California State University, Fresno Foundation,
a recognized Auxiliary Corporation of California State University, Fresno

MISTING: A Viable Conservation Management Practice (CMP) for Reducing PM_{10} Generated by Disking

Final Project Report

Prepared for:

California Association of Resource Conservation Districts

Prepared by:

Dr. A. Alexandrou, Dr. C. Krauter, S. Ashkan, and D. Adhikari

Time covered: March 2008 – September 2011

California State University - Fresno

December 2011

Disclaimers

The statements and conclusions in this report are those of the contractor and not necessarily those of the sponsor. The mention of commercial products, their source, or their use in connection with material herein is not to be construed as actual or implied endorsement of such products.

The most important disclaimer with regard to the conclusions from this project is related to the relative results compared to the absolute values for the data monitored and modeled. The field monitoring procedures and, especially, the AERMOD modeling were different from those used in most previous projects from which PM emissions have been estimated or published. The methods and modeling were consistent for all sampling sites monitored in this project. Comparing PM emissions from this project with values from other projects conducted using other monitoring and modeling methods should not be considered a valid comparison. The modifications required to use AERMOD for this project required the sampling locations to be much closer to the particulate source than is generally the case for large, stationary sources for which AERMOD was designed. The emissions modeled under these circumstances are very likely to be higher than would be the case if the samplers had been farther downwind from a stationary source.

A similar consideration is related to the uniformity of the soils at the monitoring sites for this project. The primary objective was to compare PM emissions when the misting system was on and off so, to that end, the soils were chosen to be as representative of soils found in the San Joaquin Valley of California. While the soils in this trial would be considered typical, PM emissions would certainly be influenced by many other, different conditions; e.g., previous crop and tillage history.

The contract provided that the dust control unit (DCU) was not to be modified during testing but to test it as is. The research team obliged by the requirement and did not modify or make any adjustments on the dust control unit.

No members of the research team and individuals collecting data for this project have any interest, financial or otherwise, direct or indirect, or engage in any business or transaction with the manufacturer of the DCU. All CSU Fresno employees participating in this project conform to all applicable conflict of interest policies.

Acknowledgements:
The field work portion of this project was conducted by students and staff in the Center for Irrigation Technology (CIT) at CSU Fresno. The following CIT staff supervised the sampling and other data collection activities at the monitoring locations:

Shawn Ashkan – Agricultural Engineer
Diganta Adhikari – Faculty Department of Industrial Technology, and
Research Associate Center for Irrigation Technology (CIT)

The following students participated in various stages of the project:

College of Engineering graduate students: Juan Gallego-Calderon and Baldeep S. Panach.

College of Engineering undergraduate student: Johnnie Siliznoff Jr.

Jordan College of Agricultural Sciences and Technology graduate student: Gerardo Orozco.

Jordan College of Agricultural Sciences and Technology undergraduate students: Hannah Fortney, Jacob Moreno, Zach Bosh, Alexandro Orozco, and Pablo Vasquez.
CIT staff Rafael Allende.

Analytical work for the project was conducted in the Department of Biological and Agricultural Engineering at Texas A&M under the direction of Dr. Brock Faulkner.

The Principle Investigators gratefully acknowledge the members of the stakeholders group who advised us during the project, specially Ron Harben (California Association of Resource Conservation Districts) and Ted Strauss and Johnnie Siliznoff (both of the USDA – Natural Resources Conservation Service).

The modeling process would have not been successfully accomplished without the help Dr. Mike Buser of Oklahoma State University, Dr. Brock Faulkner of Texas A&M, and the modelers of the San Joaquin Valley Air Pollution Control District (SJVAPCD), Leland Villalvazo and Glenn Reed. James Sweet's (Senior Air Quality Specialist / Atmospheric Scientist) comments during the project were, as always, enlightened and helpful.

The investigators would like to acknowledge the cooperation of anonymous growers who allowed us access to their fields, often with little advanced notice.

This Report was submitted in fulfillment of CSU Fresno Foundation project No. 37643 for the project titled "Dust Plume Suppression".

This page intentionally left blank

TABLE OF CONTENTS

List of Figures **Page**

List of Tables **Page**

Glossary of terms, abbreviations, symbols and units

General terms

CARCD - California Association of Resource Conservation Districts
CARB – California Air Resources Board
CDFA – California Department of Food and Agriculture
CIT - Center for Irrigation Technology at CSU Fresno
CSU Fresno – California State University at Fresno
CWI - California Water Institute
EPA – Environmental Protection Agency
NRCS - Natural Resources Conservation Service
SJVAPCD – San Joaquin Valley Air Pollution Control District
Texas A&M – Texas A&M University
TAMU - Texas A&M University
UAL - University Agricultural Laboratory at Fresno State

Research terms and units

AEROMOD - Air dispersion model which uses information from emission sources and meteorological conditions to calculate how a pollutant moves through the atmosphere and the concentration of that pollutant.

Conservation Management Practices (CMP) – In this report, CMPs are agricultural conservation practices (e.g., reduced passes of agricultural equipment, watering roads, and using conservation tillage methods) that reduce the emission of air pollutants, namely particulate matter pollution. The San Joaquin Valley Air Pollution Control District administers the air quality planning program with the purpose of reducing particulate matter from agricultural sources through farmers applying Conservation Management Practices (CMPs).

Emissions – In this report, “emissions” is a term used in a general sense to describe the presence of a mixture of particulate matter made up of solid particles and liquid droplets found in the air. The term is not intended to imply an emission rate or emission factor when used in this report.

Emission rate - Emission rate can be defined as the amount of particulate matter discharged to the air per unit time.

FRM – Federal Reference Method.

ISCST3 - The Industrial Source Complex Short Term (ISCST3) model was formerly the US EPA’s regulatory air dispersion model. It has been replaced by AERMOD.

Particulate matter (PM) – In this report, particulate matter is the term used for a mixture of solid particles and liquid droplets found in the air.

PM_{10} - The U.S. EPA defines PM_{10} as particulate matter with a diameter of 10 micrometers collected with 50% efficiency by a PM_{10} sampling collection device (EPA).

$PM_{2.5}$ - EPA defines $PM_{2.5}$ as particulate matter with a diameter of 2.5 micrometers collected with 50% efficiency by a $PM_{2.5}$ sampling collection device (EPA).

Total Suspended Particulate (TSP) - Particles ranging in size from 0.1 micrometer to about 30 micrometer in diameter are referred to as total suspended particulate matter (TSP). TSP includes a broad range of particle sizes including fine, coarse, and super coarse particles (EPA).

Executive Summary

California State University, Fresno, was awarded a contract in July of 2008 by California Association of Resource Conservation Districts to investigate the Particulate Matter (PM) reducing potential of an existing dust control unit (DCU) attached to a common agricultural disk during field disking operations. The DCU consists of a misting apparatus (water tank, pressure pump, pressure regulator, pipes, and nozzles) mounted on a field disk. A no-cost extension was requested and approved. The extension was requested because part of the analytical work was carried out in Texas A&M and it took longer than expected to obtain the results. Moreover, a near-field air dispersion model (AERMOD) was used for data analysis. Its use was not anticipated in the initial contract. The modeling process was time consuming and it required as input, data from the Texas A&M analysis.

Stakeholders that may benefit from this project are the Central Valley farmers. Funds spent as anticipated.

Methods and objectives

Field sampling took place in summer and fall of 2009 and 2010. Sites monitored were all located in Fresno County. PM samplers were placed upwind and downwind to monitor $PM_{2.5}$, PM_{10} and TSP. At the same time local meteorological data were recorded using two meteorological stations in situ. Sample filters were sent to Texas A&M for particle size analysis. Data were modeled with AERMOD, an atmospheric dispersion model, and emission rates were determined for the individual operations.

The primary objectives of this study were to: 1. quantify the PM-reducing potential of an existing DCU misting apparatus attached to a common agricultural disk, 2. substantiate the temperature-reducing effect of the fine water mist on the heated dust plume generated by the disk, 3. substantiate previous emission factors for disking, 4. substantiate previous emission reduction standards for night farming, and 5. contribute to the verification of the validity of the methodology and field protocols for evaluating conservation management practices.

Results

First objective - Quantify the PM-reducing potential of an existing DCU misting apparatus attached to a common agricultural disk

The primary objective was to compare PM emissions reduction from the use of the DCU. In the valid replications of the trial, the DCU reduced PM10 an average of 22.2%. For the most common soil texture, sandy loam, PM10 reduction averaged 30.9%. Loamy sand, clay and clay loam soils results were less conclusive due to the limited number of replications and environmental variability. In general, the loading of $PM_{2.5}$ filters for both treatments (mist off and on) was too small to render $PM_{2.5}$ measurements with the same precision as for the larger PM fractions.

Second objective- substantiate the temperature-reducing effect of the fine water mist on the heated dust plume generated by the disk

Temperature sensors and a vertical air temperature profiler were used in attempts to substantiate the temperature-reducing effect of the fine water mist on the heated dust plume generated by the disk. Neither method provided reliable results. An ARI sponsored project will test nozzles in a wind tunnel and should provide more reliable results.

Third objective- substantiate previous emission factors for disking

The original objective of comparing PM emissions from this project with values from other projects conducted using other monitoring and modeling methods was essentially invalidated by the substitution of the new AERMOD model for the ISC-ST model used for most previous studies. Additional data from the follow-up ARI project and other researchers will eventually enable valid comparisons with previous work.

Fourth Objective- substantiate previous emission reduction standards for night farming

Substantiating previous PM emission reductions for night farming were unsuccessful due to the absence of reliable soil surface temperature data. This data will be directly measured in the ARI study rather than the reliance on CIMIS soil temperatures as was the case in this trial. Direct measurement of soil surface temperatures was not possible with the resources available in this preliminary study.

Fifth Objective- contribute to the verification of the validity of the methodology and field protocols for evaluating conservation management practices

Members of the research team participated in discussions on the Policy on Approval of New Conservation Management Practices (CMPs) that took place at the San Joaquin Air Pollution Control District (SJVAPCD) Agricultural Technical Committee (Ag Tech) in April-May 2010. The research team contributed to the discussions and also submitted written comments. The policy was subsequently approved by the air district.

Recommendations

The DCU appears to provide significant PM_{10} reduction in tillage on the most common soil texture in the San Joaquin Valley. It is likely that similar reductions would occur on other soils but insufficient valid data in this limited trial did not allow confirmation on other soil textures. The levels of $PM_{2.5}$ were so low in the trial that conclusions and recommendations are inconclusive regarding these smaller particles.

There is a need to establish the optimum droplet size of the cooling, fine water mist which achieves the best dust plume heat reduction and, thus, the best PM reduction. This is necessary so that the water consumption of the unit could be established.

INTRODUCTION

The San Joaquin Valley is the home of the nation's most productive agriculture industry. Agriculture and agriculture-related businesses thrived as a result of the Valley's climate, excellent soil, extensive irrigation network, and its location between the San Francisco Bay Area and Southern California markets. According to the California Department of Food and Agriculture (CDFA), eight of the top ten agricultural counties based on income in the United States are located in California, and six of California's top 10 counties are located in the San Joaquin Valley Air Basin (SJVAB). Although the amount of farmland is continually being reduced by urbanization, agriculture is expected to remain the region's economic engine for many years to come.

Particulate matter (PM) is a generic term for solid, liquid, or semi-volatile materials (except pure water) in the atmosphere varying in size and composition. Primary sources directly emit PM into the atmosphere and include both human and natural activities and processes. Most primary PM emissions are generated from human (anthropogenic) activity. These types of activities include agricultural operations, industrial processes, combustion of wood and fossil fuels, construction and demolition activities, and entrainment of road dust into the air. The 2002 emissions of California inventory indicates that PM_{10} emissions from agriculture-related sources total 197 tons per day, or more than half of all directly emitted PM_{10} emissions.

Air quality standards based on PM_{10} reflect the fraction of PM no greater than 10 microns (1 micron = 1/1000th of a meter) in aerodynamic equivalent diameter. Data from the California Regional PM_{10}/$PM_{2.5}$ Air Quality Study (CRPAQS) indicates that geologic material comprises about 46 percent of the mass on an annual basis. Although agriculture is only responsible for a portion of these geologic emissions, several agricultural source categories are likely to exceed significant source thresholds.

California State University, Fresno, was awarded a contract by California Association of Resource Conservation Districts to investigate the Particulate Matter (PM)-reducing potential of an existing dust control unit (DCU) attached to a common agricultural disk during field disking operations. It is worth noting that the funding came from NRCS state and national conservation innovation grants (CIG). Sampling was conducted in the University Agricultural Laboratory in Fresno, California, and in fields in Fresno County in 2009 and 2010.

Key Personnel

A team was put in place to carry out the study. The team consisted of Dr. A. Alexandrou, Dr. C. Krauter, S. Ashkan and D. Adhikari. Dr. Alexandrou is an agricultural engineer. His research interests include soil mechanics, soil implement interaction and mechanical weed control. During the last five years at Fresno State, he has developed an interest in the area of air quality and energy issues as related to agriculture. In the area of air quality, his research has focused on particulate matter (PM) emissions from agricultural operations and emissions from small engines. He also worked on energy budget for field crops. Sponsors of his research include federal agencies such as the USDA Natural Resources Conservation Service, state agencies such as California Air Resource Board, the San Joaquin Valley Air Pollution Control District, industries such as Sun Maid, and agricultural groups such as the NISEI Farmers League.

Dr. Krauter is a soil scientist with extensive work in the area of air quality in agriculture. His research interests include irrigation and water-plant relations. The last fifteen years, he has developed an interest in the area of air quality. In the area of air quality his research has focused on particulate matter (PM) emissions from agricultural operations and volatile organic compound (VOC) emissions from dairies and confined animal facilities. He has been successful in obtaining external funding for his research. Sponsors of his research include federal agencies such as the USDA Natural Resources Conservation Service, state agencies such as California Air Resource Board, the San Joaquin Valley Air Pollution Control District, industries such as Sun Maid, and agricultural groups such as NISEI Farmers League.

