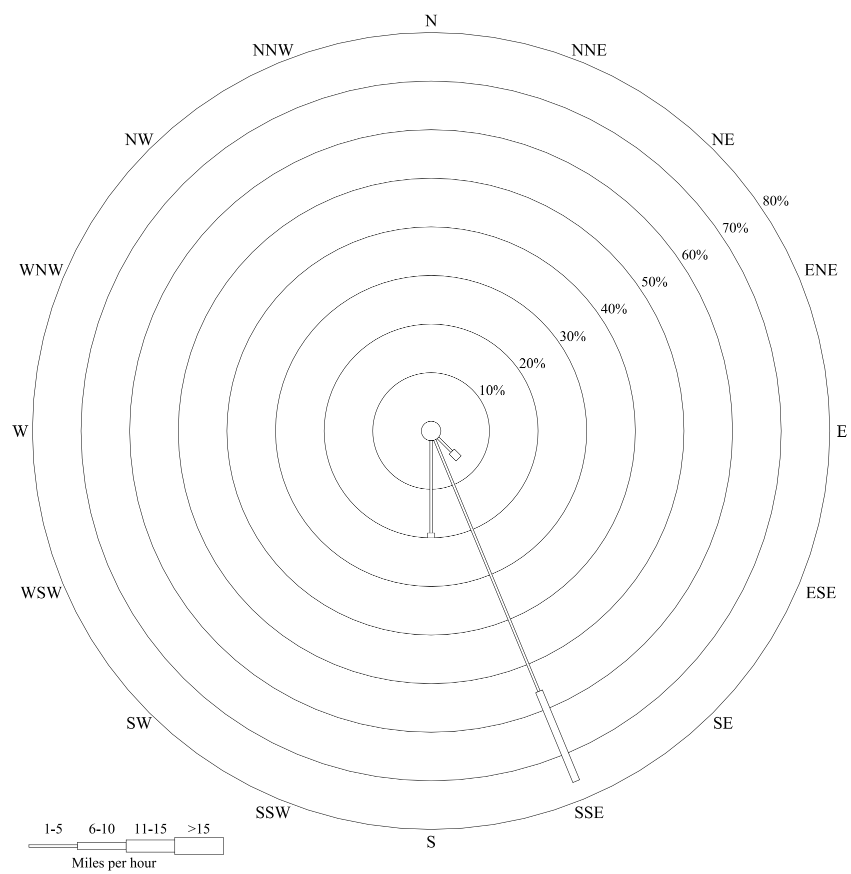
Location:	Feedyard C
Year:	2007
Station:	North TSP
Test Number:	8
Start Date:	7/14/07
Start Time:	3:23 P.M.
End Date:	7/14/07
End Time:	6:16 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	6.10 mi/h
Calm Winds:	0%
Comments:	



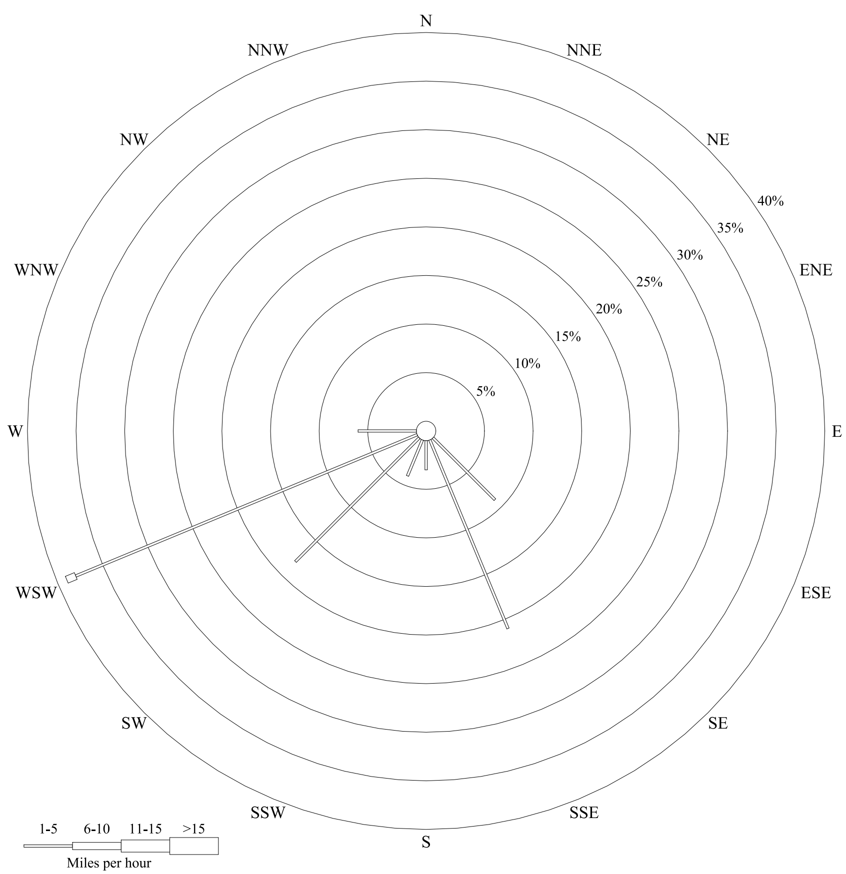
Location:	Feedyard C
Year:	2007
Station:	North TSP
Test Number:	9
Start Date:	7/14/07
Start Time:	6:19 P.M.
End Date:	7/14/07
End Time:	9:04 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	6.44 mi/h
Calm Winds:	0%
Comments:	



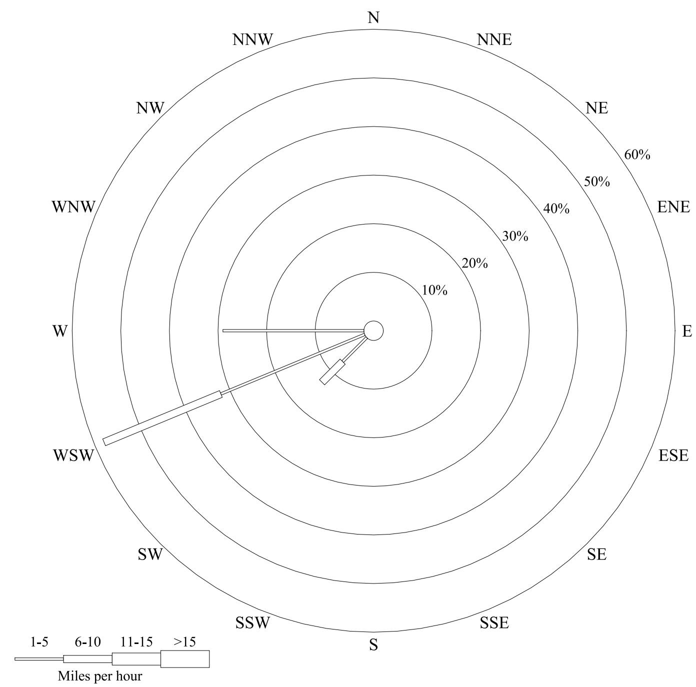
Location:	Feedyard C
Year:	2007
Station:	North TSP
Test Number:	10
Start Date:	7/14/07
Start Time:	9:09 P.M.
End Date:	7/15/07
End Time:	12:17 A.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	5.05 mi/h
Calm Winds:	0%
Comments:	



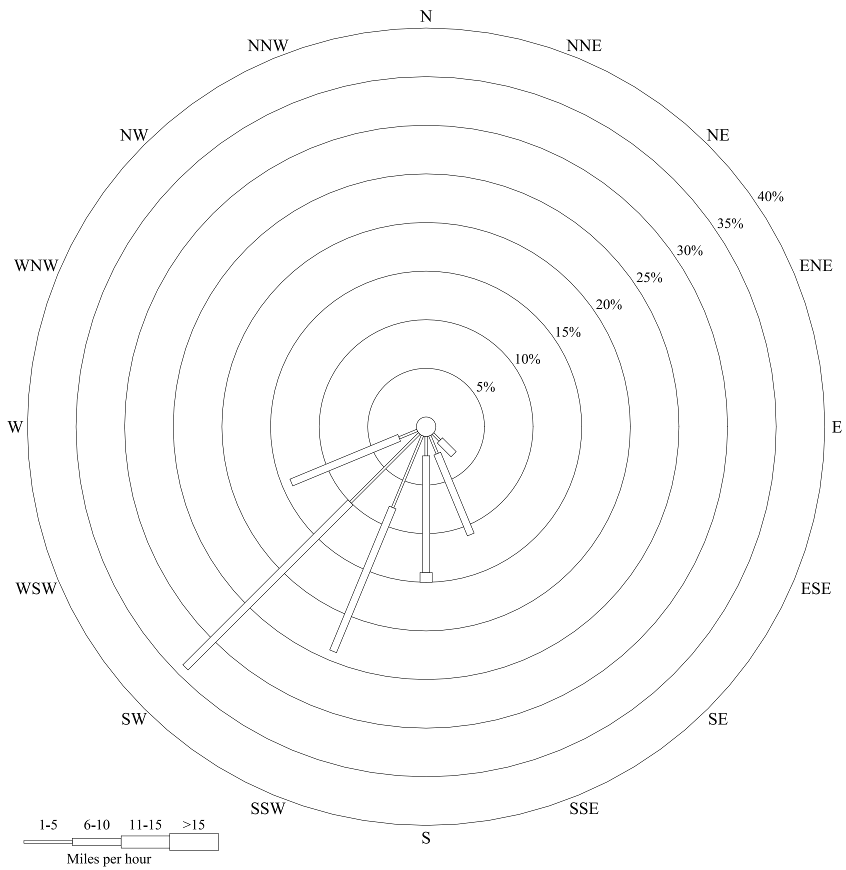
Location:	Feedyard C
Year:	2007
Station:	North TSP
Test Number:	11
Start Date:	7/15/07
Start Time:	12:21 A.M.
End Date:	7/15/07
End Time:	6:11 A.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	3.56 mi/h
Calm Winds:	0%
Comments:	



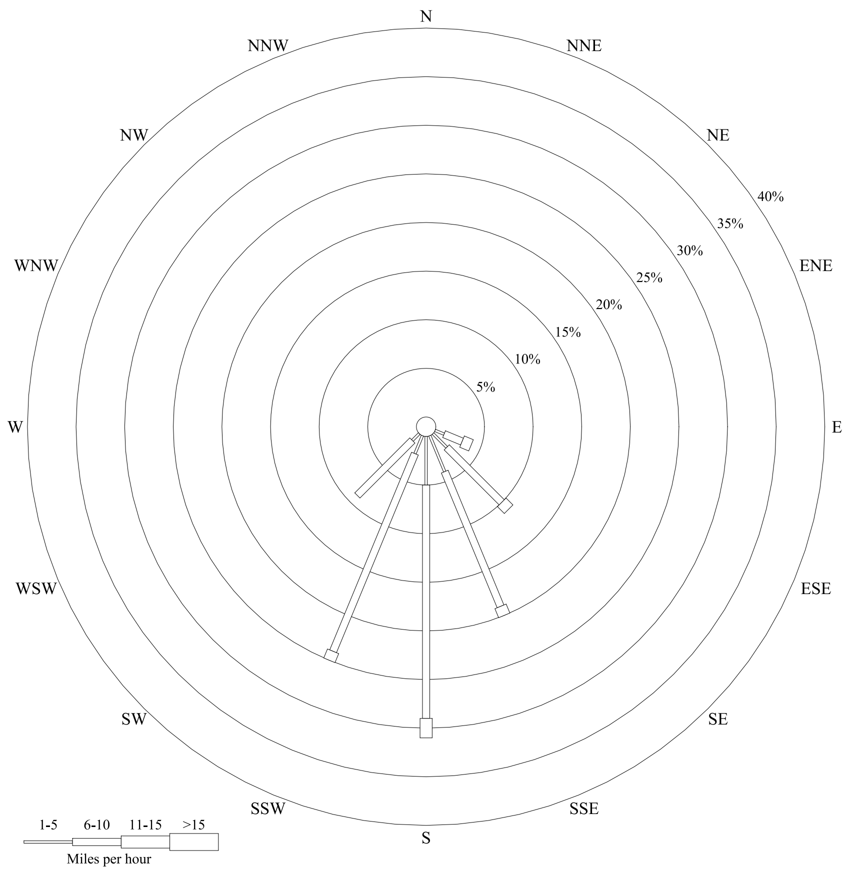
Location:	Feedyard C
Year:	2007
Station:	North TSP
Test Number:	12
Start Date:	7/15/07
Start Time:	6:17 A.M.
End Date:	7/15/07
End Time:	9:14 A.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	5.09 mi/h
Calm Winds:	0%
Comments:	



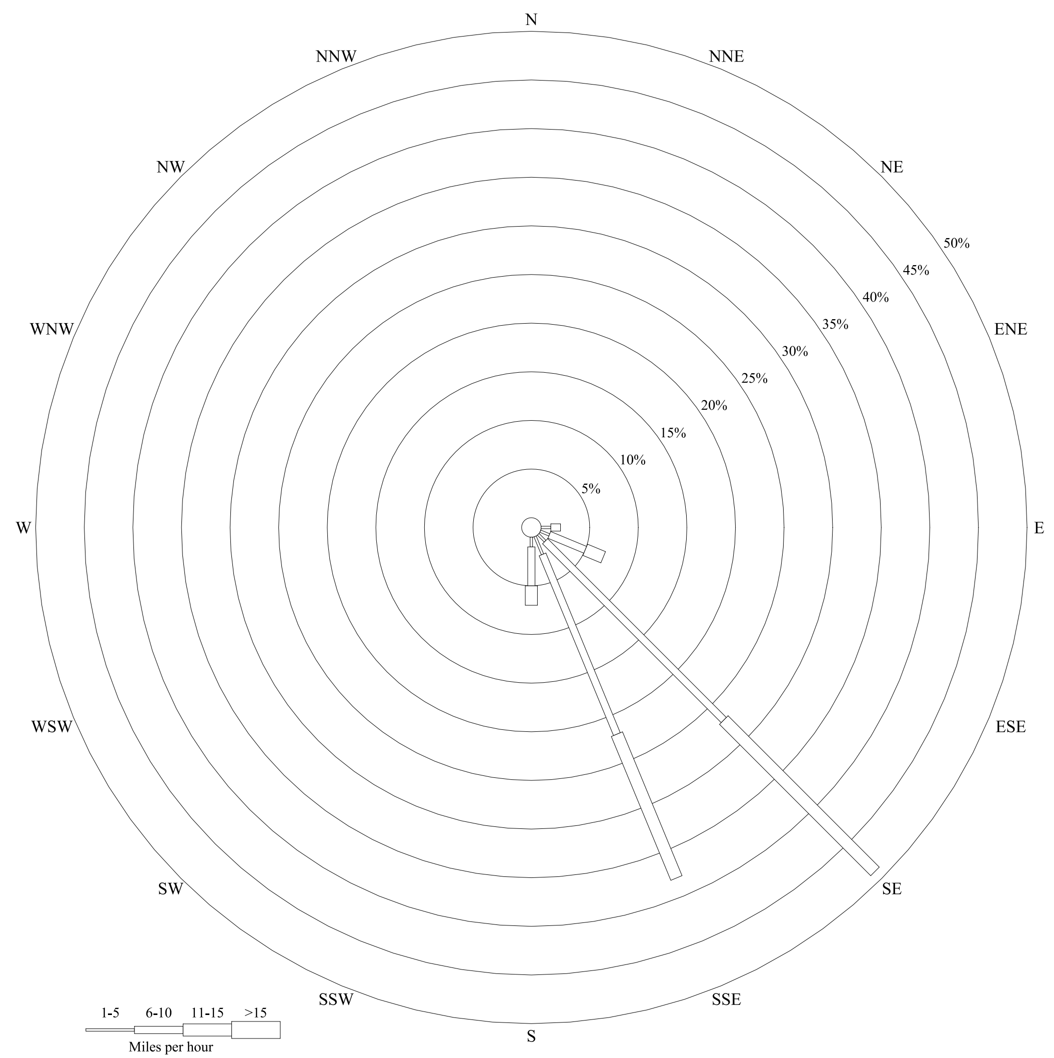
Location:	Feedyard C
Year:	2007
Station:	North TSP
Test Number:	13
Start Date:	7/15/07
Start Time:	9:17 A.M.
End Date:	7/15/07
End Time:	12:06 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	6.48 mi/h
Calm Winds:	0%
Comments:	



Location:	Feedyard C
Year:	2007
Station:	North TSP
Test Number:	14
Start Date:	7/15/07
Start Time:	12:09 P.M.
End Date:	7/15/07
End Time:	3:00 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	7.62 mi/h
Calm Winds:	0%
Comments:	

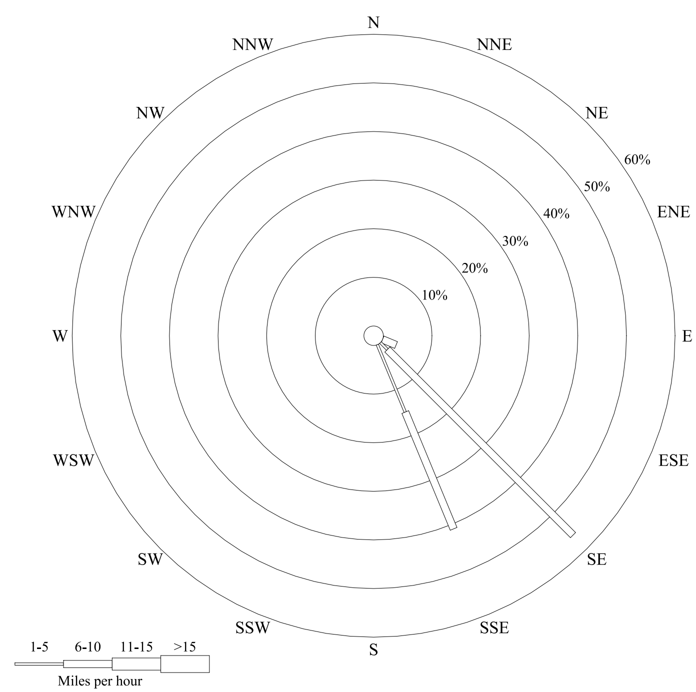


Location:	Feedyard C
Year:	2007
Station:	North TSP
Test Number:	15
Start Date:	7/15/07
Start Time:	3:04 P.M.
End Date:	7/15/07
End Time:	6:20 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	9.69 mi/h
Calm Winds:	0%
Comments:	

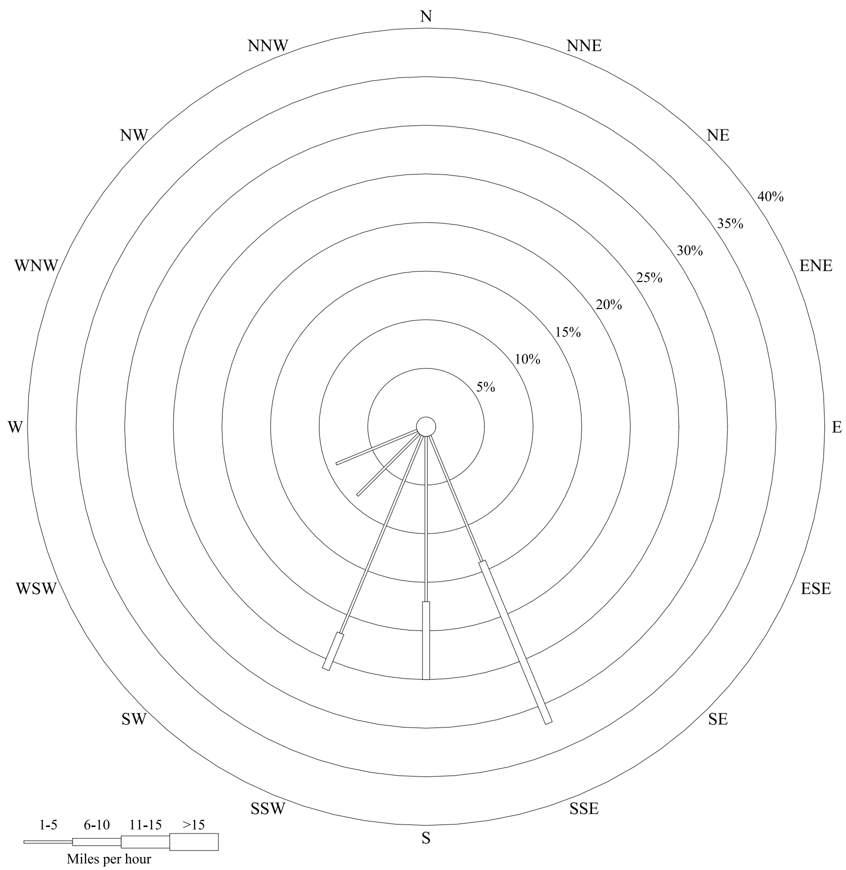


Location:	Feedyard C
Year:	2007
Station:	North TSP
Test Number:	16
Start Date:	7/15/07
Start Time:	6:23 P.M.
End Date:	7/15/07
End Time:	9:01 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	10.96 mi/h
Calm Winds:	0%
Comments:	