Mr. Ashkan is an air quality researcher in the Center for Irrigation Technology, California State University- Fresno. He earned a M.Sc. degree in agricultural engineering from the University of Nebraska in 1979. Mr. Ashkan has been actively involved in collecting and analyzing gaseous emissions from dairies and PM emissions from agricultural farms in the San Joaquin Valley since 2006.

D. Adhikari is an irrigation and instrumentation specialist and works at the Center for Irrigation Technology (CIT) California State University, Fresno. He also serves as a faculty member for the Department of Industrial Technology at CSUF where he teaches classes on automation, design, and process control. His areas of expertise and research are in the field of air quality, soil salinity, land reclamation, crop co-efficient (Kc) development, groundwater, protocol development, and sensor networks. He has successfully secured grants from Agricultural Research Institute, Irrigation Association, Valley Clean Air Now, and various other state, federal, and private entities.

Progress reports for this project have been submitted to the Agricultural Technical (Ag Tech) committee of the SJVAPCD. The committee advices the San Joaquin Valley Air Pollution Control District on regulatory and policy issues related to agriculture. Part of the analytical work carried out for this project was carried out at Texas A&M University under the supervision of Dr. Brock Faulkner. Fresno State used AERMOD to model the data. During the modeling process the research team contacted the modelers of the SJVAPCD for consultation.

Funding

This project was funded by national NRCS Conservation Innovation Grant No.68-3A75-7-101.

Leveraging

Funding for a follow-up project was obtained from the Agricultural Research Initiative (ARI) for $420,000 to further investigate some of the issues (e.g., nozzle sizes, water pressure, and nozzle orientation) raised by this project.

Project Objectives

This project focuses on PM emissions during field disking operations. The project objectives were:

1) To quantify the PM-reducing potential of an existing DCU misting apparatus attached to a common agricultural disk
2) To substantiate the temperature-reducing effect of the fine water mist on the heated dust plume generated by the disk
3) To substantiate previous emission factors for disking
4) To substantiate previous emission reduction standards for night farming
5) To contribute to the verification of the validity of the methodology and field protocols for evaluating conservation management practices

BACKGROUND

Prior to the passage of California Senate Bill 700, agriculture was exempt from state air quality rules; however, in 2005, State legislation removed the agricultural exemption. As a result of this legislation, the San Joaquin Valley Unified Air Pollution Control District (the Air District), developed Rule 4550 requiring agricultural operations of 100 contiguous acres or more to write and implement an air quality plan - called a Conservation Management Practices (CMP) Plan. A CMP is an activity or practice that farmers implement on their farms to help reduce PM emissions. These CMP plans address five categories of potential PM emission sources: land preparation and cultivation, harvest activities, unpaved roads, unpaved equipment yards, and other cultural practices (reduction of windblown dust and burning agricultural residues). Each crop grown on a farm is required to have three CMPs and the farm is required to have two CMPs for all unpaved roads and equipment storage areas.

Reducing the PM once it has been entrained in the air by misting apparatus is one potential control point for PM_{10} emission reduction that has not been fully evaluated. The subject of this study, called a Dust Control Unit (DCU) by its manufacturer, may provide an opportunity for previously unrecognized control point. Soil temperatures can exceed 54^o C (130^o F) in the summer. As these hot soil particles are thrown into the air by a disk or other implement, they heat the air mass in which they are entrained. Because this PM-laden air mass is now hotter than the ambient air temperature, the air mass rises – taking the PM_{10} with it. The fine water mist of the DCU acts as a cooling agent (due to the latent heat of evaporation) to reduce the temperature of the PM-laden air mass to the same as or less than the ambient air temperature thereby allowing gravity to return the PM to the soil surface.

On August 30, 2006, the Air District completed a Visible Emissions Evaluation (VEE) on a DCU attached to a Challenger tractor and 22-foot field disk. Although visible dust emissions (VDE) are not acceptable for determining the PM-reducing value of a CMP, VDE did indicate a potential for the CMP to reduce PM. The Air District took an average of twenty four readings with the DCU turned off and on. “Using these values, the water spray attachment achieved a 38% reduction in visible emissions observed.” Also included in the Air District’s report, “The data collected does not demonstrate a reduction in particulate concentration with or without water spray on the tilling device. VEEs did show a reduction of visible emissions when water spray was used.” The project reported here is the first time that a candidate CMP will be tested to determine its PM reducing capabilities using the Protocol established by the Air District. The equipment and methodology employed in this study are described further in the subsequent sections.

Small particles, less than 10 microns in diameter, pose a great health risk because they can get deep into the respiratory system and contribute to serious health problems. Agricultural field disking operations is a common cultural practice used by most Central Valley producers that generates PM emissions. The DCU may reduce these emissions to the benefit of most Central Valley farmers and inhabitants.

REVIEW OF METHODS

This project monitored PM emissions during field disking operations. It uses filter based sampling techniques and AERMOD for modeling purposes. The use of this regulatory model is relatively new in this type of application. This innovative aspect of the project also generated difficulties since the team had to deal with the infant problems that the introduction of a new technique normally generates.

Sites description

Trials were carried out in summer/fall of 2009 and 2010 at various sites on the CSUF University Agricultural Laboratory (UAL) fields, in agricultural fields in the Fowler area, and agricultural fields in the southwest part of Fresno County (Figs 1, 2, 3, and 4 and Table 1). Mapped soil properties are shown in Table 2. The fields were divided into plots approximately 0.25 miles long in each case. UAL fields are located within the city limits of Fresno and are surrounded by urban development. All other sampling sites were surrounded by agricultural fields and access roads.

Table 1. Dates, locations, soil types and type of disking operations monitored.

Date	Location	Soil Type	Type of run
Summer of 2008*	North and South of CWI	Sandy loam	Mist on – Mist off
6/22/2009	North of CWI**	Sandy loam	Mist on – Mist off
6/23/2009	North of CWI	Sandy loam	Mist on – Mist off
6/24/2009	North of CWI	Sandy loam	Mist on – Mist off
7/1/2009	East of CWI	Sandy loam	Mist on – Mist off
7/6/2009	East of CWI	Sandy loam	Mist on – Mist off
7/7/2009	East of CWI	Sandy loam	Mist on – Mist off
7/8/2009	East of CWI	Sandy loam	Mist on – Mist off
7/9/2009	North of CWI	Sandy loam	Mist on – Mist off
7/20/2009	South of CIT***	Sandy loam	Mist on – Mist off
7/21/2009	South of CIT	Sandy loam	Mist on – Mist off
7/22/2009	South of CIT	Sandy loam	Mist on – Mist off
10/29/2009	Fowler area	Loamy sand	Mist on – Mist off Mist on – Mist off Mist on – Mist off Mist on – Mist off
9/1/2010	San Diego/Manning	Clay	Mist on – Mist off Mist on – Mist off
9/2/2010	South/Washoe	Clay loam	Mist on – Mist off

* Trials during summer 2008 were preliminary and were used to familiarize the technical team with the equipment and the sampling techniques.
** California Water Institute
*** Center for Irrigation Technology

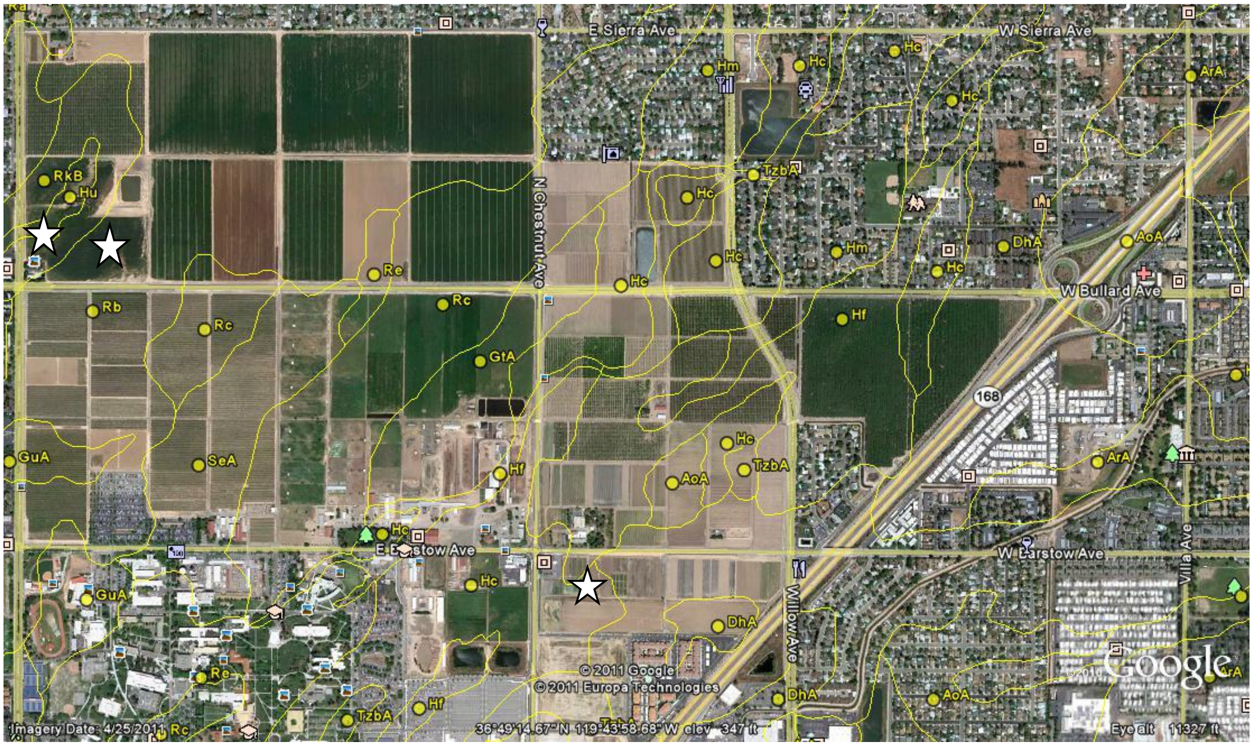


Figure 1. Soil map of the fields where disking operations were monitored with the location of sample sites shown by the white star. The monitored disking operations took place on a field with soil mapped as Rd- Ramona sandy loam, hard substratum (star), RkB—Rocklin sandy loam, Hc-Hanford sandy loam and Hu—Hildreth clay.

Figure 2. Soil map of the fields where disking operations were monitored with the location of sample sites shown by the white star. The monitored disking operations took place on a field with soil classified as DhA-Delhi loamy sand.

Figure 3. Soil map of the fields where disking operations were monitored with the location of sample sites shown by the white star. The monitored disking operations all took place on a field with soil mapped as 462—Ciervo, wet-Ciervo complex.

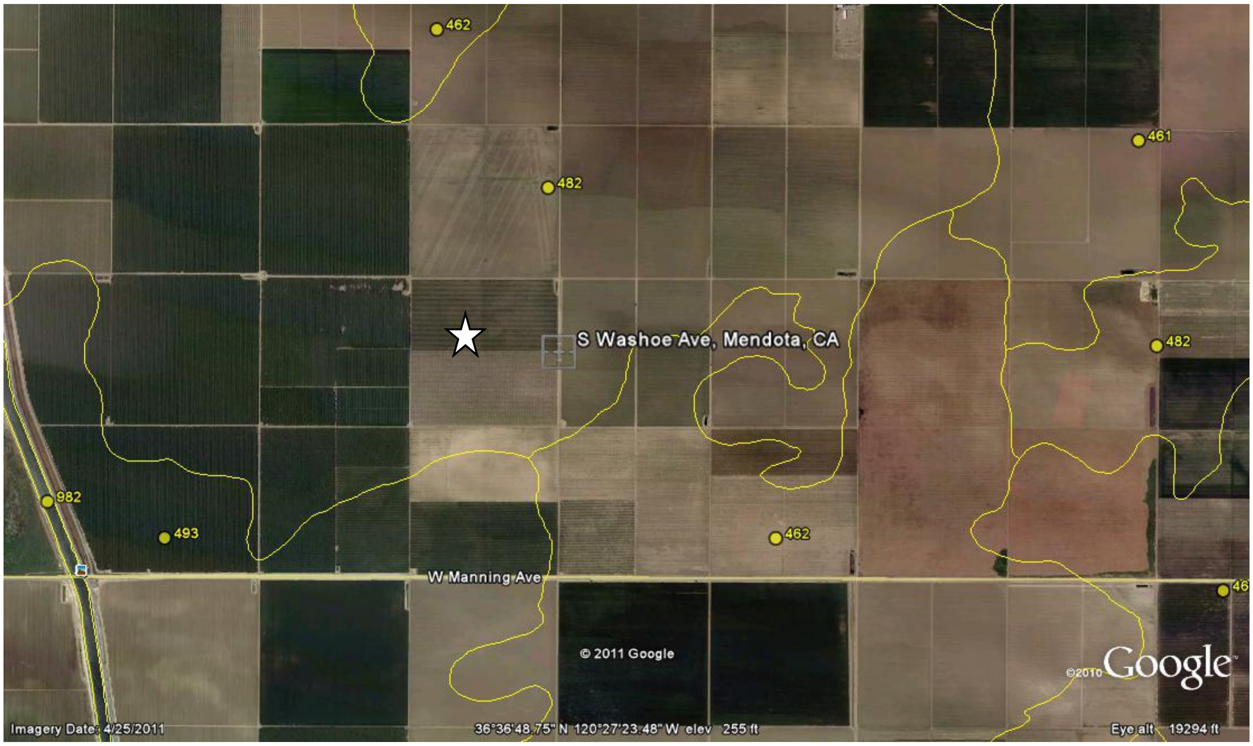


Figure 4. Soil map of the fields where disking operations were monitored with the location of sample sites shown by the white star. The monitored disking operations all took place on a field with soil mapped as 482—Calflax clay loam.

Table 2. Mapped soil properties of the fields monitored.

Location	Soil Type	Typical profile
North of CWI	RkB—Rocklin sandy loam, 3 to 9 percent slopes	• *0 to 17 inches:* Sandy loam
North of CWI	Hu—Hildreth clay	• *0 to 10 inches:* Clay
East of CWI	Rb—Ramona sandy loam, hard substratum	• *0 to 12 inches:* Sandy loam
South of CIT	Hc—Hanford sandy loam	• *0 to 16 inches:* Sandy loam
Fowler area	DhA—Delhi loamy sand	• *0 to 7 inches:* Loamy sand
San Diego/Manning	462—Ciervo, wet-Ciervo complex, saline-sodic, 0 to 1 percent slopes	• *0 to 17 inches:* Clay
South/Washoe	482—Calflax clay loam, saline-sodic, wet, 0 to 1 percent slopes	• *0 to 8 inches:* Clay loam

Operation description

The sampling sites were selected with the help of the stakeholders and permission was secured from the owners when necessary. The team was in contact with the respective owners/farm manager and when operations were scheduled to take place the team assembled its equipment and set it up in the field. This process worked well. The tractor was provided by the owner or the university farm laboratory. Due to the limited period of consistent wind speed, the large number of samplers and the time involved for setting up the equipment, only one site could be monitored per day. The sampling always included both mist on and off.

The 12-foot disk was a primary tillage implement and consisted of two gangs of concave disks in tandem (Figure 5) that rotate when engaged with the soil. The gang angle, which controls cutting aggressiveness, was adjustable. During the trials the adjustment remained unchanged. During operation, the disks of the gangs cut and lift the soil, and throw it in opposite directions. This action achieves soil pulverization, inversion, and mixes the soil at the working depth. The disk has a wheel-mounted pull hitch. The depth of the cultivation was approximately 12.7 centimeters (5 inches) for all runs.

Figure 5. The disk and the mounted dust control unit.

The disk had a dust control unit attached to it as shown in Figure 6. The manufacturer attached the unit to the disk in June 2008. Preliminary trials were carried out later in summer of 2008 to familiarize the team with the DCU and the particulate matter sampling techniques. The DCU consisted of a water tank, an electric pump, filters, booms, pressure control valve, pipes and spray nozzles. The spray nozzles were selected by the manufacturer and were not tested for optimized for droplet size by the research team. Specifications for droplet size could not be determined for this study but will be evaluated in the follow-up project. During field testing 33 nozzles were on, 11 in the front boom and 22 on the two rear booms. The water consumption during the field trials was approximately 12 gallons per acre. The unit and all adjustments on the spray system were done by the manufacturer. Table 3 shows the equipment milestone events.

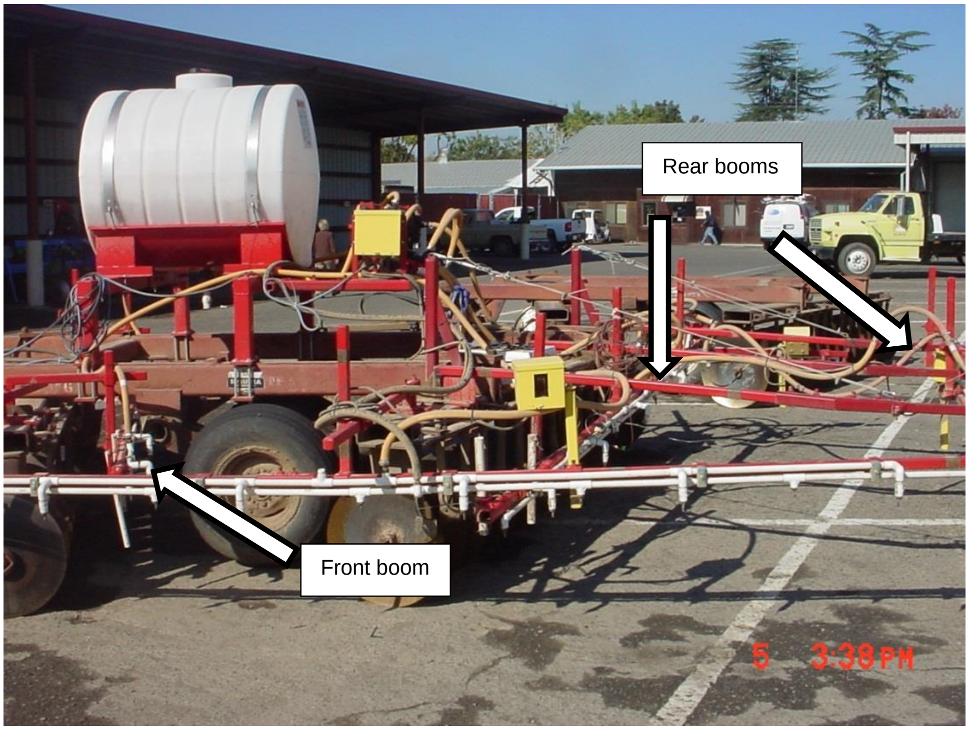


Figure 6. The disk, the mounted dust control unit and the booms.

Table 3. Equipment milestone events.

Event	Date
June 2008	Field disk modified
Summer 2008	Preliminary trials take place
Fall 2008	Analysis of data from preliminary trials
Spring 2009	Modification of PM sampling equipment
Summer 2009 and 2010	Trials take place

The speed of the tractor for the disking operations was kept at 4.5 miles per hour which is considered typical for the area and the operation. A tractor was leased and used for the trials during the summer of 2009. The field was flagged and the operator was cultivating every other row as shown in Figure 7. The length of the plot was about one quarter of a mile and the distance between rows was 15 feet.

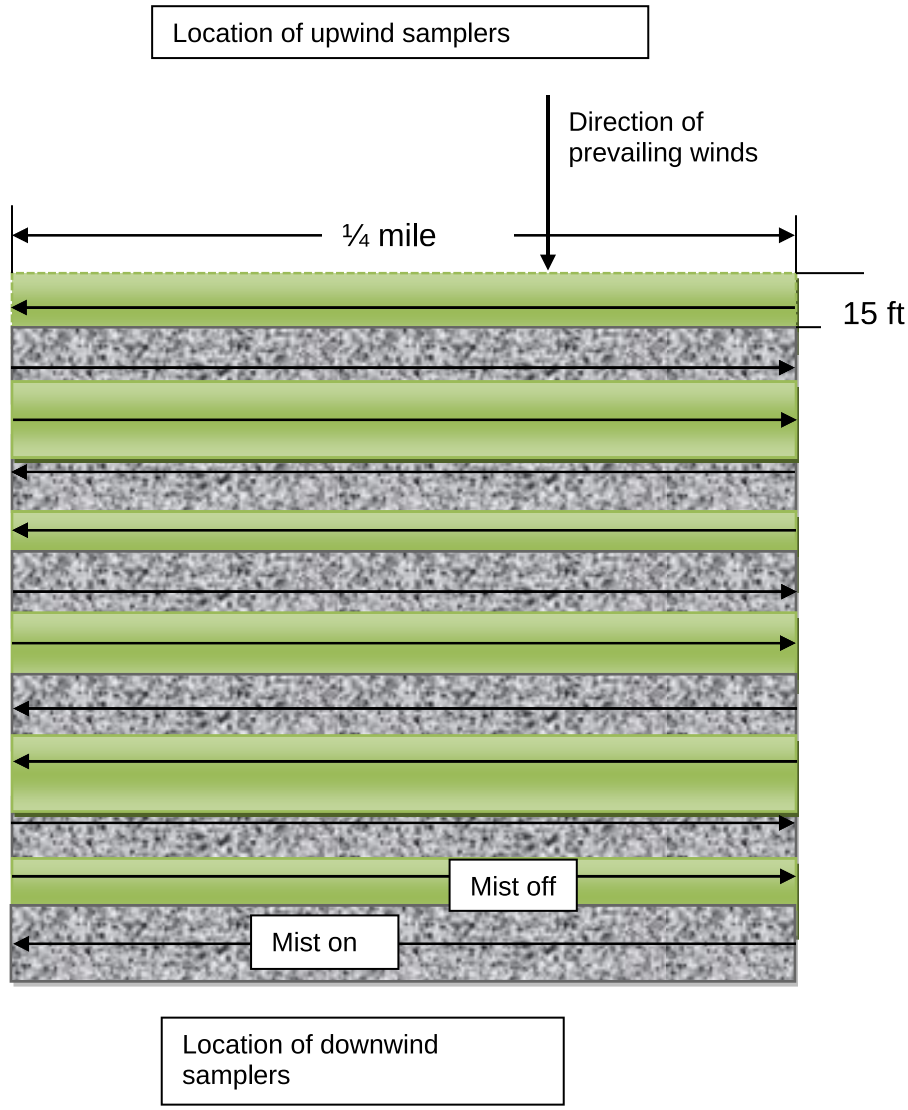


Figure 7. Field layout indicating the direction of travel of the tractor during disking operations (green rows indicate misting system on while grey rows indicate system off).

SAMPLING METHODOLOGY

This project compared PM emissions generated during field disking operations from two different treatments namely, mist off and mist on. PM studies are sensitive to environmental conditions such as humidity, wind speed and direction, solar radiation, and air temperature. Moreover, the effect of the treatments (mist on and mist off) on PM emissions may be confounded by differences in soil type and conditions such as soil structure, degree of soil disaggregation, crop residue, gravimetric water content and soil temperature. In order to reduce the effects of environmental variability on PM emissions, sampling of both treatments for the same site took place the same day with a time difference of no more than 30 minutes. This time span allowed the research team to change the filters on the inlet heads. To reduce the effect of soil conditions on PM emissions, the field sampled was divided into rows with the treatments (mist off or mist on) in alternating rows (Figure 7).

There were no guidelines as to the number of rows to be cultivated for measuring PM emissions during disking operations. It was decided that ten would be the minimum number of rows to be tilled in order to receive sufficient loading on the filters. Depending on the size and shape of the field, ten to fifteen rows were cultivated for each treatment in this project. Figure 8 shows a sequence of photos which depict the movement of the plume toward the samplers as the tractor cultivates.

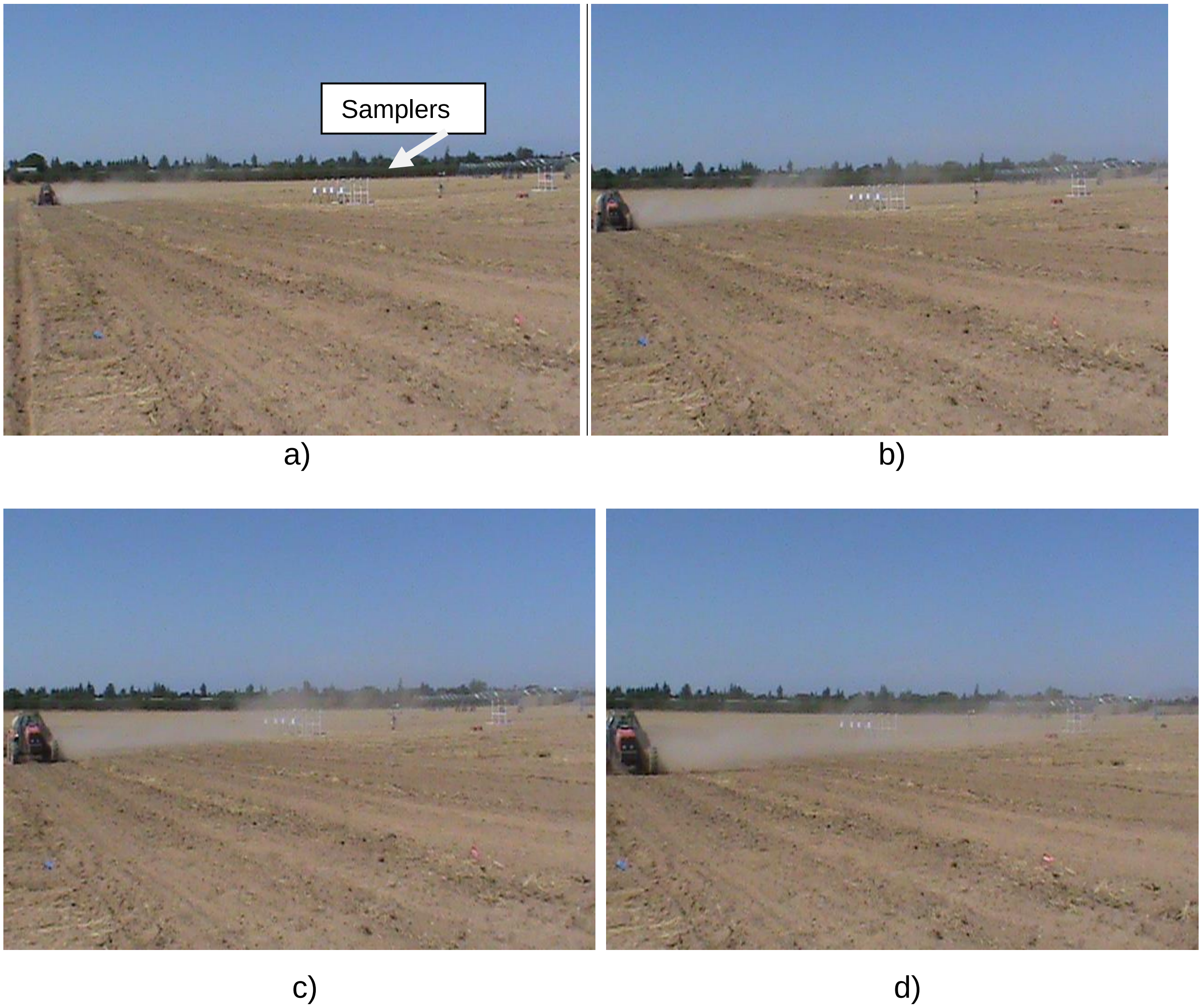


Figure 8. Sequence of photos showing a tractor cultivating while passing in front of the PM samplers.