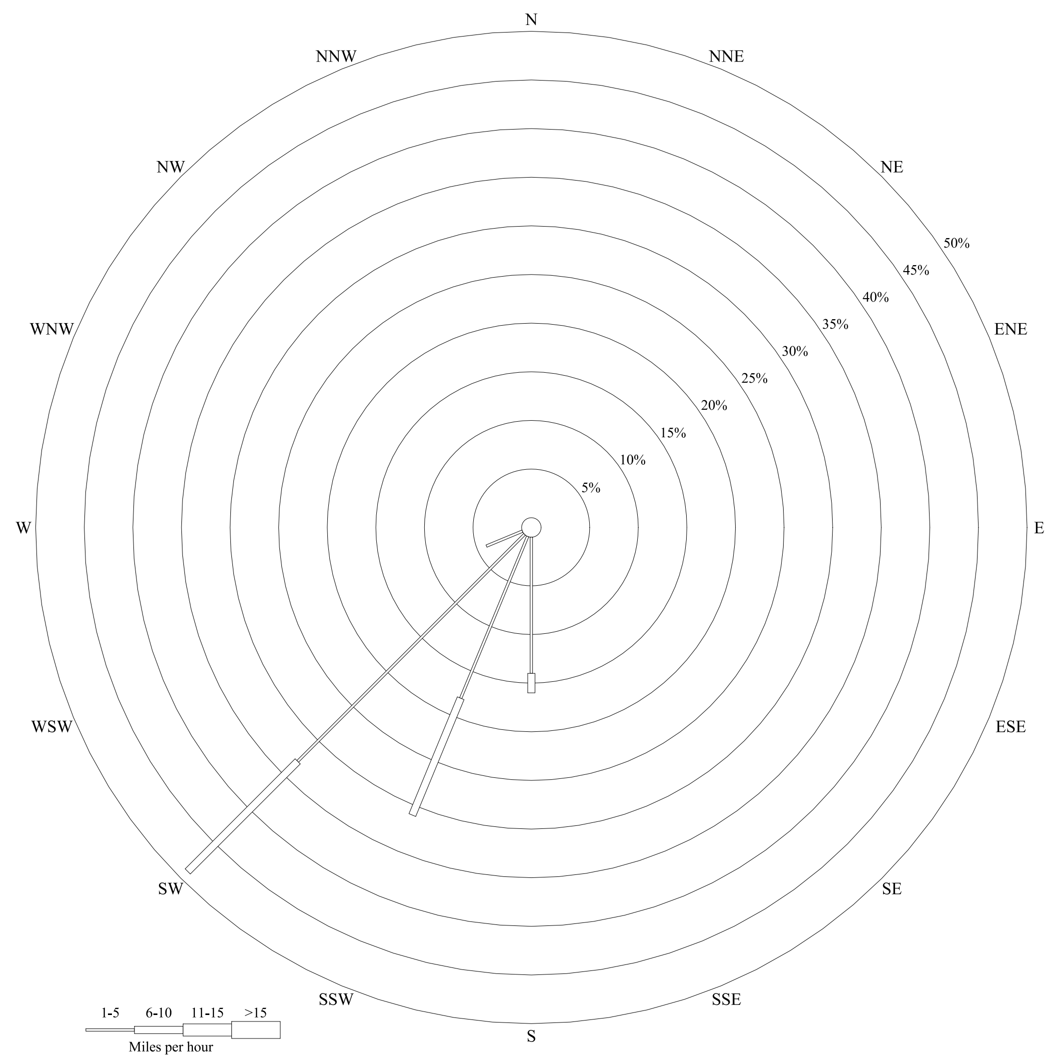
Location:	Feedyard C
Year:	2007
Station:	North TSP
Test Number:	17
Start Date:	7/15/07
Start Time:	9:05 P.M.
End Date:	7/16/07
End Time:	12:13 A.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	6.81 mi/h
Calm Winds:	0%
Comments:	



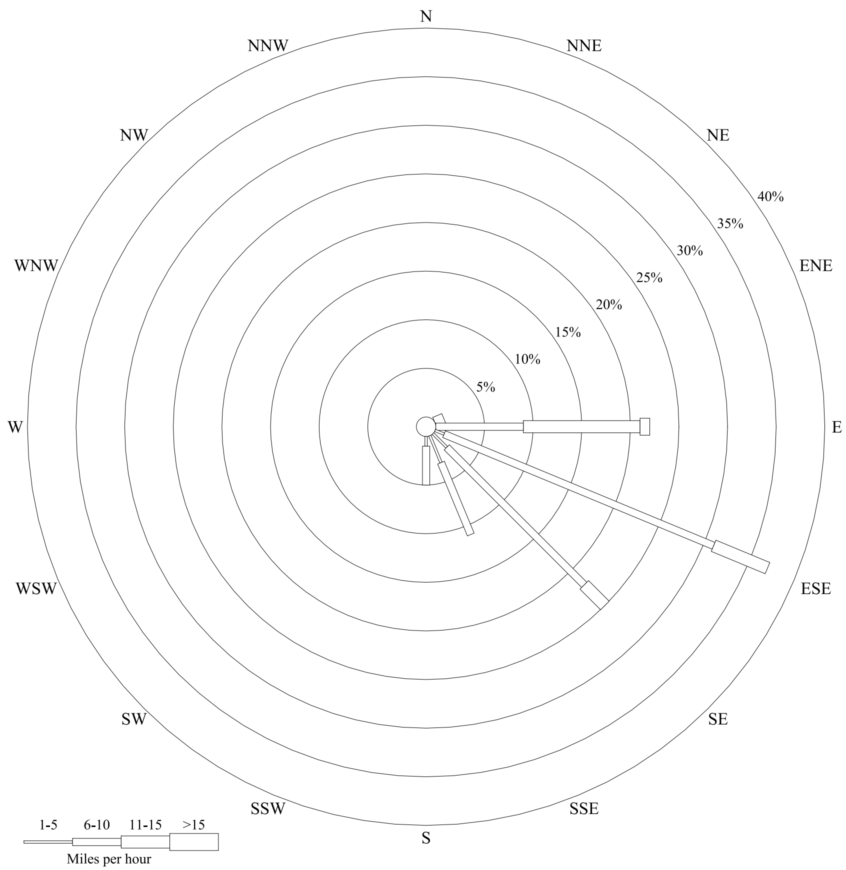
Location:	Feedyard C
Year:	2007
Station:	North TSP
Test Number:	18
Start Date:	7/16/07
Start Time:	12:16 A.M.
End Date:	7/16/07
End Time:	6:26 A.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	4.93 mi/h
Calm Winds:	0%
Comments:	



Location:	Feedyard C
Year:	2007
Station:	North TSP
Test Number:	19
Start Date:	7/16/07
Start Time:	6:30 A.M.
End Date:	7/16/07
End Time:	9:31 A.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	5.28 mi/h
Calm Winds:	0%
Comments:	

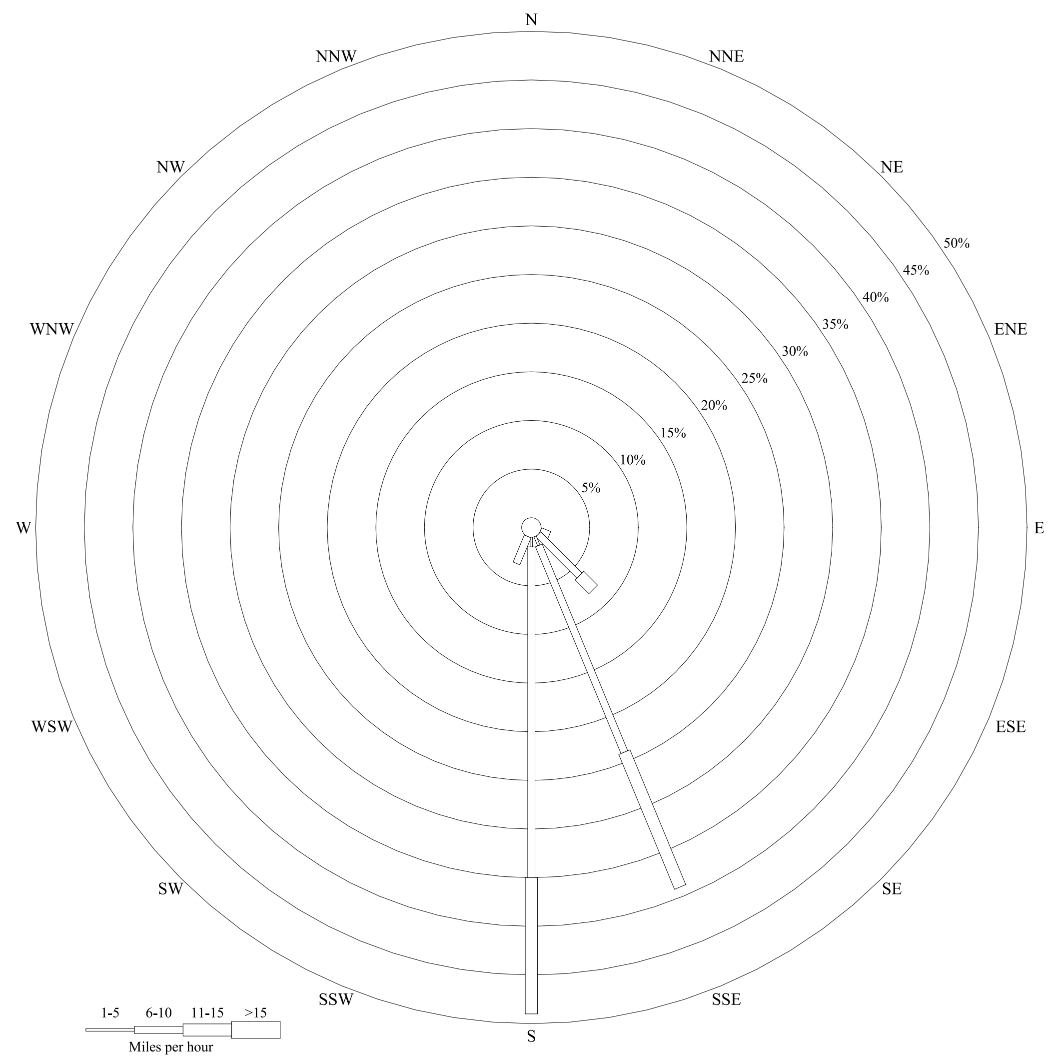


Location:	Feedyard C
Year:	2007
Station:	North TSP
Test Number:	20
Start Date:	7/16/07
Start Time:	9:34 A.M.
End Date:	7/16/07
End Time:	12:13 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	8.86 mi/h
Calm Winds:	0%
Comments:	