During this study the following PM parameters were measured: $PM_{2.5}$, PM_{10}, and Total Suspended Particulate (TSP). TSP is not a federal or state PM ambient air quality standard. In this project, TSP measurements were used to determine $PM_{2.5}$ and PM_{10} through analysis of particle size distribution. Performance and operational requirements of the U.S. EPA and California Air Resources Board were met, as much as possible, by following the Federal Reference Methods for $PM_{2.5}$ and PM_{10} measurements. These federal methods, however, are for 24-hour period ambient sampling, whereas sampling period in this study was one hour or less. The shorter sampling period was due to the fact that the disking procedures occurred relatively quickly. The short sampling period resulted in very small sample sizes which made precise measurement challenging.

All PM measurements in this study were based on a filter sampling method with constant low-volume airflow (1 cubic meter per hour = 16.67 liters per minute).

Electrical air samplers drew ambient air and the suspended PM was separated and collected on filters. Filters were weighed before and after sampling to determine the net gain due to PM mass. The mass concentration (micrograms per cubic meter, $\mu g/m^3$) was computed as the total mass of collected particles in the $PM_{2.5}$, PM_{10}, and TSP size ranges divided by the actual volume of air sampled. Each sample was collected during a 30- to 75 minute period depending on the field conditions and the particular operation. Upwind samplers required more measurement time than downwind samplers to collect sufficient mass for gravimetric analysis. All the results of $PM_{2.5}$, PM_{10}, and TSP measurements in this study were expressed in units of mass per unit volume of air ($\mu g/m^3$) for each operation. All the relevant site data such as soil, meteorological, and surface parameters were collected at the time of field sampling. Sampling equipment, procedures, data analysis and QA/QC procedures are described in more detail in Appendix A - Protocol for Measurement of Particulate Matter (PM).

Size-Selective Inlet Heads

This project used three different size-selective inlet heads to collect $PM_{2.5}$, PM_{10}, and TSP. $PM_{2.5}$ and PM_{10} particles are those particles with an aerodynamic equivalent diameter (AED) less than or equal to a nominal 2.5 and 10 micrometers, respectively; TSP has no specific particle size selectivity.

Sampling Methods

Potential biases associated with use of federal reference method (FRM) samplers in agricultural environments, identified by Buser et al. (11), were addressed by the use of two different sampling methods in this project, namely: Federal Reference Method (FRM), and Texas A&M University Method (TAMU). It should be noted that the use of the FRM was not specified in the research contract.

The FRM includes $PM_{2.5}$, and PM_{10}. The TAMU method includes $PM_{2.5}$, PM_{10}, and TSP. Additionally, $PM_{2.5}$ and PM_{10} were determined through particle size distribution analysis using TSP data. Table 4 and Figure 9 show the number and type of PM samplers for different sampling methods for upwind and downwind locations. Upwind samplers indicated the ambient background condition, and downwind samplers indicated the background plus the PM mass produced by the agricultural operation. The measured PM concentration of upwind samplers was subtracted from the downwind samplers to give net measured mass concentrations for each operation.

Table 4. Number of PM samplers for each sampling method and location.

Sampling Method	Upwind Samplers			Downwind Samplers		
	$PM_{2.5}$	PM_{10}	TSP	$PM_{2.5}$	PM_{10}	TSP
Federal Reference Method (FRM)	1	1		2	2	
Texas A&M University Method (TAMU)			1	3	3	3
Total	**1**	**1**	**1**	**5**	**5**	**3**

Airflow calibration

The size-selective inlets of various PM samplers require carefully controlled volumetric airflows to maintain the desired cut-point, thus accurate measurements of airflow rate and volume were very important in this study. The cut-off characteristics of different samplers depend on the speed of the air passing through the inlets and the volume of air sampled was used to calculate the PM concentration. The volumetric flow rates can vary with changes of atmospheric temperature and pressure and PM loading on the filter.

The BGI PQ200 (Ambient Fine Particulate Sampler) was checked for flow rate verification on a regular schedule using Deltacal calibrator (BGI Inc.) as recommended by the manufacturer and required by EPA. The manufacturer's procedures were followed as described in the PQ200 manual. A leak test was performed prior to calibration.

The sharp edge orifice meter of the TAMU samplers was calibrated at the beginning and at the end of field sampling season using the Deltacal (BGI Inc.) and a stationary inclined manometer (Model 246, 0-6" W.C., Dwyer Instruments Inc.). A leak test was performed prior to calibration of sharp edge orifice. The orifice calibration relationship is expressed in terms of actual flow rate versus the manometer pressure drop in inches of water. The pressure transducers was checked and calibrated at the beginning of each filed sampling event using the inclined manometer and a calibration pump (Model A-396A, Dwyer Instruments Inc.).

Sampling filters

PM analysis requires weighing PM filters to an accuracy of 0.00001 gram. After preliminary trials it was found that the electrostatic charge on the filter was affecting the reading of the analytical balance. An antistatic kit was acquired which uses high voltage to generate positively and negatively charged ions that are attracted by the electrostatically charged object (filter) and neutralizes the disruptive electrostatic charge on the surface of the weighing sample. After discussions with the air district staff, it was decided to purchase teflon filters (2-µm pore size, 46.2-mm diameter, PTFE, Whatman Inc.) which are used by EPA for point samplers. Polytetrafluoroethylene (PTFE) is the material of choice for porous membrane filters because of their high efficiency for all particle sizes (15). See Appendix A for additional information.

Location of Samplers

The samplers were placed upwind and downwind of each sampling location (Figure 9). The upwind location had FMR PM_{10} and FMR $PM_{2.5}$ samplers and TAMU TSP. There were 2 sampling downwind locations at 5 meters from the nearest pass of the disk/blade/harvester. A small number of samplers were located at 25m from the downwind edge of the test area to study the effect of distance on the modeled emissions. At 5 meters distance, which is the main sampling location, samplers comprised of co-located FRM PM_{10} and $PM_{2.5}$ and TAMU PM_{10}, $PM_{2.5}$ and TSP (Figure 10).

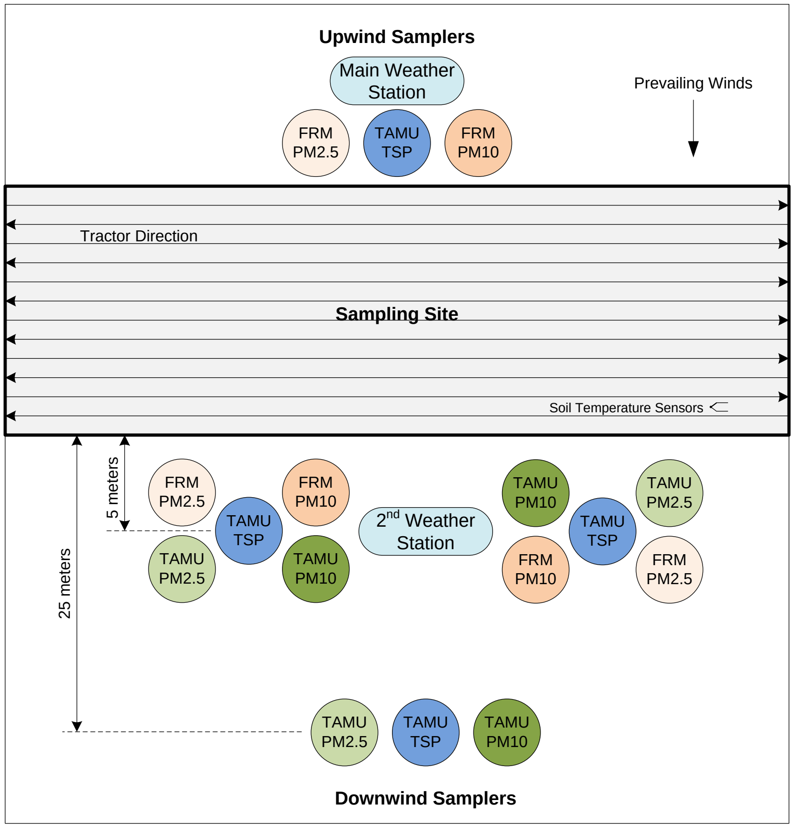


Figure 9. Schematic locations of the samplers.

Figure 10. Downwind samplers in a field.

Meteorological data

A portable weather station was placed upwind and used to collect representative site specific meteorological data in all field sampling events. Surface (local) meteorological data included air temperature, relative humidity, wind speed and direction, barometric pressure, and radiant flux. Table 5 lists major sensors mounted on the portable weather station. Another weather station was placed downwind to collect air temperature, relative humidity, and wind speed and direction. Upper layer meteorological data were taken from nearby California Irrigation Management Information System (CIMIS) stations, depending upon the location of field sampling (Table 6). Surface characteristics of the sampling site (weather station) were assessed using EPA recommendations. Soil temperature sensors provided the average temperature of the top 10 cm (4 inches) of soil. Meteorological data such as wind velocity are shown in Appendix C.

Table 5. Sensors mounted on the weather stations.

Sensors	Model	Manufacturer
Measurement & Control Datalogger	CR5000	Campbell Scientific
Pyranometer	CMP 6	Kipp & Zonen
Pyranometer	CMP 22	Kipp & Zonen
3-D Sonic Anemometer	CSAT3	Campbell Scientific
2-D Sonic Anemometers (2 units)	WINDSONIC1-L	Gill Instruments
Wind Monitor, Speed and Direction (2 units)	5305	RM Young
Temperature & Humidity (2 units)	HMP50	Vaisala
Barometric Pressure	CS100	Setra as Model 278
Soil Temperature Sensors*	TCAV-L	Campbell Scientific

* Soil temperature in the field was measured and averaged for the first 10 centimeters (4 inches) below the soils surface.

Table 6. Daily averages of various meteorological data. Data were taken from CIMIS stations 80 (Fresno State) and 2 (Five Points).

Date	Solar Radiation (Ly/Day)	Max Air Temperature (°F)	Min Air Temperature (°F)	Av Wind Speed (miles/hour)	Av Soil Temperature* (°F)
6/22/2009	720	86.6	55.3	5.1	75.5
6/23/2009	718	95.6	56.8	3.8	75.2
6/24/2009	717	98.9	61.1	5.3	75.6
7/1/2009	714	96.4	65.7	5.1	79.3
7/6/2009	732	89.0	57.0	7.0	78.8
7/7/2009	736	90.3	57.9	5.5	76.6
7/8/2009	731	88.7	59.0	6.2	76.9
7/9/2009	733	90.3	59.5	5.7	77.0
7/20/2009	685	101.6	72.1	6.6	81.1
7/21/2009	694	98.3	64.9	5.9	83.2
10/29/2009	349	63.7	33.7	2.8	59.7
9/1/2010	571	91.8	53.4	4.3	71.2
9/2/2010	574	100.6	57.6	3.7	72.0

* CIMIS measures soil temperature at 15 centimeters (6 inches) below the soil surface. CIMIS uses a well-watered, actively growing, closely clipped grass that is completely shading the soil as a reference crop; therefore, soil temperatures are usually cooler than a dry, non-vegetated, non-shaded soil surface.

Soil Analysis

Soil samples were collected for moisture analysis each day of field sampling at random locations in the fields. These were placed in sealed plastic bags and transferred to the lab immediately after the field testing. They were placed in an oven and dried overnight at 105°C. Mass soil water content was calculated as the initial weight of the soil sample and container, minus the oven-dried weight of the sample and container, divided by the weight of the dry soil in the sample.

$$field\ water\ content\ (\%) = \frac{\textbf{weight of moist soil} - \textbf{weght of oven dried soil}}{\textbf{weight of oven dried soil}} \times 100$$

Field residue coverage

Some of the fields sampled had residue coverage (Figure 11). In order to quantify the amount of residue coverage, the line transect method (NRCS, Agronomy Tech Note #MN-19) was used. A 100 foot cable with 100 marks along its length was employed. The percent residue cover was determined by counting the number of marks under which residue is seen. The procedure was repeated 5 times and the average is shown in Table 7.

Figure 11. Residue on the field north of CWI, June 23, 2009.

Table 7. Cover residue percentage of the various experimental sites.

Date	Soil type	Cover residue (%)
6/22/2009	Sandy Loam	56
6/23/2009	Sandy Loam	63
6/24/2009	Sandy Loam	52
7/1/2009	Sandy Loam	54
7/6/2009	Sandy Loam	37
7/7/2009	Sandy Loam	40
7/8/2009	Sandy Loam	26
7/9/2009	Sandy Loam	17
7/20/2009	Sandy Loam	54
7/21/2009	Sandy Loam	56
7/22/2009	Sandy Loam	50
10/29/2009	Loamy sand	NA
9/1/2010	Clay	NA
9/1/2010	Clay	NA
9/2/2010	Clay Loam	NA

Modeling

Initially the ISCST3 (Industrial Source Complex Short Term) model was going to be used for modeling purposes. EPA and San Joaquin Valley Air Pollution Control District (SJVAPCD) changed to AERMOD, an atmospheric dispersion model and this obliged the research team to switch to this model as well. AERMOD is a steady-state plume model that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, including treatment of both surface and elevated sources, and both simple and complex terrain (12). Both local and field meteorological data required by AERMOD were collected and were used in the AERMOD air dispersion modeling. AERMOD requires meteorological data and 3 surface characteristics: surface roughness length, albedo, and Bowen ratio. Modeling procedures are described in greater detail in Appendix B.