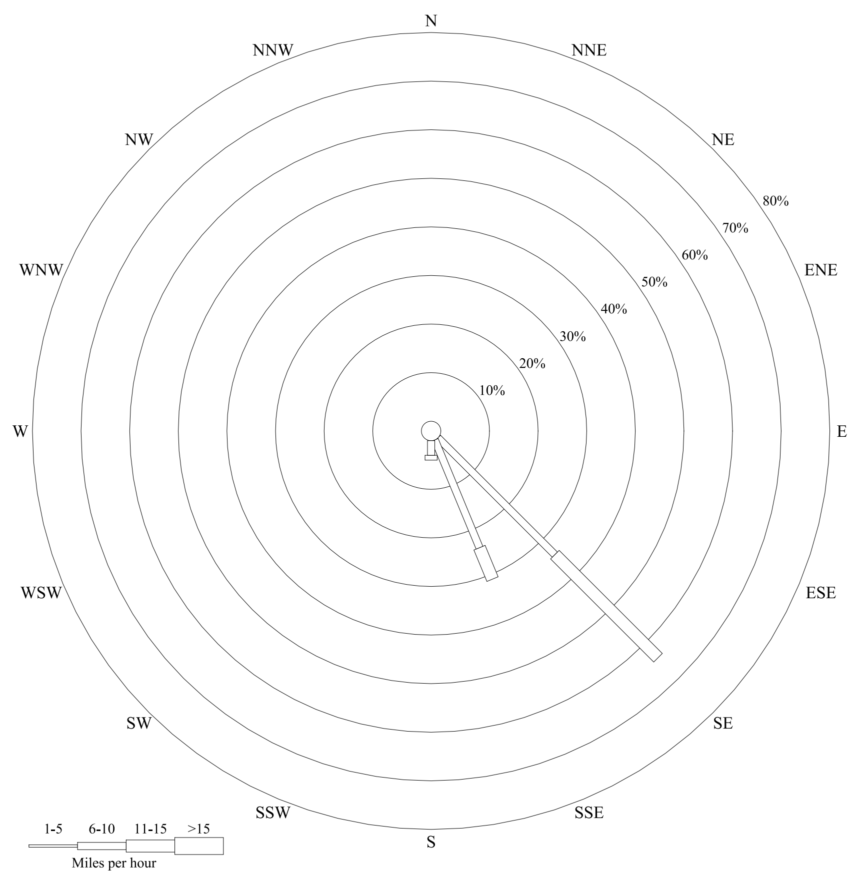


Location:	Feedyard C
Year:	2007
Station:	North TSP
Test Number:	21
Start Date:	7/16/07
Start Time:	12:16 P.M.
End Date:	7/16/07
End Time:	3:17 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	8.99 mi/h
Calm Winds:	0%
Comments:	

Location:	Feedyard C
Year:	2007
Station:	North TSP
Test Number:	22
Start Date:	7/16/07
Start Time:	3:20 P.M.
End Date:	7/16/07
End Time:	6:15 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	9.52 mi/h
Calm Winds:	0%
Comments:	

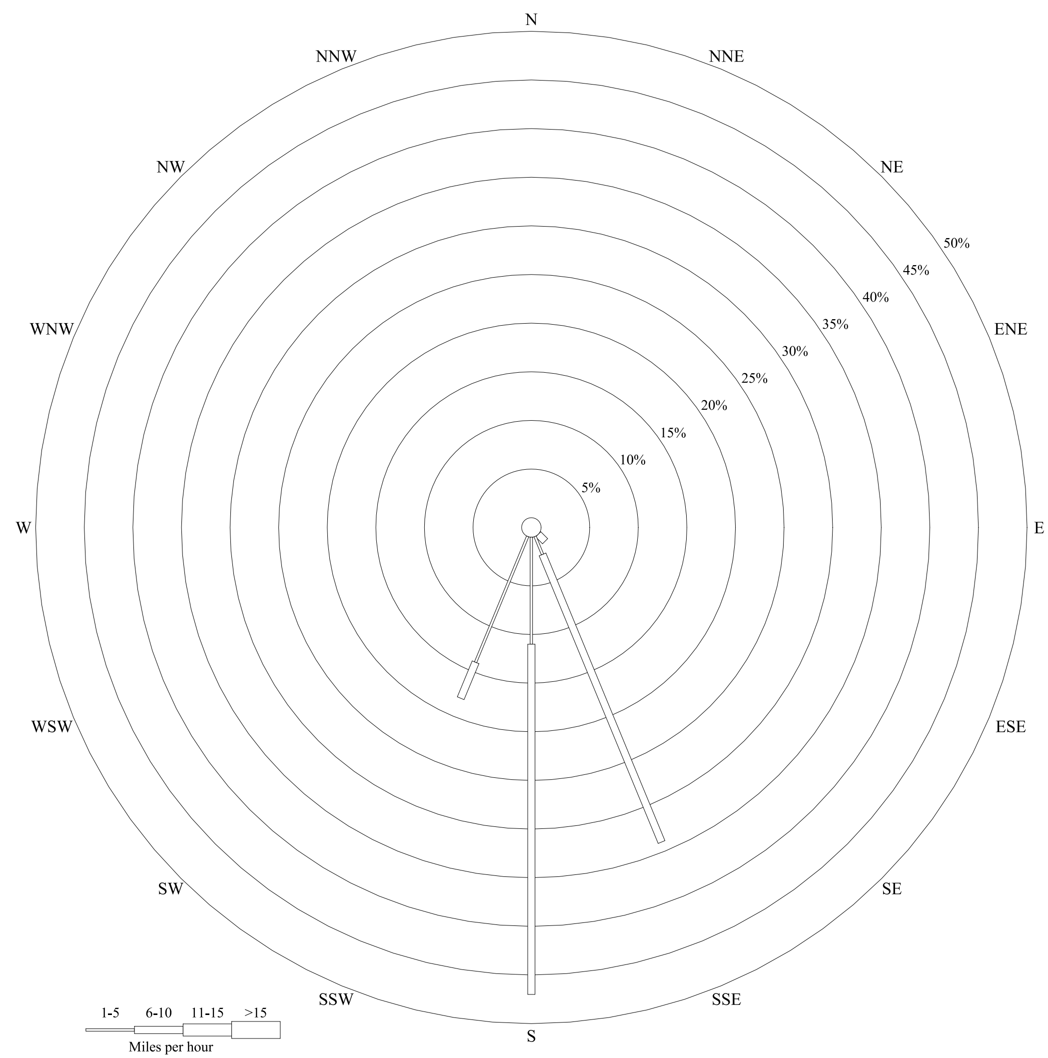


Location:	Feedyard C
Year:	2007
Station:	North TSP
Test Number:	23
Start Date:	7/16/07
Start Time:	6:18 P.M.
End Date:	7/16/07
End Time:	9:11 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	10.21 mi/h
Calm Winds:	0%
Comments:	

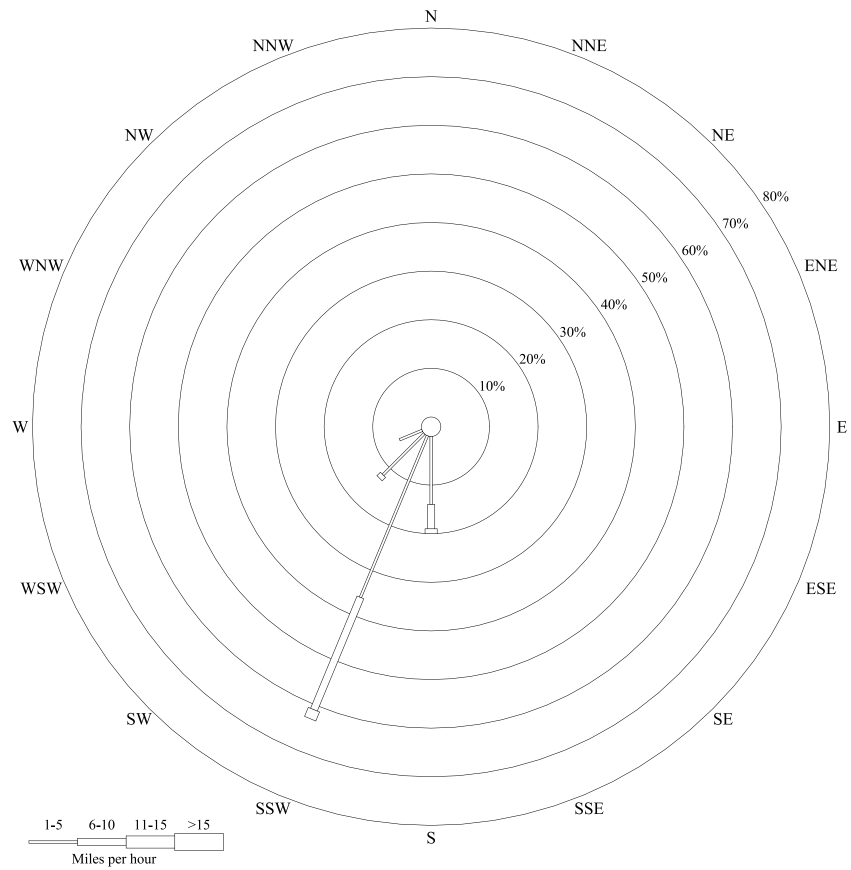


Location:	Feedyard C
Year:	2007
Station:	North TSP
Test Number:	24
Start Date:	7/16/07
Start Time:	9:14 P.M.
End Date:	7/17/07
End Time:	12:12 A.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	8.00 mi/h
Calm Winds:	0%
Comments:	