Quality Assurance

Quality assurance and measurement protocol procedures are described in Appendix A. Quality assurance and modeling procedures are described in detail in Appendix B.

RESULTS

First Objective - Quantify the PM-reducing potential of an existing DCU misting apparatus attached to a common agricultural disk

The first project objective was to quantify the PM-reducing potential of an existing DCU misting apparatus attached to a common agricultural disk. To establish the potential, concentrations of PM_{10}, $PM_{2.5}$ and TSP were measured during disking operations when the misting apparatus was on and off.

$PM_{2.5}$, PM_{10} and TSP concentrations

Goodrich et al. (14) used particle size distribution analyses and showed that $PM_{2.5}$ constituted only 0.9% of TSP sampled during almond sweeping harvesting operations. Holmen et al. (15) found that during agricultural field operations, particle mass distributions of $PM_{2.5}$ were approximately 50% of the measured PM_{10}. The above mentioned studies indicate a very large variability in relation to percentage of $PM_{2.5}$ and PM_{10} generated during agricultural field operations.

In this study, $PM_{2.5}$, PM_{10}, and TSP concentrations were measured during all field sampling operations. Table 8 shows average net (downwind less upwind) measured $PM_{2.5}$ and PM_{10} concentration as a percentage of TSP for all field operations and soils monitored. The concentrations of $PM_{2.5}$ emitted during the sampling period for most of the field sampling operations were a relatively small percentage of the total suspended matter averaging 6.89%. This number is considered small and falls within expectations. In June 22 (mist on); July 9th (mist on); and October 29 (mist off and mist on, second trial) the concentration of $PM_{2.5}$ is significantly higher than in other disking operations. As mentioned above, emissions depend on environmental conditions such as wind speed and direction. Analysis of the wind data indicated that during these tests there was a variation in the wind speed and direction. This may have affected the loading on the filters. The actual loading of the $PM_{2.5}$ filters is rather small and a small change in the loading may create a significant increase in the actual concentration. In addition, the actual amount of $PM_{2.5}$ captured on the filters in the field was so small that the accuracy of the weight differences was certainly less than those for the larger PM fractions. Therefore, differences in these $PM_{2.5}$ percentages cannot be given the same validity as other data from this study.

Measured PM_{10} concentration as a percentage of TSP for all operations and soils monitored is averaging 42.73%. This percentage is considered reasonable. $PM_{2.5}$ as a percentage of PM_{10} is less than 20%. This percentage is lower than the one reported by Holmen et al. (2008). On June 22, July 9, and October 29, 2009, the concentration of $PM_{2.5}$ as a percentage of PM_{10} is rather high (19-55%). This may be an anomaly, but may also be related to the soil structure of clay soil which consists mostly of clay soil separates, with a diameter less than 0.002mm. $PM_{2.5}$ emission rate estimate was an average of 0.57g/s.

Table 8. Average $PM_{2.5}$ and PM_{10} measured concentration as a percentage of TSP net for all operations monitored, $PM_{2.5}$ as a percent of PM_{10} and PM_{10} estimate emission rates.

Operation	$PM_{2.5}$ % of TSP	PM_{10} % of TSP	$PM_{2.5}$ % of PM_{10}	$PM_{2.5}$ estimate (g/s)
Mist off (6-22-2009)	10.07%	52.24%	19.27%	0.79
Mist on (6-22-2009)	19.98%	35.98%	55.55%	2.37
Mist off (6-23-2009)	3.16%	35.78%	8.82%	0.66
Mist on (6-23-2009)	2.07%	22.70%	9.13%	0.42
Mist off (6-24-2009)	6.69%	89.44%	7.49%	0.54
Mist on (6-24-2009)	2.40%	41.95%	5.73%	0.19
Mist off (7-01-2009)	1.89%	42.12%	4.48%	0.43
Mist on (7-01-2009)	3.55%	64.83%	5.48%	0.25
Mist off (7-06-2009)	1.19%	38.66%	3.08%	0.67
Mist on (7-06-2009)	3.20%	40.80%	7.85%	0.86
Mist off (7-07-2009)	2.54%	35.52%	7.14%	0.42
Mist on (7-07-2009)	2.35%	47.69%	4.93%	0.69
Mist off (7-08-2009)	2.39%	44.24%	5.39%	1.55
Mist on (7-08-2009)	4.70%	56.14%	8.36%	1.80
Mist off (7-09-2009)	1.70%	48.73%	3.48%	0.26
Mist on (7-09-2009)	15.89%	50.46%	31.50%	1.27
Mist off (7-20-2009)	1.62%	44.99%	3.59%	0.19
Mist on (7-20-2009)	2.05%	53.65%	3.81%	0.21
Mist off (7-21-2009)	2.84%	37.49%	7.57%	0.29
Mist on (7-21-2009)	2.79%	42.27%	6.59%	0.37
Mist off (7-22-2009)	2.55%	52.59%	4.86%	0.32
Mist on (7-22-2009)	2.54%	41.15%	6.16%	0.13
Mist off (10-29-2009)	*	26.64%	*	*
Mist on (10-29-2009)	6.98%	28.02%	24.90%	0.16
Mist off 2 (10-29-2009)	6.59%	21.23%	31.04%	0.04
Mist on 2 (10-29-2009)	21.93%	47.12%	46.54%	0.25
Mist off 2 (9-01-2010)	2.40%	31.34%	7.66%	0.18
Mist on 2 (9-01-2010)	1.69%	42.80%	3.94%	0.13
Mist off (9-02-2010)	3.83%	27.30%	14.02%	0.51
Mist on (9-02-2010)	4.82%	38.26%	12.59%	0.61
Average	**5.15%**	**42.73%**	**12.45%**	**0.57**
Average (mist off)	**3.53%**	**41.89%**	**9.14%**	**0.49**
Average (mist on)	**6.46%**	**43.59%**	**15.54%**	**0.65**

* $PM_{2.5}$ samplers presented technical problems which rendered the collected data unreliable.

Modeled PM_{10} Emission Differences

PM concentrations determined from the net mass collected on the filters in the field included all non-volatile forms of PM, mineral, organic, and soluble as the FRM was designed to measure. The particle size distribution (PSD) of PM collected on TSP filters was analyzed at TAMU using a particle size analyzer (Beckman Coulter Multisizer 3). Filters were placed in a glass beaker containing a lithium-chloride methanol electrolyte solution, and the beaker was placed into a sonic bath for 5 minutes. During sonication, PM particles were released from the filter into the electrolyte solution, which was then filtered through a 100µm screen before analysis. The organic and soluble fractions of PM were dissolved in the methanol, leaving mineral PM suspended in the solution.

After the data were analyzed and emission rates were calculated using AERMOD, the modeled emissions percentage change was calculated using the following formula:

$$Percent\ change\ in\ emission\ rate = \frac{emission\ rate\ mist\ off - emission\ rate\ mist\ on}{emission\ rate\ mist\ on} * 100$$

This formula allows the comparison between mist on and mist off and assessment of the effect of mist in the calculated emission rate. Table 9 shows the change in emission rate per sampling date. It also shows average wind speed, the field air temperature and the measured in situ soil temperature. The soil temperature in the field was measured and averaged for the top 10 centimeters (4 inches). Graphs are included in Appendix D.

Table 9a. Percent change in emission rate and the corresponding soil temperatures gravimetric water content and soil types (SI units).

Date (1)	Soil type (2)	PM_{10} change % (3)	Average wind speed (m/s)** (4)	Average Air Temp ºC (5)	Average Soil Temp ºC*** (6)	Average Soil Temp ºC (CIMIS)**** (7)	Gravimetric Water Content % (8)	Average Soil Temp - Air Temp ºC (6)-(5)	Average Soil Temp CIMIS - Air Temp ºC (7)-(5)
6/22/2009	Sandy Loam	31.45	3.55	30.8	*	24.0	1.18	NA	-6.8
6/23/2009	Sandy Loam	55.03	2.95	34.7	*	23.1	0.95	NA	-11.6
6/24/2009	Sandy Loam	16.39	2.30	37.5	39.7	24.0	1.64	2.2	-13.5
7/1/2009	Sandy Loam	-1.69	2.37	37.1	46.9	26.3	0.63	9.8	-10.8
7/6/2009	Sandy Loam	56.87	1.71	32.3	40.4	25.9	0.37	8.1	-6.4
7/7/2009	Sandy Loam	-43.49	3.24	32.9	50.5	24.5	0.43	17.6	-8.4
7/8/2009	Sandy Loam	32.79	2.09	30.8	40.6	24.7	0.54	9.8	-6.1
7/9/2009	Sandy Loam	39.88	1.67	17.9	24.2	24.4	1.31	6.3	6.5
7/20/2009	Sandy Loam	67.89	2.32	40.7	51.4	27.1	0.17	10.7	-13.6
7/21/2009	Sandy Loam	-47.46	1.76	38.6	46.5	28.7	0.39	7.9	-9.9
7/22/2009	Sandy Loam	132.24	2.16	35.8	47.5	26.1	0.38	11.7	-9.7
10/29/2009	Loamy sand	-37.19	0.72	17.3	10.8	15.9	4.15	-6.5	1.4
10/29/2009	Loamy sand	-68.5	0.6	17.8	11.2	16.0	4.15	-6.6	-1.8
9/1/2010	Clay	158.12	3.05	30.2	*	23.3	3.91	NA	-6.9
9/1/2010	Clay	-30.21	3.14	33.3	*	23.6	3.85	NA	-9.7
9/2/2010	Clay Loam	-7.38	3.3	37.1	*	24.4	4.02	NA	-12.7

*Soil temperature data were not obtained due to sensor and/or data logger failure.
**Average wind speed during the run as measured by the in situ weather station.
***Soil temperature in the field was measured and averaged for the first 10 centimeters (4 inches) below the soils surface.
****CIMIS measures soil temperature at 15 centimeters (6 inches) below the soil surface. CIMIS uses a well-watered, actively growing, closely clipped grass that is completely shading the soil as a reference crop; therefore, soil temperatures are usually cooler than a dry, non-vegetated, non-shaded soil surface.

Table 9b. Percent change in emission rate and the corresponding soil temperatures gravimetric water content and soil types (imperial units).

Date (1)	Soil type (2)	PM_{10} change % (3)	Average wind speed (mph)** (4)	Avg Air Temp ºF (5)	Avg Soil Temp ºF*** (6)	Avg Soil Temp ºF (CIMIS)**** (7)	Gravimetric Water Content % (8)	Avg Soil Temp - Air Temp ºF (6)-(5)	Avg Soil Temp CIMIS - Air Temp ºF (7)-(5)
6/22/2009	Sandy Loam	31.45	7.94	87.4	*	75.2	1.18	NA	-12.2
6/23/2009	Sandy Loam	55.03	6.60	94.5	*	73.6	0.95	NA	-20.9
6/24/2009	Sandy Loam	16.39	5.14	99.5	103.5	75.2	1.64	4.0	-24.3
7/1/2009	Sandy Loam	-1.69	5.30	98.8	116.4	79.3	0.63	17.6	-19.5
7/6/2009	Sandy Loam	56.87	3.83	90.1	104.7	78.6	0.37	14.6	-11.5
7/7/2009	Sandy Loam	-43.49	7.25	91.2	122.9	76.1	0.43	31.7	-15.1
7/8/2009	Sandy Loam	32.79	4.68	87.4	105.1	76.5	0.54	17.7	-10.9
7/9/2009	Sandy Loam	39.88	3.74	64.2	75.6	75.9	1.31	11.4	11.7
7/20/2009	Sandy Loam	67.89	5.19	105.3	124.5	80.8	0.17	19.2	-24.5
7/21/2009	Sandy Loam	-47.46	3.94	101.5	115.7	83.7	0.39	14.2	-17.8
7/22/2009	Sandy Loam	132.24	4.83	96.4	117.5	79.0	0.38	21.1	-17.4
10/29/2009	Loamy sand	-37.19	1.61	63.1	51.44	60.6	4.15	-11.7	-2.5
10/29/2009	Loamy sand	-68.5	1.34	64.0	52.2	60.8	4.15	-11.8	-3.2
9/1/2010	Clay	158.12	6.82	86.4	*	73.9	3.91	NA	-12.5
9/1/2010	Clay	-30.21	7.02	91.9	*	74.5	3.85	NA	-17.4
9/2/2010	Clay Loam	-7.38	7.38	98.8	*	75.9	4.02	NA	-22.9

*Soil temperature data were not obtained due to sensor and/or data logger failure.
**Average wind speed during the run as measured by the in situ weather station.
***Soil temperature in the field was measured and averaged for the first 10 centimeters (4 inches) below the soils surface.
****CIMIS measures soil temperature at 15 centimeters (6 inches) below the soil surface. CIMIS uses a well-watered, actively growing, closely clipped grass that is completely shading the soil as a reference crop; therefore, soil temperatures are usually cooler than a dry, non-vegetated, non-shaded soil surface.

Sandy loam soil

Sandy loam is, by far, the most common of the soil textures mapped in the San Joaquin Valley. In this study and in order to reduce the effects of the environmental conditions on PM emissions, sampling of both treatments for the same site took place the same day. To reduce the effect of soil conditions on PM emissions, the field sampled was divided into rows and every other row was treated alike (mist off or mist on) (Figure 7). Therefore, the effect of the gravimetric water content, and soil's disaggregation between treatments was minimized. Madden (2009) showed that PM_{10} generated by disking on Reif fine sandy loam and a Yolo silt loam depends on gravimetric water content, number of sequential diskings and the soil's weighed mean ped diameter, a measure of the soil's disaggregation.

Table 9 shows PM_{10} emissions rate change between the two treatments for all runs carried out in this study. For sandy loam soil, the mist on treatment reduced PM_{10} emissions between 132% and 16%. For three replications, June 1st, 7th, and 21st the difference was negative. A possible explanation for these anomalies may be the sensitivity of AERMOD to wind speed when values were less than 10 m/s and particularly when values were less than 5 m/s, as was the case for these replicates (Faulkner et al., 2008).

Loamy sand soil

There were only two runs carried out on loamy sand soil. Both tests were carried out in a vineyard at the end of October with a water content of 4.15% and a temperature difference between the first 10 cm of topsoil and air at around 6.5 degrees Celsius (11.7 degrees Fahrenheit) (Table 9). Moreover, the average wind velocity for both runs was 0.72 m/s (1.61 miles/hour) and 0.60 m/s (1.34 miles per hour) respectively, although maximum wind velocity reached 1 m/s (2.24 miles/hour). Two miles per hour have been considered a threshold for PM emissions sampling. At velocities less than 2 miles per hour, derived data may not been considered reliable.

Clay and clay loam soil

Trials were carried out in Fresno County on clay and clay loam soil at the beginning of September of 2009. For those tests wind velocity was high over 3m/s (around 7 miles per hour) which may have reduced the validity of the modeled results.

Second Objective - Substantiate the temperature-reducing effect of the fine water mist on the heated dust plume generated by the disk

Temperature sensors

The second project objective was to substantiate the temperature-reducing effect of the fine water mist on the heated dust plume generated by the disk. To determine this effect, the research team used temperature probes mounted on the disk to monitor air temperature during disking operations. The probes were mounted from the frame of the disk and were placed 12.7 cm (5 inches) behind the disk and approximately 10 inches from the soil. They were connected to the data logger and monitored temperature changes. During trials the tip of the temperature sensors was rapidly coated with moisture and soil particles. During operation the mist mixed with the air-born dust particles and was deposited in the tip of the sensors forming mud. The mud on the tip affected the measurements and prevented the collection of usable data.

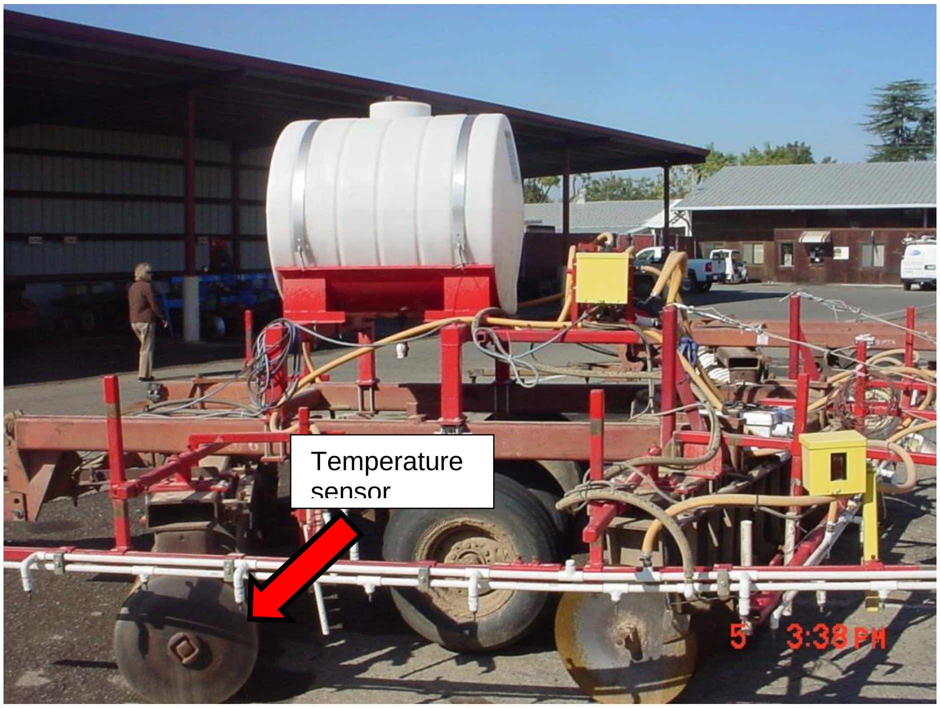


Figure 12. Location of the temperature sensor on the disk.

Vertical air temperature profiler

A second approach used a vertical air temperature profiler to substantiate differences in the air temperature as created by the disking operations. The air temperature profiler is a remote sensing instrument that measures temperature within the planetary boundary layer. It has been used in applications in the monitoring of urban air quality. A profiler was leased for a week and trials were carried out in Fresno to verify its ability to measure temperature differences of the rising dust plume which was generated by the disks.

The team devoted a considerable amount of time and resources to substantiate the temperature-reducing effect of the fine water mist on the heated dust plume generated by the disk while it was in operation. The efforts and the techniques used proved unsuccessful in monitoring the temperature during field disking. Further work will be included in an ARI follow-up grant to clarify the effect of soil temperature. It will be carried out in a wind tunnel under controlled conditions.

Third Objective-Substantiate previous emission factors for disking

The third objective of the project was to substantiate previous emission factors for disking. The field monitoring procedures and especially the AERMOD modeling were different from those used in most previous projects from which PM emissions during disking have been estimated or published. The methods and modeling were very consistent for all sampling sites monitored in this project so the comparison of one disking operation to the others is quite valid. Comparing PM emissions from this project with values from other projects conducted using other monitoring and modeling methods should not be considered valid. The modifications required to use AERMOD for this project required the sampling locations to be much closer to the source than is generally the case for large, stationary sources for which AERMOD was designed. The emissions modeled under these circumstances are very likely to be higher than would be the case if the samplers had been farther downwind from a stationary source. Additional data from the ARI follow-up project should be useful in clarifying this issue.

Fourth Objective - Substantiate previous emission reduction standards for night farming

The fourth objective of the project was to substantiate previous emission reduction standards for night farming. "Night farming" indicates that farming related activities take place during night when both soil and air temperature are both lower than daytime temperatures and the soil temperature is lower than the air temperature due to the absence of solar radiation.

CIMIS data indicated that during night, from around 21:00 to 08:00, air temperature is lower than the soil temperature (Figure 13). For the purposes of this project a trial took place starting at 6:30am and finishing at 7:30am. Mist on achieved a reduction of 40%. Data presented in Figure 13 were obtained from CIMIS. CIMIS measures soil temperature at 15 centimeters (6 inches) below the soil surface where the soil temperature is relatively constant. Also, CIMIS uses a well-watered, actively growing, closely clipped grass that is completely shading the soil as a reference crop; therefore, soil temperatures are usually cooler than a dry, non-vegetated, non-shaded soil surface.

The ARI grant will directly measure soil temperature at and near the surface which should provide much better correlation with the DCU treatments.

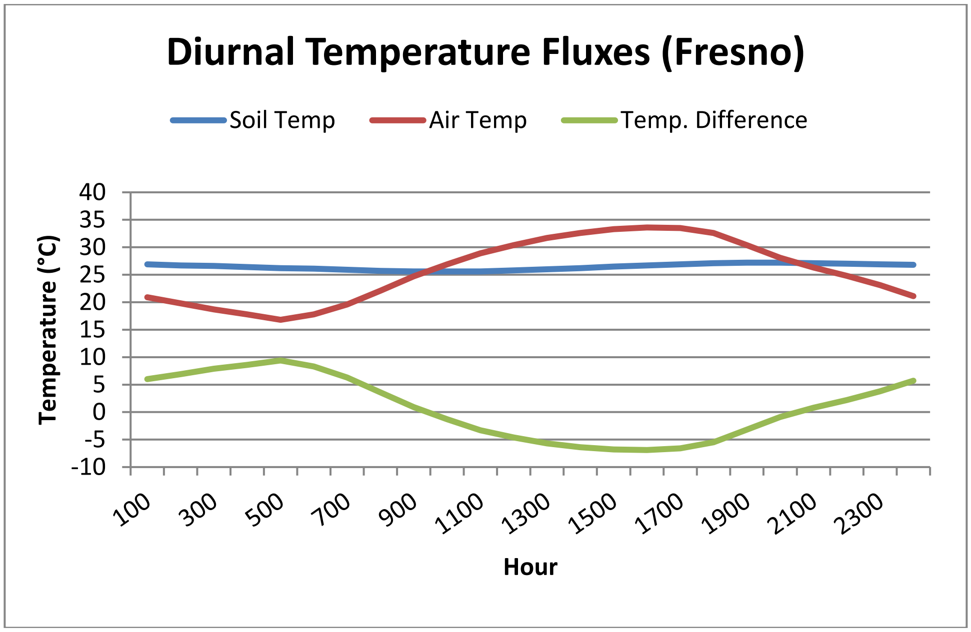


Figure 13. Diurnal temperature fluxes for a typical summer day in Fresno, CA. Data were taken from the CIMIS station 80, located at Fresno State. (NOTE: You have to use actual measured soil temperatures rather than CIMIS soil temperatures due to the conditions under which the CIMIS soils are measured. CIMIS uses a well-watered, actively growing, closely clipped grass that is completely shading the soil as a reference crop; therefore, soil temperatures are usually cooler than a dry, non-vegetated, non-shaded soil surface.)

In terms of substantiating previous PM emissions reductions for night farming, it is worth noting, as it is for Objective Three, that PM emission values for each disking operation should only be compared with the results monitored and modeled in this project for the other disking operations. The field monitoring procedures and, especially, the AERMOD modeling were different from those used in most previous projects from which PM emissions during disking have been estimated or published. The methods and modeling were very consistent for all sampling sites monitored in this project so the comparison of one disking operation to the others is quite valid. Comparing PM emissions from this project with values from other projects conducted using other monitoring and modeling methods should not be considered valid. The modifications required to use AERMOD for this project required the sampling locations to be much closer to the source than is generally the case for large, stationary sources for which AERMOD was designed. The emissions modeled under these circumstances are very likely to be higher than would be the case if the samplers had been farther downwind from a stationary source.

Fifth Objective - Contribute to the verification of the validity of the methodology and field protocols for evaluating conservation management practices

The fifth objective was to contribute to the verification of the validity of the methodology and field protocols for evaluating conservation management practices. Discussions on the Policy on Approval of New Conservation Management Practices (CMPs) took place in the San

Joaquin Air Pollution Control District (SJVAPCD) Agricultural Technical Committee (Ag Tech) in April-May 2010. Members of the research team participated in the discussions and submitted written comments. The policy developed by the committee was approved by the air district.

CONCLUSIONS AND RECOMMENDATIONS

A dust control unit (DCU) mounted on a field disk was tested at the University Agricultural Laboratory at CSUF. The DCU was tested with the mist 'ON' and 'OFF' during field disking operations. The project objectives as stated in the original proposal and contract were:

1) To quantify the PM-reducing potential of an existing DCU misting apparatus attached to a common agricultural disk
2) To substantiate the temperature-reducing effect of the fine water mist on the heated dust plume generated by the disk
3) To substantiate previous emission factors for disking.
4) To substantiate previous emission reduction standards for night farming
5) To contribute to the verification of the validity of the methodology and field protocols for evaluating conservation management practices

First Objective - Quantify the PM-reducing potential of an existing DCU misting apparatus attached to a common agricultural disk

Operation of the DCU reduced PM emissions in most of the replications of the study. Overall, the DCU reduced PM_{10} during disking operations an average of 22.2%. On the most common soil texture, sandy loam, PM_{10} reduction was between 132% and 16% with an average of 30.9%. For loamy sand, clay and clay loam soils results from the limited number of replications were inconclusive. A possible explanation may be the sensitivity of AERMOD to wind speed when values were less than 10 m/s and particularly when values were less than 5 m/s (Faulkner et al., 2008).

Second objective - Substantiate the temperature-reducing effect of the fine water mist on the heated dust plume generated by the disk

Temperature sensors and a vertical air temperature profiler were used to substantiate the temperature-reducing effect of the fine water mist on the heated dust plume generated by the disk. Neither method provided reliable results. The follow-up ARI sponsored project will test nozzles in a wind tunnel and should provide more reliable results.

Third Objective - Substantiate previous emission factors for disking

The third objective of the project was to substantiate previous emission factors for disking. Due to the change from the ISCST3 to the AERMOD model, comparing PM emissions from this project with values from other projects conducted using other monitoring and modeling methods should not be considered valid. The field monitoring procedures and, especially, the AERMOD modeling were different from those used in most previous projects from which PM emissions during disking have been estimated or published.

Fourth Objective - Substantiate previous emission reduction standards for night farming

In terms of substantiating previous PM emissions reductions for night farming, conditions where the soil temperature is below the air temperature, the use of CIMIS data (from 15cm) in this preliminary study did not properly characterize the soil surface temperature. Direct measurement of temperatures at and near the soil surface will be included in the ARI project. The single test under night conditions (T air > T soil) was carried out in July 9, 2009 at 6:29am. The DCU achieved a PM_{10} reduction of 40% but the lack of detailed soil temperature data precludes conclusions from this limited data.

Fifth Objective - Contribute to the verification of the validity of the methodology and field protocols for evaluating conservation management practices

The fifth objective was to contribute to the verification of the validity of the methodology and field protocols for evaluating conservation management practices. Team members participated in discussions on the Approval of New Conservation Management Practices (CMPs) Policy that took place in the San Joaquin Air Pollution Control District (SJVAPCD) Agricultural Technical Committee (Ag Tech) in April-May 2010. The policy developed by the committee was subsequently approved by the air district.

REFERENCES

1. California Department of Food and Agriculture. 2009. California Agricultural Production Statistics 2009-2010. http://www.cdfa.ca.gov/statistics/.