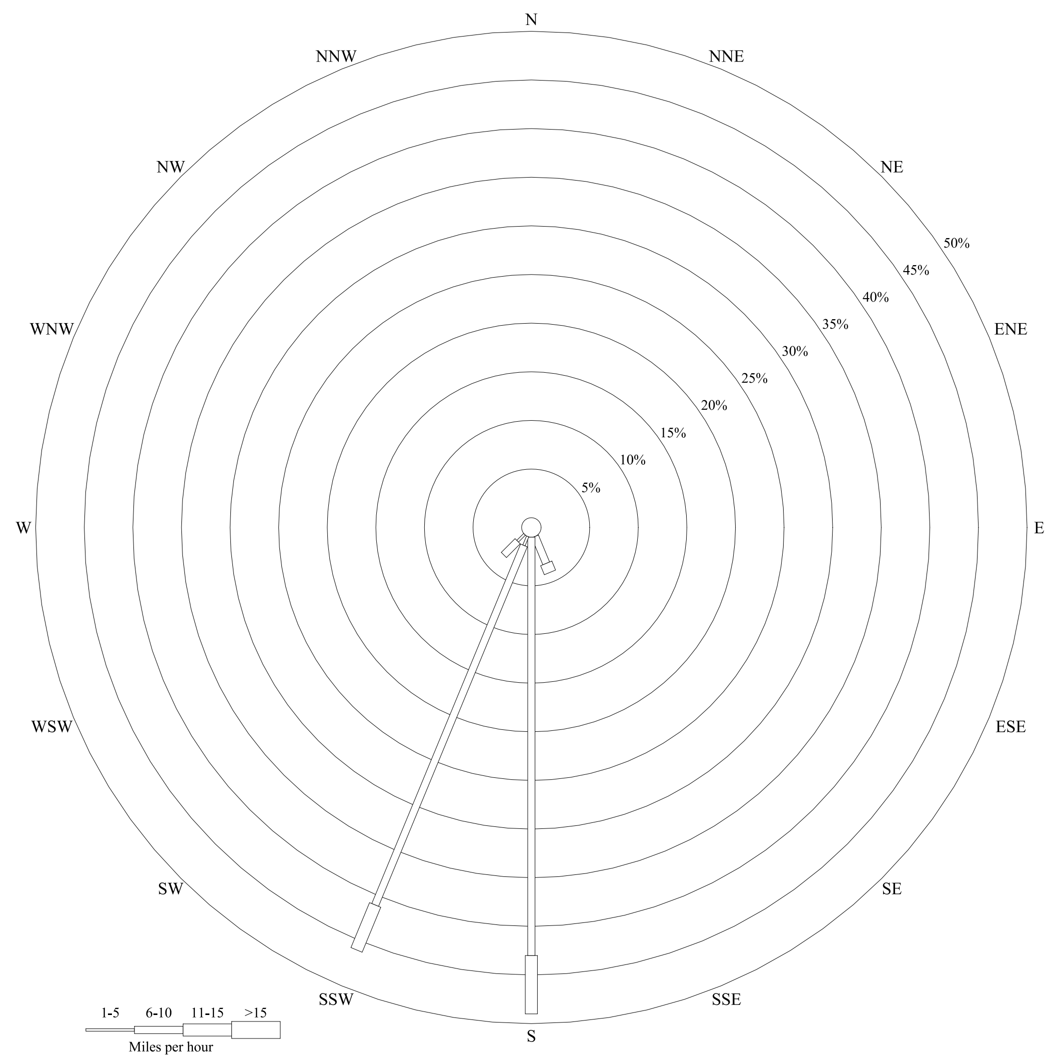
Location:	Feedyard C
Year:	2007
Station:	North TSP
Test Number:	25
Start Date:	7/17/07
Start Time:	12:16 A.M.
End Date:	7/17/07
End Time:	6:26 A.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	6.07 mi/h
Calm Winds:	0%
Comments:	



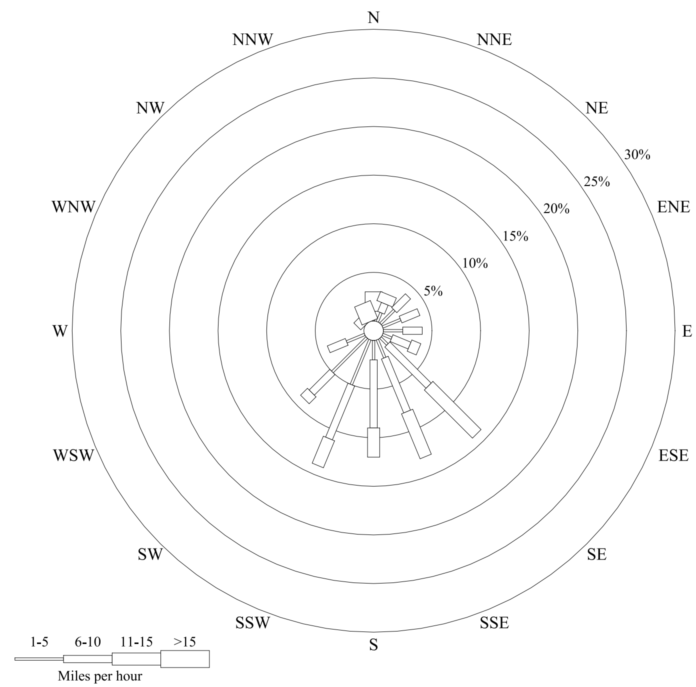
Location:	Feedyard C
Year:	2007
Station:	North TSP
Test Number:	26
Start Date:	7/17/07
Start Time:	6:30 A.M.
End Date:	7/17/07
End Time:	9:12 A.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	4.97 mi/h
Calm Winds:	0%
Comments:	



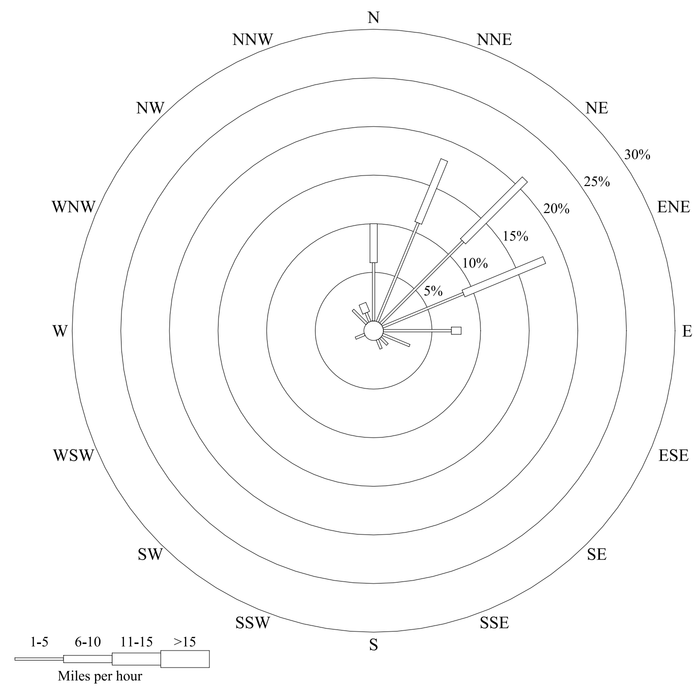
Location:	Feedyard C
Year:	2007
Station:	North TSP
Test Number:	27
Start Date:	7/17/07
Start Time:	9:20 A.M.
End Date:	7/17/07
End Time:	12:28 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	9.17 mi/h
Calm Winds:	0%
Comments:	



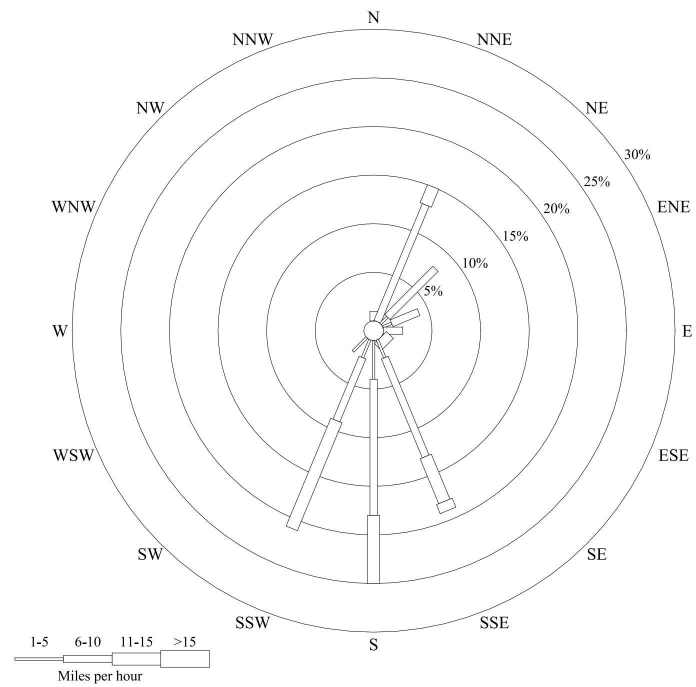
Location:	Feedyard E
Year:	2007
Station:	South TSP
Test Number:	All Tests
Start Date:	7/9/07
Start Time:	12:41 P.M.
End Date:	7/12/07
End Time:	3:18 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	8.47 mi/h
Calm Winds:	2%
Comments:	



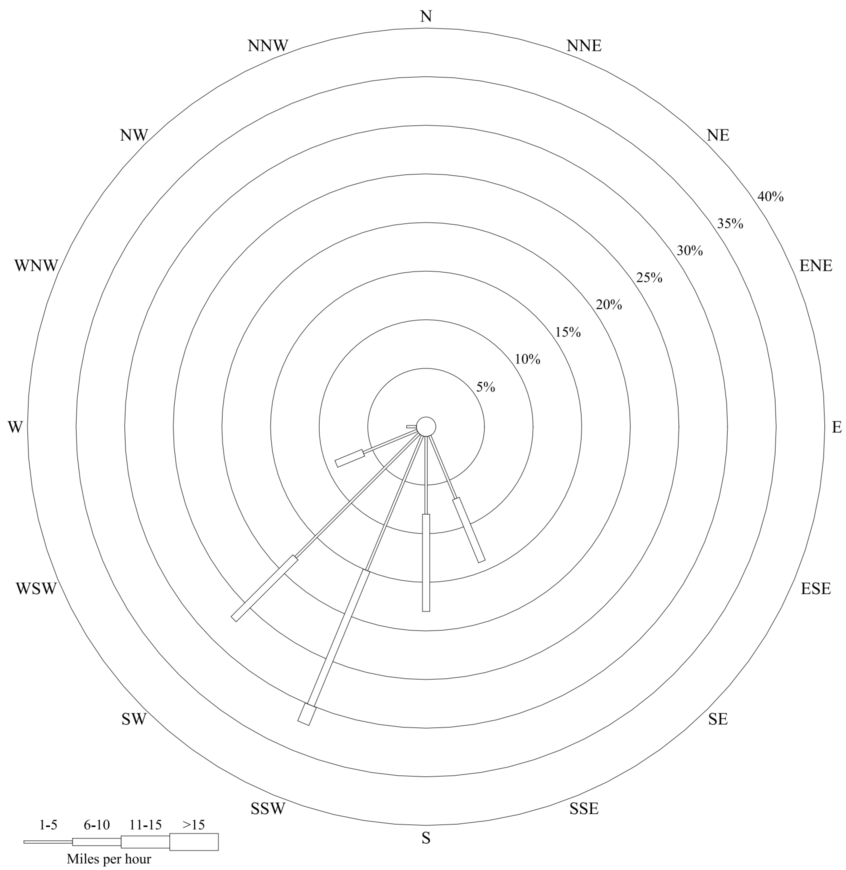
Location: Feedyard E	
Year: 2007	
Station: South TSP	
Test Number: 1	
Start Date: 7/9/07	
Start Time: 12:41 P.M.	
End Date: 7/9/07	
End Time: 5:10 P.M.	
Display: Wind Speed	
Unit: mi/h	
Orientation: Direction (blowing from)	
Avg. Wind Speed: 4.26 mi/h	
Calm Winds: 13%	
Comments:	