2. U.S. EPA. 2010 Particulate Matter. Basic Information. http://www.epa.gov/oar/particlepollution/basic.html.

3. Hinds, W. C. 1999. Aerosol Technology: Properties, Behavior, and Measurement of Airborne Particles, 2nd Edition. John Wiley & Sons, New York.

4. California Air Resources Board. 2008. Index of Methodologies by Major Category, Appendix A, Agricultural Activities. http://www.arb.ca.gov/ei/areasrc/onehtm/oneapp.htm.

5. Fresno County Department of Agriculture. 2009. 2008 Agricultural Crop and Livestock Report. http://www.co.fresno.ca.us/uploadedFiles/Departments/Agricultural_Commissioner/PDF/2008%20Crop%20Report%20All.pdf.

6. Peacock, W. L., Vasquez, S. J., Hashim, J. M., Fidelibus, M. W., Leavitt, G. M., Klonsky, K. M. and De Moura, R. L. 2006. Sample costs to establish a vineyard and produce grapes for raisins. UCCE.

7. Vasquez, S. J., Fidelibus, M. W., Christensen, L. P., Peacock, W. L., Klonsky, K. M. and De Moura, R. L. 2006. Sample costs to establish a vineyard and produce grapes for raisins. Continuous Tray Dried Raisins. UCCE.

8. Christensen, P. 2000. Current Developments in Harvest Mechanization and DOV, in: Raisin Production Manual. University of California, Agricultural and Natural Resources Publication 3393, Oakland, CA.

9. Vasquez, S. J., Peacock, W. L., Leavitt, G. M., Christensen, L. P., Sutter, S. R., Hembree, K. J., Klonsky, K. M., Katayama D. G. and De Moura, R. L. 2003. Sample costs to establish a vineyard and produce Dried-On-Vine raisins. UCCE.

10. National Resource Conservation Service (NRCS). 2010. Web Soil Survey. June 15, 2010. http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm.

11. Buser, M., C. Parnell Jr., B. Shaw, and R. Lacey. 2007. Particulate matter sampler errors due to the interaction of particle size and sampler performance characteristics: background and theory. *Trans. ASABE* 50(1): 221-228.

12. Environmental Protection Agency (EPA). 2010. Technology Transfer Network Support Center for Regulatory Atmospheric Modeling. June 16, 2010. http://www.epa.gov/ttn/scram/dispersion_prefrec.htm#aermod.

13. Faulkner, W. B., Goodrich, L. B., Botlaguduru, V. S. V., Capareda, S. C. and Parnell, C. B.. 2009. Particulate Matter Emission Factors for Almond Harvest as a Function of Harvester Speed. *J. Air & Waste Manage. Assoc.* **59**:943–949.

14. Goodrich, L. B., Faulkner, W. B., Capareda, S. C., Krauter, C. and Parnell, C. B. 2009. Particulate Matter Emissions from Reduced-Pass Almond Sweeping. *Transactions of the ASABE.* 52(5): 1669-1675.

15. B. Holmén , B., Miller, D., Hiscox, A. Yang, W., Wang, J., Sammis, T. and Bottoms, R. 2008. Near-source particulate emissions and plume dynamics from agricultural field operations. J. Atmos. Chem. Vol. 59 (2): 117-134.

16. Madden, N. M. 2009. Soil properties and particulate matter emissions from tillage. PhD dissertation, University of California, Davis, 2009.

17. Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at http://websoilsurvey.nrcs.usda.gov/. Accessed 08/02/2011.

18. Agronomy Tech Note #MN-19. Estimating crop residue cover. Natural Resources Conservation Service, USDA. St. Paul, MN.

19. Faulkner, W. B., Shaw, B. W. and Grotsch, T. 2008. Sensitivity of Two Dispersion Models (AERMOD and ISCST3) to Input Parameters for a Rural Ground-Level Area Source *J. Air & Waste Manage. Assoc*. **58**:1288–1296.

California State University, Fresno Foundation,
a recognized Auxiliary Corporation of California State University, Fresno

Misting: A Viable Conservation Management Practice (CMP)
For
Reducing PM10 Generated by Disking

APPENDIX A

Protocol for Measurement of Particulate Matter (PM)

A-1 Introduction

The California State University at Fresno collected particulate matter (PM) data from agricultural disking operations. This protocol, which was prepared prior to field data collection, describes measurement and data collection methods for PM study.

This project is funded by USDA-Natural Resources Conservation Service (NRCS) through the California Association of Resource Conservation Districts with the following objectives:

1. Quantify the PM-reducing potential of an existing DCU misting apparatus attached to a common agricultural disk
2. Substantiate the temperature-reducing effect of the fine water mist on the heated dust plume generated by the disk
3. Substantiate previous emission factors for disking
4. Substantiate previous emission reduction standards for night farming and
5. Contribute to the verification of the validity of the methodology and field protocols for evaluating conservation management practices.

A-2 Scope and Test Methods

The following PM indicators were measured in this study: $PM_{2.5}$, PM_{10}, and Total Suspended Particulate (TSP). Currently, TSP is not a federal or state PM ambient air quality standard. In these projects, TSP measurements were used to determine $PM_{2.5}$ and PM_{10} through analysis of particle size distribution. In addition to the research objectives of these projects, performance and operational requirements of the U.S. Environmental Protection Agency (EPA) and California Air Resources Board (ARB) were complied by following the Federal Reference Methods for $PM_{2.5}$, and PM_{10} measurements. These federal methods, however, are for 24-hour period ambient sampling, whereas sampling period in this study is about one hour.

All PM measurements in this study were filter-based sampling method with constant low-volume airflow (1 cubic meter per hour = 16.67 liters per minute). Electrical air samplers drew air and suspended PM was separated by particle-size separators and collected on filters, which were weighed before and after sampling to determine the net gain due to PM mass. The mass concentration (micrograms per cubic meter, $\mu g/m^3$) was computed as the total mass of collected particles in the $PM_{2.5}$, PM_{10}, and TSP size ranges divided by the actual volume of air sampled (local temperature and pressure). Each sample was collected during a 30- to 75-minute period to collect adequate PM mass, depending upon the type of operation. Upwind samplers required more measurement times than downwind samplers to collect sufficient mass for gravimetric analysis. Therefore, upwind samplers run more than downwind samplers and then were averaged for the test duration period. All the results of $PM_{2.5}$, PM_{10}, and TSP measurements in this study were expressed in units of mass per unit volume of air per unit area ($\mu g/m^3/ha$) for each operation. All the relevant site data such as soil, meteorological and surface parameters were collected at the time of field sampling.

The focus of this study was to compare PM_{10} and $PM_{2.5}$ components of mechanically generated fugitive dust during disking operations. Specifically this study compares PM_{10} emissions when a DCU is on and off. This comparison provides information on relative rather than absolute emission rates. Comparative field tests were made in similar environmental conditions, as emission rates are very sensitive to environmental conditions such as relative humidity, wind direction variability, solar radiation, and soil and air temperature.

Representative monitors were located upwind and downwind of the test areas to obtain net PM emissions. The EPA AERMOD was used to model PM emissions in this study. This technique uses an indirect calculation through the application of an atmospheric dispersion model (AERMOD).

A-3 Size-Selective Inlet Heads

These projects use 3 different size-selective inlet heads to collect $PM_{2.5}$, PM_{10}, and TSP. $PM_{2.5}$ and PM_{10} particles are those particles with an aerodynamic diameter less than or equal to a nominal 2.5 and 10 micrometers, respectively; TSP has no particular particle size selectivity.

$PM_{2.5}$ and PM_{10} use EPA- and California-approved inlet heads manufactured by BGI Inc. (BGI, Waltham, MA). PM_{10} inlet head is basically identical to $PM_{2.5}$ inlet head except that Very Sharp Cut Cyclone (VSCC) is removed and replaced by a straight passage. TSP inlet head is designed and made in-house by the Texas A&M University. The design of this low-volume inlet head is based on the EPA-approved high-volume TSP inlet head.

The vertical height of all ambient air inlet heads was 2 meters above ground level, and the horizontal distance between collocated inlets was at least 1.2 meters and no more than 3 meters.

All PM inlets were regularly cleaned with brush, clean air, and lint-free wipe before field sampling to prevent build-up of dust that could change the cut-off characteristics of the inlets. PM_{10} and $PM_{2.5}$ samplers do not have 100% efficiency, i.e., do not have absolute particle size limits (cut points). In PM sampling, the cut point is the particle size where 50% of the PM is captured by the pre-separator and 50% of the PM penetrates to the filter. It means that a portion of PM greater than the size of interest (PM_{10} or $PM_{2.5}$) is collected on the filter and a portion of PM less than the size of interest is not collected on the filter. The 50% cut points for PM_{10} and $PM_{2.5}$ have been established by EPA at 10±0.5 and 2.5±0.2 micrometers, respectively.

The original EPA high-volume TSP sampler does not have a clearly defined upper PM size cutoff. According to EPA, TSP uses a high-volume sampler (1,130-1,700 liters per minute) to collect particles with an aerodynamic equivalent diameter (AED) of approximately 100 micrometers or less. TSP, however, is commonly recognized as PM that is 25 to 40 micrometers AED and smaller, depending on the wind speed. Unlike PM_{10} and $PM_{2.5}$ samplers, high-volume TSP samplers have poor precision and wide variation in the upper particle size cut due to wind speed.

A-4 Sampling Methods

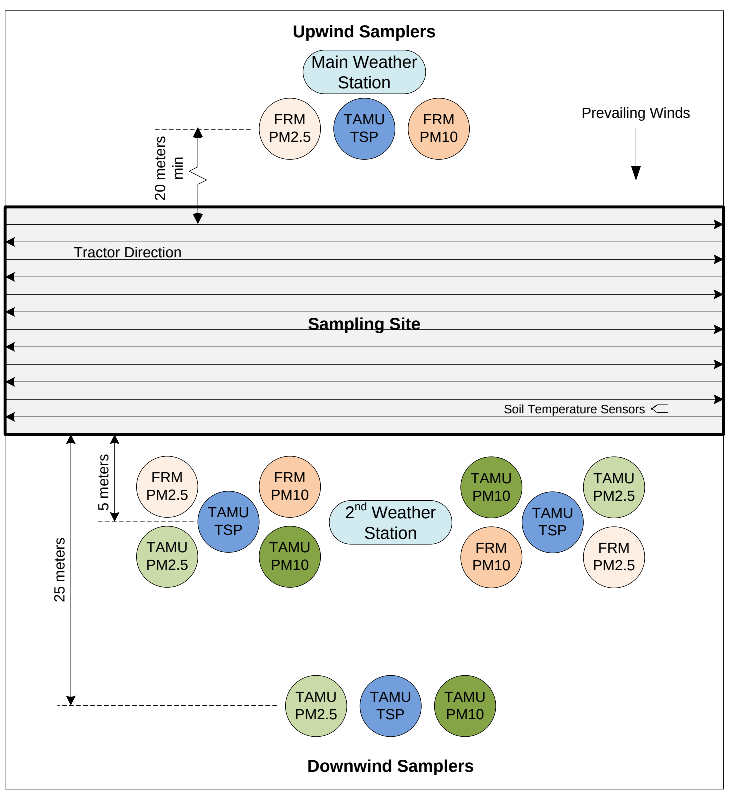
Two different sampling methods were employed in these projects, namely: Federal Reference Method (FRM), and Texas A&M University Method (TAMU).

FRM includes $PM_{2.5}$, and PM_{10}. TAMU includes $PM_{2.5}$, PM_{10}, and TSP. Additionally, $PM_{2.5}$ and PM_{10} was determined through particle size distribution analysis using TSP data. The following table and figure show the number and type of PM samplers for different sampling methods for upwind and downwind locations. Upwind samplers indicated the ambient background condition, and downwind samplers indicated the background plus the PM mass produced by the field sampling. The measured PM concentration of upwind samplers was subtracted from the downwind samplers to give net measured mass concentrations for each operation.