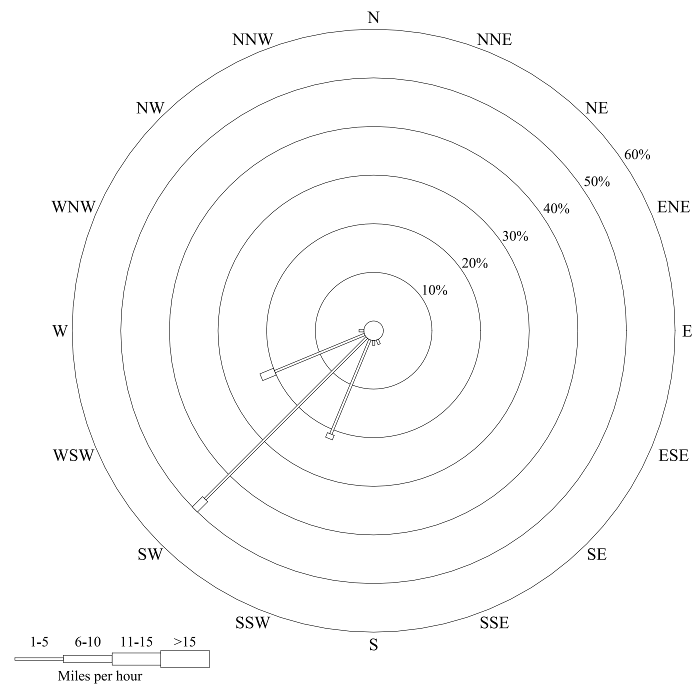
Location:	Feedyard E
Year:	2007
Station:	South TSP
Test Number:	2
Start Date:	7/9/07
Start Time:	5:13 P.M.
End Date:	7/9/07
End Time:	9:17 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	8.80 mi/h
Calm Winds:	0%
Comments:	



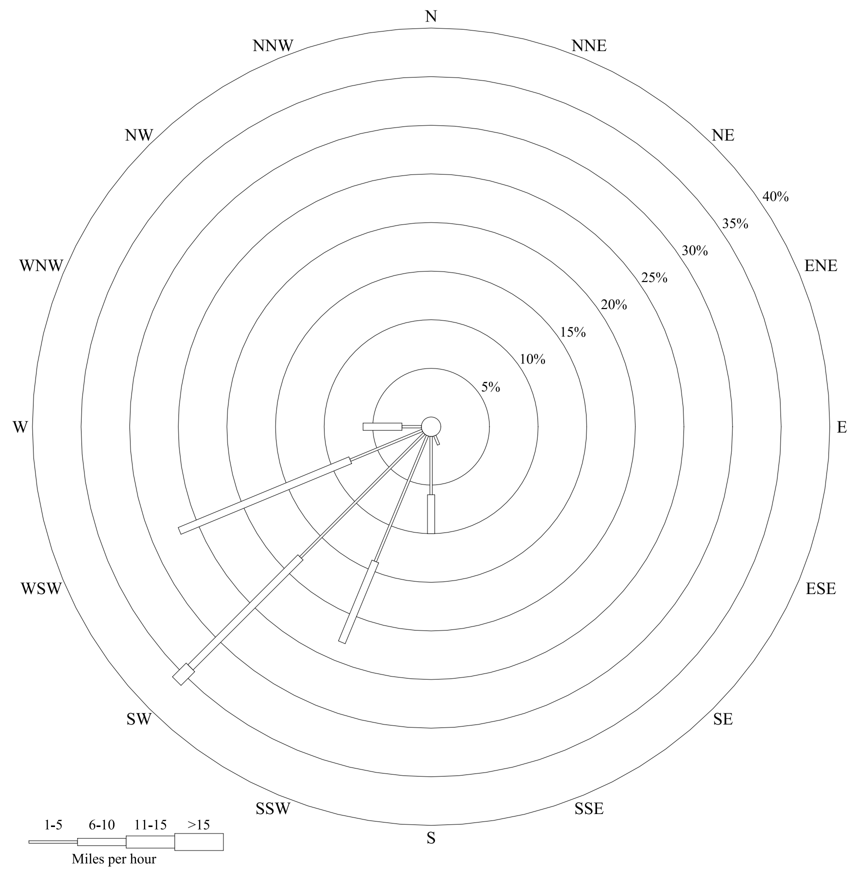
Location:	Feedyard E
Year:	2007
Station:	South TSP
Test Number:	3
Start Date:	7/9/07
Start Time:	9:18 P.M.
End Date:	7/10/07
End Time:	2:08 A.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	5.62 mi/h
Calm Winds:	0%
Comments:	



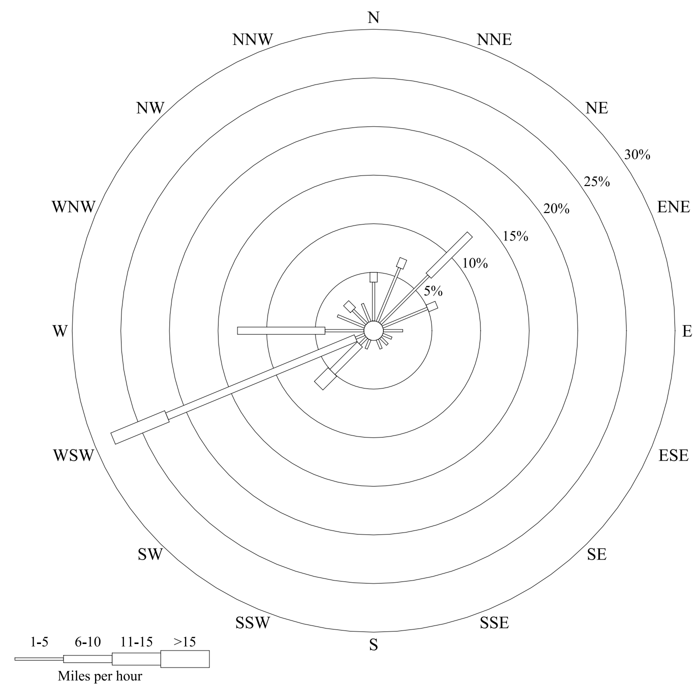
Location:	Feedyard E
Year:	2007
Station:	South TSP
Test Number:	4
Start Date:	7/10/07
Start Time:	2:11 A.M.
End Date:	7/10/07
End Time:	6:48 A.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	3.71 mi/h
Calm Winds:	2%
Comments:	



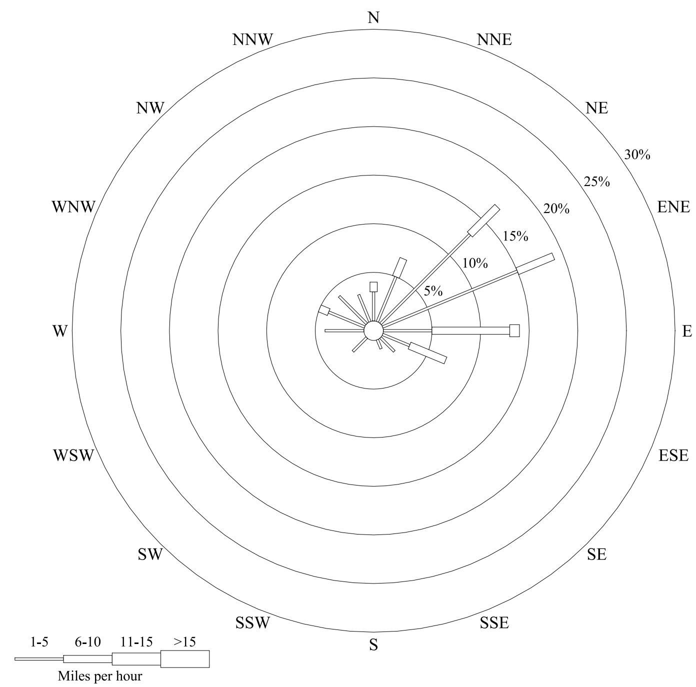
Location:	Feedyard E
Year:	2007
Station:	South TSP
Test Number:	5
Start Date:	7/10/07
Start Time:	6:50 A.M.
End Date:	7/10/07
End Time:	10:09 A.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	5.51 mi/h
Calm Winds:	1%
Comments:	



Location:	Feedyard E
Year:	2007
Station:	South TSP
Test Number:	6
Start Date:	7/10/07
Start Time:	10:10 A.M.
End Date:	7/10/07
End Time:	12:52 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	5.95 mi/h
Calm Winds:	8%
Comments:	

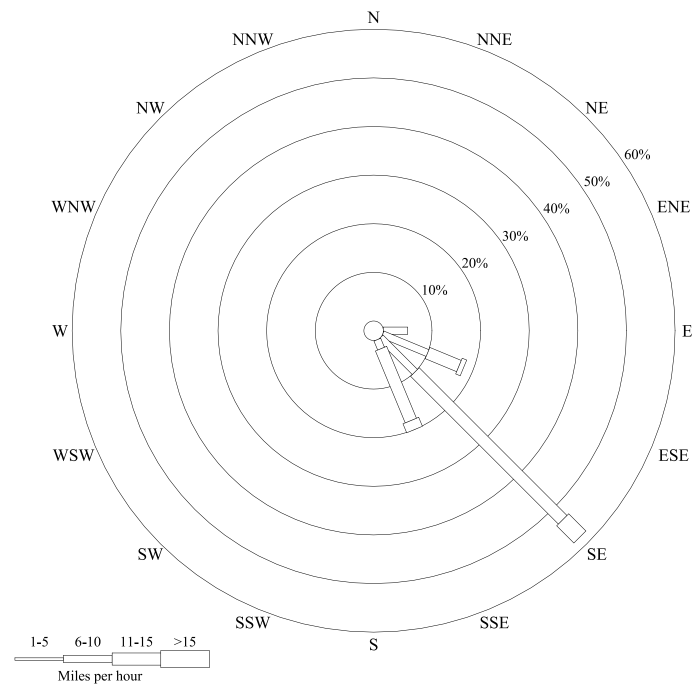


Location:	Feedyard E
Year:	2007
Station:	South TSP
Test Number:	7
Start Date:	7/10/07
Start Time:	12:54 P.M.
End Date:	7/10/07
End Time:	3:31 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	4.17 mi/h
Calm Winds:	11%
Comments:	

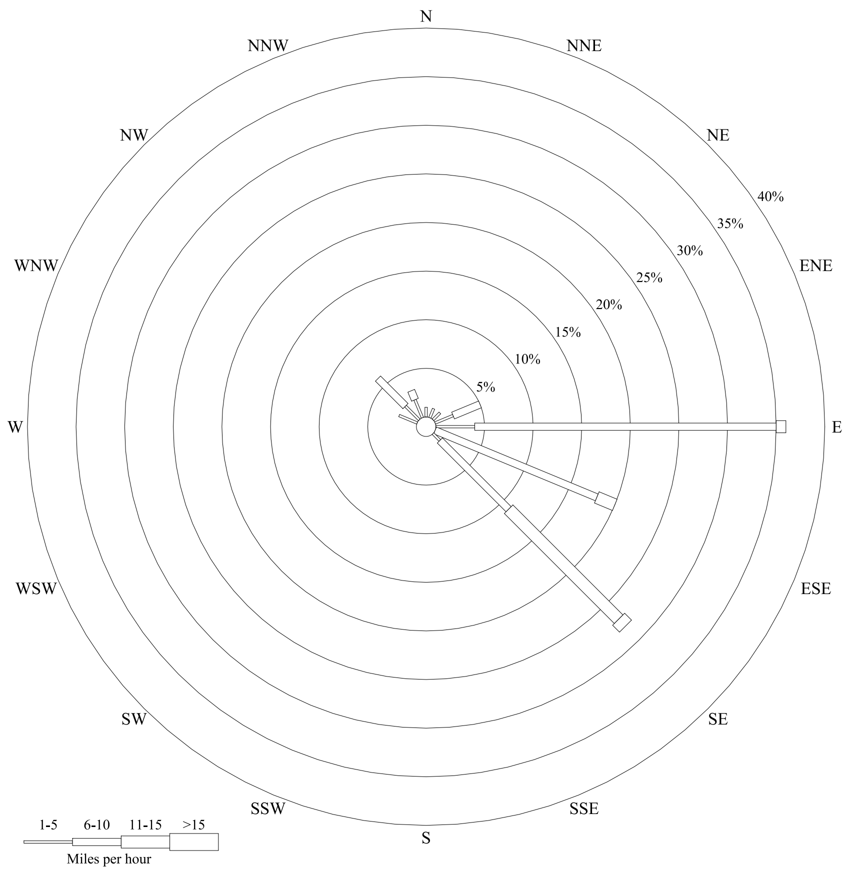


Location:	Feedyard E
Year:	2007
Station:	South TSP
Test Number:	8
Start Date:	7/10/07
Start Time:	3:33 P.M.
End Date:	7/10/07
End Time:	6:35 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	11.02 mi/h
Calm Winds:	0%
Comments:	

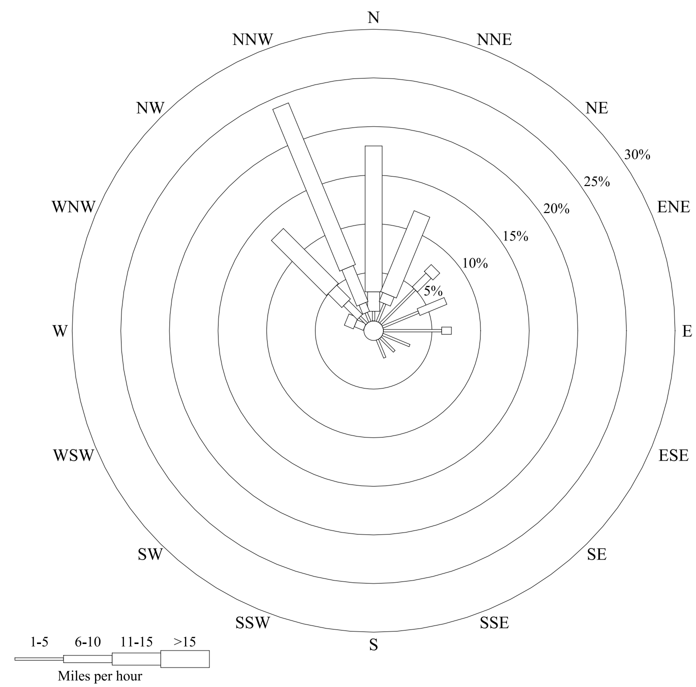
Location:	Feedyard E
Year:	2007
Station:	South TSP
Test Number:	9
Start Date:	7/10/07
Start Time:	6:37 P.M.
End Date:	7/10/07
End Time:	9:49 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	11.80 mi/h
Calm Winds:	0%
Comments:	



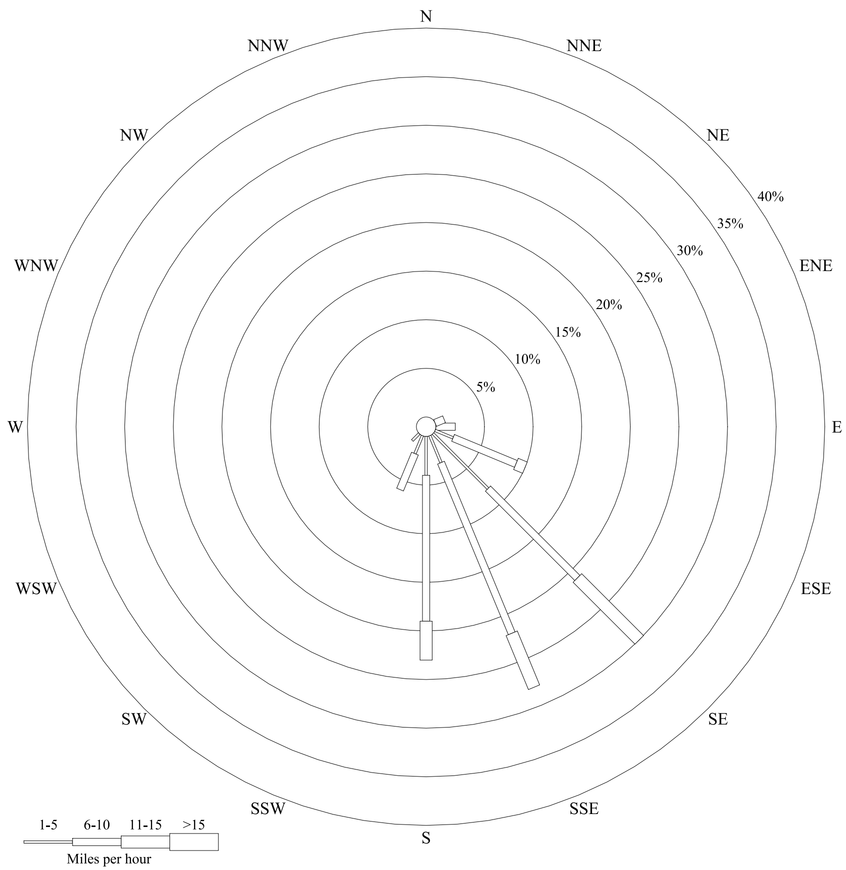
Location:	Feedyard E
Year:	2007
Station:	South TSP
Test Number:	10
Start Date:	7/10/07
Start Time:	9:50 P.M.
End Date:	7/11/07
End Time:	12:55 A.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	8.34 mi/h
Calm Winds:	0%
Comments:	



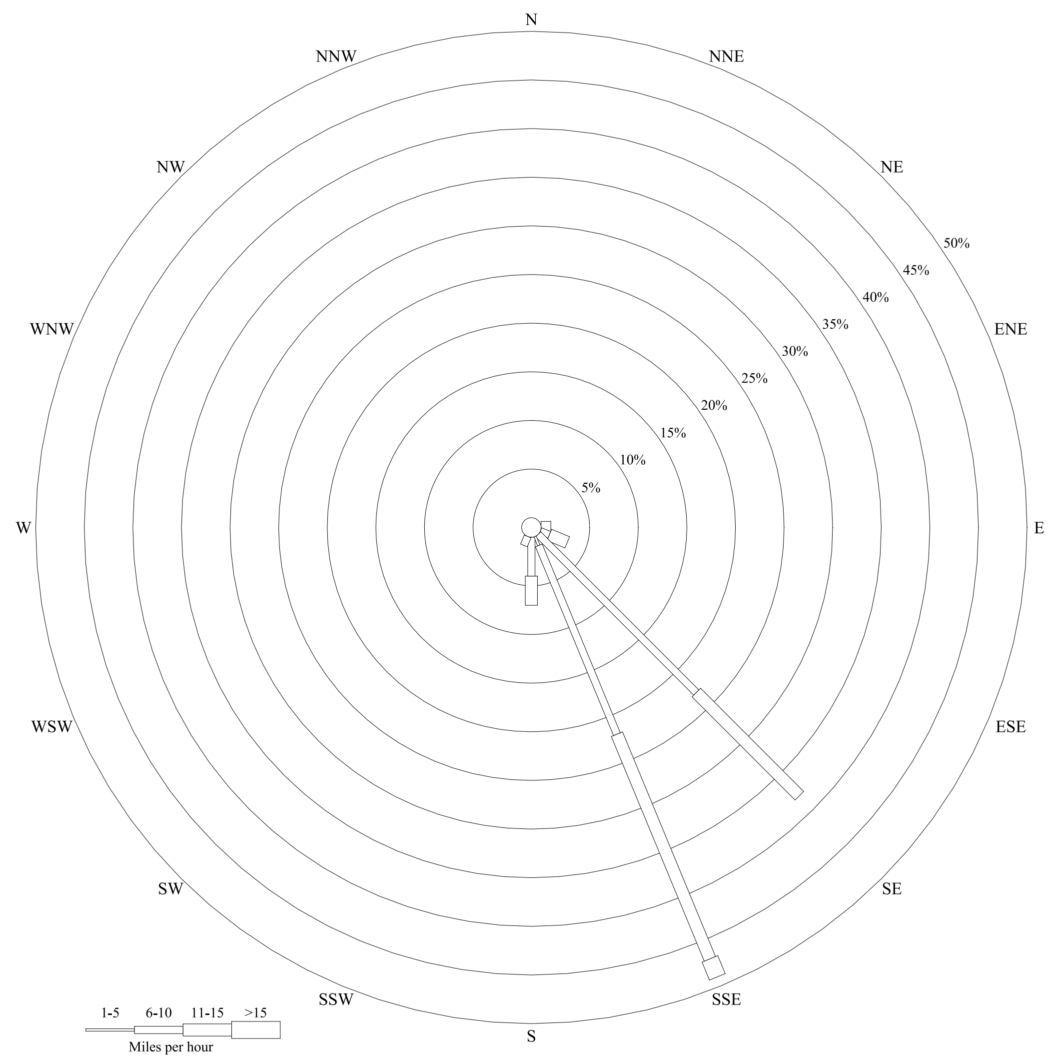
Location:	Feedyard E
Year:	2007
Station:	South TSP
Test Number:	11
Start Date:	7/11/07
Start Time:	12:58 A.M.
End Date:	7/11/07
End Time:	9:54 A.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	13.17 mi/h
Calm Winds:	2%
Comments:	



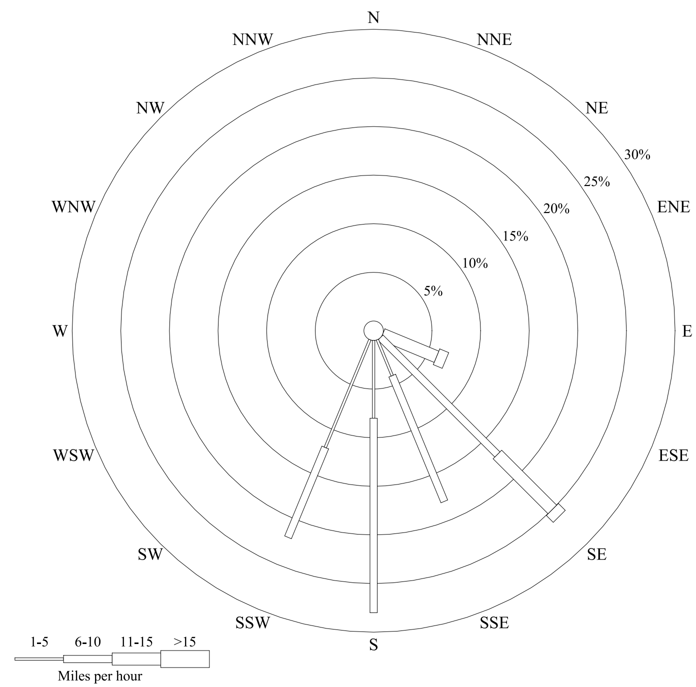
Location:	Feedyard E
Year:	2007
Station:	South TSP
Test Number:	12
Start Date:	7/11/07
Start Time:	9:57 A.M.
End Date:	7/11/07
End Time:	3:12 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	8.11 mi/h
Calm Winds:	0%
Comments:	



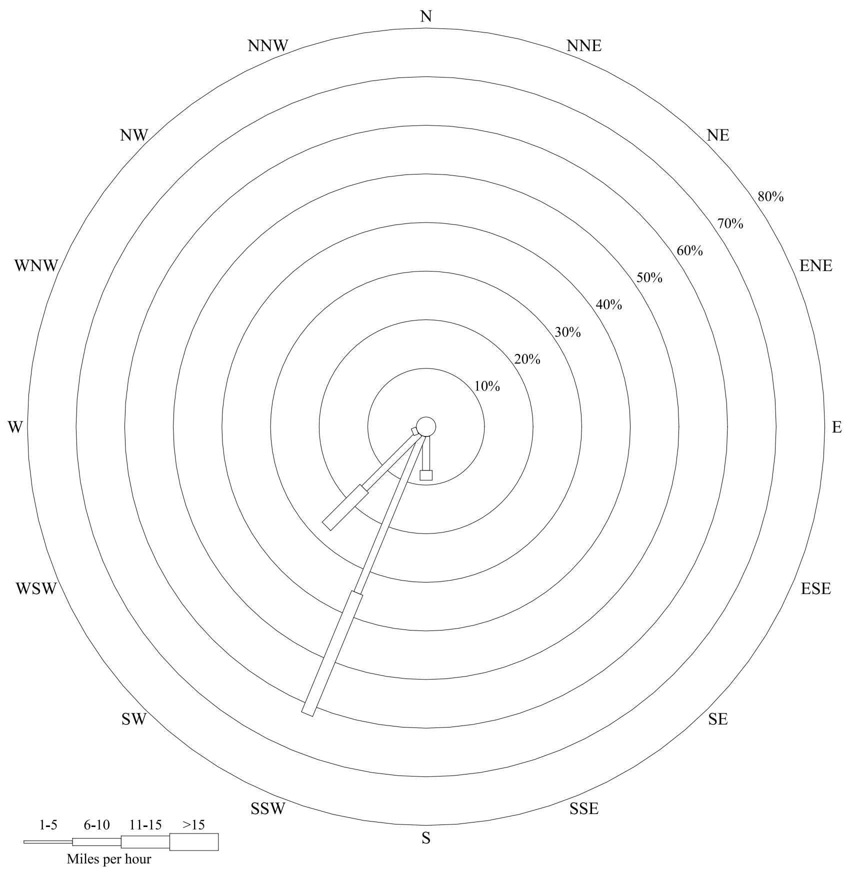
Location:	Feedyard E
Year:	2007
Station:	South TSP
Test Number:	13
Start Date:	7/11/07
Start Time:	3:13 P.M.
End Date:	7/11/07
End Time:	9:13 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	10.69 mi/h
Calm Winds:	0%
Comments:	



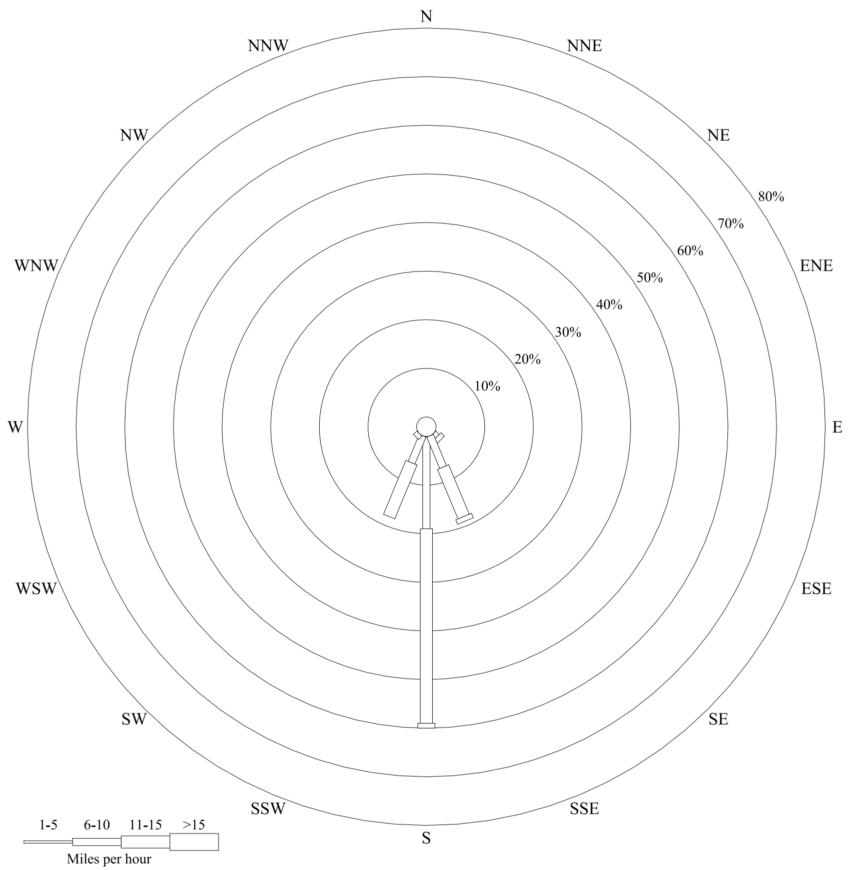
Location:	Feedyard E
Year:	2007
Station:	South TSP
Test Number:	14
Start Date:	7/11/07
Start Time:	9:16 P.M.
End Date:	7/12/07
End Time:	6:42 A.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	7.75 mi/h
Calm Winds:	0%
Comments:	



Location:	Feedyard E
Year:	2007
Station:	South TSP
Test Number:	15
Start Date:	7/12/07
Start Time:	6:45 A.M.
End Date:	7/12/07
End Time:	12:34 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	9.99 mi/h
Calm Winds:	0%
Comments:	



Location:	Feedyard E
Year:	2007
Station:	South TSP
Test Number:	16
Start Date:	7/12/07
Start Time:	12:36 P.M.
End Date:	7/12/07
End Time:	3:18 P.M.
Display:	Wind Speed
Unit:	mi/h
Orientation:	Direction (blowing from)
Avg. Wind Speed:	11.52 mi/h
Calm Winds:	0%
Comments:	



VITA

Stewart James Skloss was born in Corpus Christi, Texas on September 4, the son of Ernest J. and Betty A. Skloss. He moved with his family to Mission, Texas in August 1997. He graduated salutatorian of Sharyland High School in May 2001.

Stewart graduated from Texas A&M University Cum Laude with a Bachelor of Science degree in Agricultural Engineering in December 2005. During his undergraduate studies he participated in Leaders in Freshman Engineering (LIFE) and the American Society of Biological and Agricultural Engineers (ASABE) Student Branch. Stewart entered the Biological and Agricultural Engineering graduate program at Texas A&M University in January 2006 and received his Master of Science degree in May 2008. His research interests include air pollution engineering and the interaction between science and policy surrounding air quality issues. He plans to publish the findings of his research in a peer-reviewed journal.

In June 2008, Stewart will begin work for Halff Associates, Inc. in McAllen, Texas. He may be reached at Department of Biological and Agricultural Engineering; c/o Dr. Calvin B. Parnell, Jr.; 207D Scoates Hall, M.S. 2117 TAMU; College Station, TX 77843. His e-mail is sskloss@tamu.edu.