Number of PM samplers for each sampling method and location

Sampling Method	Upwind Samplers			Downwind Samplers		
	$PM_{2.5}$	PM_{10}	TSP	$PM_{2.5}$	PM_{10}	TSP
Federal Reference Method (FRM)	1	1		2	2	
Texas A&M University Method (TAMU)			1	3	3	3
Total	1	1	1	5	5	3

Locations of PM samplers



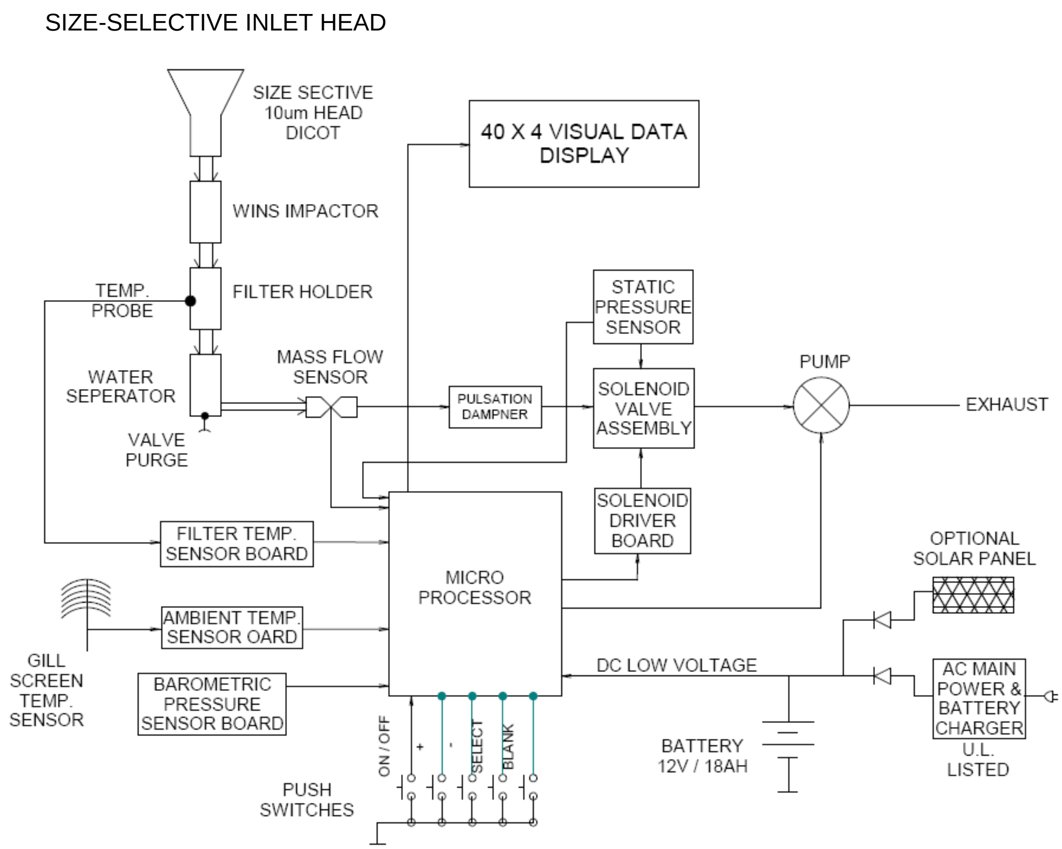
A-4-1 Federal Reference Method (FRM)

PQ200 PM samplers (BGI Inc.) were used for $PM_{2.5}$, and PM_{10} with the following EPA designation numbers:

- $PM_{2.5}$: RFPS-0498-116
- PM_{10}: RFPS-1298-125
- PMc: RFPS-1208-173

All the requirements of EPA and the manufacturer's recommendations were followed when using PQ200 instrument. The PQ200 is a microprocessor-controlled, volumetric flow rate air sampling apparatus. Measurement of EPA defined PMc requires the use of 2 PQ200 samplers; one should be set up for PM10 and the other one as a PM2.5 sampler, and satisfying specific operating instructions to perform the measurements.

The PQ system was maintained and checked per manufacturer's recommendations. The following figure shows the schematic of PQ200 (BGI Inc.).



Schematic View of PQ200 PM Sampling System

A-4-2 Texas A&M University Method (TAMU)

TAMU sampling system uses the same $PM_{2.5}$ and PM_{10} inlet heads as FRM (BGI Inc.), but the TSP inlet is designed and made in-house by Texas A&M University.

PM researchers in Texas A&M University suggest that EPA's PM size-selective inlet heads over-sample $PM_{2.5}$ and PM_{10} of agricultural operations such as disking and harvesting. They propose an alternative method of determining $PM_{2.5}$ and PM_{10} concentrations, which combines TSP measurement and corresponding particle size distribution. In this study, $PM_{2.5}$ and PM_{10} were measured directly using FRM and TAMU methods, and indirectly using TSP and particle size distribution analysis as proposed by the Texas A&M University. TSP filter samples were sent to Texas A&M University for particle size analysis.

The following equipment was used in TAMU sampling system to provide and calculate the airflow rate for PM sampling:

- Diaphragm pump (Model 927CA18, Gardner Denver Inc.) to provide the airflow and pull the PM-entrained air through the samplers,
- Sharp-edge orifice meter (3/16", made in-house by Texas A&M University) to measure the airflow,
- Differential pressure transducer (Model PX274-X05DI, Omega Engineering Inc.) to convert the pressure readings across the orifice meter to an output current (4-20 mA),
- Needle valve (Model B-1RM4, Swagelok) to adjust the airflow,
- Magnehelic gage (Model 2002, 0-2" inches of water, Dwyer Instruments Inc.) to view the required pressure drop across the orifice meter,
- Data logger (HOBO Model U12-006, Onset Computer Corp.) to record the output of pressure transducer, and
- Pulsation Dampener.

The following equation was used to set the required pressure drop across the orifice meter:

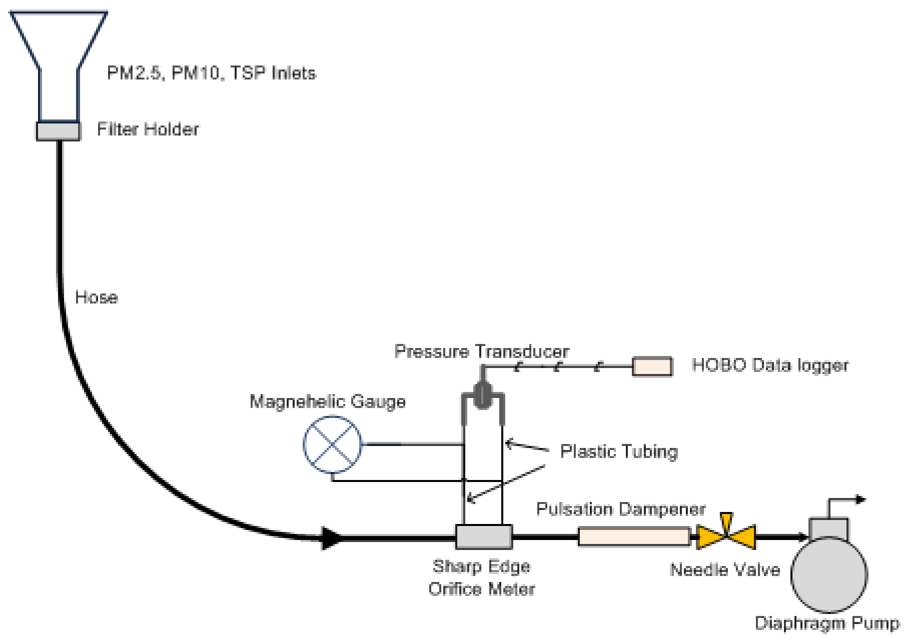
$$Q = 3.478 * K * D_o * \sqrt{\frac{\Delta P}{\sigma_a}}$$

where

Q = airflow rate (cubic meter per second)
K = orifice coefficient (dimensionless)
D_o = orifice diameter (meter)
ΔP = pressure drop across the orifice meter (millimeter H2O)
σ_a = Air density (kilogram per cubic meter)

The output from data logger, converted to millimeter H2O, was used to calculate instantaneous volumetric flow rate. Barometric pressure, air temperature, and relative humidity was measured by

Perception II (Davis Instrument) for calculating the air density at the beginning of each field sampling. Schematic of TAMU sampling equipment is shown in the following figure.



Schematic View of Texas A&M University PM Sampling System

A-5 Airflow Calibration

The size-selective inlets of various PM samplers require carefully controlled volumetric airflows to maintain the desired cut-point, thus accurate measurements of airflow rate and volume are very important in this study. The cut-off characteristics of different samplers depend on the speed of the air passing through the inlets, and the volume of air sampled will be used to calculate the PM concentration. The volumetric flow rates can vary with changes of atmospheric temperature and pressure, and PM loading on the filter.

The BGI PQ200 was checked for flow rate verification on a regular schedule using Deltacal (BGI Inc.) as recommended by the manufacturer and required by EPA. The manufacturer's procedures was followed as described in the PQ200 manual. A leak test was performed prior to calibration.

The sharp edge orifice meter was calibrated at the beginning and at the end of field sampling season using the Deltacal (BGI Inc.) and a stationary inclined manometer (Model 246, 0-6" W.C., Dwyer Instruments Inc.). A leak test was performed prior to calibration of sharp edge orifice. The orifice calibration relationship is expressed in terms of actual flow rate versus the manometer pressure drop in inches of water. The pressure transducers was checked and calibrated at the beginning of each filed sampling event using the inclined manometer and a calibration pump (Model A-396A, Dwyer Instruments Inc.).

A-6 Filter Weighing

Accurate gravimetric weighing of filters is essential as the mass of sampled PM was small in this study. Weight of filters before and after sampling was determined accurately, reproducibly and with minimal uncertainty.

Teflon filters (2-um pore size, 46.2-mm diameter, PTFE, with supporting ring, Whatman Inc.) were used to collect PM samples. The mass of PM was determined by pre- and post-weighing of the sample filters. An electronic microbalance with a readability of 0 .001 mg (Model MX5, Mettler-Toledo Inc., Switzerland) was used to weigh the filters. The balance was located on a sturdy, vibration-free base and calibrated twice a year, at the beginning and at the end of field sampling season.

A-6-1 Filter Handling and Conditioning

All filters were visually inspected for defects or signs of contamination using a light table, and discarded if any defects are noted (e.g., discoloration, pinhole, loose material, irregular surface). Petri dishes (50x9 mm diameter, Pall Corp.) were used to store the filters in the weighing room. Filter cassettes, protected within metal canisters, were used to transport the filters between the balance room and the sampling locations. Non-serrated tweezers were used to handle the filters to minimize possible contamination.

Teflon filters accumulate a surface electrical charge which could affect the weight. The residual electrostatic charge on the filter may produce a force between the filter on the weighing pan and the microbalance independent of filter weight and thus could bias the weight measurements. Earth-grounded conductive mats were placed on the weighing table surface and beneath the operator’s feet to reduce electrostatic charge buildup. Further, filters were treated with a high- voltage anti-static device (PRX U-Electrode, HAUG GmbH&CO. KG, Germany) before weighing to neutralize the electrostatic charges.

Moisture content can affect filter weight. Filters were equilibrated for a minimum of 24 hours in a controlled balance room before weighing. During the equilibration periods, the air temperature was maintained at a mean value of 20-23ºC (68-74ºF), and relative humidity was maintained at a mean value of 30-40%. Filters were kept on a conditioning rack that covers the filters from top but it is open on all four sides. The holding time for pre- and post-sampling filters is 10 days maximum. Before pre-sampling and after post-sampling, filters were stored in labeled Petri dishes. Filter equilibration was repeated prior to weighing if the temperature or relative humidity in the equilibration room is different from the limits. Air temperature and relative humidity were monitored using 12-Bit Temp Smart Sensor (Onset Computer Corp.) and recorded continuously using HOBO micro station (Onset Computer Corp.). The temperature and relative humidity sensors of the equilibration room were checked against certified sensors before the start of PM measurements and at the end of field sampling.

The balance room was kept closed at all times except when the balance was in use. The balance chamber, tables, floor, and all dust catching surfaces were cleaned regularly. The HVAC filters were inspected biweekly and replaced if necessary. The controlled room air supply was filtered as well to reduce dust circulation in the balance room.

A-6-2 Filter Blanks

Filter lot blanks were used to determine filter weight stability due to the loss of gaseous material to or from filters over long periods of time (e.g., 4 weeks). The weight stability of filters was determined by assigning 2 new filters from each box of new filters received from the manufacturer. After an initial conditioning, the lot blanks were weighed and reweighed with other sample filters from the same box.

Field and lab blank filters were used for quality assurance (QA) purposes for each field sampling event. Blanks were used to monitor contamination during sampling, transport, storage or weighing.

At each weighing session, new field blanks were weighed along with the pre-loading sample filters. 5 field blank filters were used in each sampling event in the following sampling systems: FRM $PM_{2.5}$, TAMU $PM_{2.5}$, FRM PM_{10}, TAMU PM_{10}, and TAMU TSP, one filter each. Field blank filters were transported to the site like sample filters, momentarily installed in the samplers, retrieved from the samplers without air sampling, and reweighed along with the sample filters after conditioning.

Like filed blanks, new lab blank filters were pre- and post-weighed, conditioned and reconditioned, and stored in Petri dishes along with sample filters. 3 lab blanks will be used for each sampling event. Lab blank filters remained in the lab during field sampling.

A-6-3 Filter Weighing Procedure

The balance was calibrated by the manufacturer's representative before the start and at the end of sampling season, twice a year. At each weighing session, the balance was calibrated using an internal mass standard. This calibration was confirmed using 100 milligram and 200 milligram mass working standards (American Society for Testing and Materials (ASTM) Class 1 Test Weights). The working standards were calibrated to primary standards annually.

An operational weighing protocol was developed and strictly enforced to ensure quality control (QC), consistent filter weighing during the course of measurements, and minimize errors due to filter handling, transfer, storage and weighing. A typical weighing sequence is given in the following table.

Typical Weighing Sequence

Weigh No.	Description
1	Empty balance pan
2	100mg working standard
3	200mg working standard
4	Control filter
5	Tare filter
6 to 18	(8) Sample filters, (4) field and lab blanks, and (1) duplicate filter (13 filters total)
19	Empty balance pan
20	100mg working standard

21	200mg working standard
22	Control filter
23	Tare filter
24 to 36	(8) Sample filters, (4) field and lab blanks, and (1) duplicate filter (13 filters total)
37	Empty balance pan
38	100mg working standard
39	200mg working standard
40	Control filter
41	Tare filter

The tare and control filters were used to monitor any significant changes in the balance room's environment that may affect the filter weights. Both the pre- and post-sampling weightings were carried out on the same analytical, by the same operator, and were completed within maximum 10 days of sampling period. All the balance weight readings were transferred to a computer automatically using the recommended manufacturer's software (Mettler Labx Direct). Every effort was made to have the same person weight the samples for the whole testing period.

A-6-4 Filter Weighing Quality Assurance (QA)/Quality Control (QC) Checks

The following data assessment and QC was used in all pre- and post-sampling filters.

Requirement	Frequency	Acceptance Criteria
Empty balance pan	1 at the beginning, 1 in the middle, and 1 at the end of each weighing session	±3 µg
100mg working mass	1 at the beginning, 1 in the middle, and 1 at the end of each weighing session	±3 µg
200mg working mass	1 at the beginning, 1 in the middle, and 1 at the end of each weighing session	±3 µg
Control Filter	1 at the beginning, 1 in the middle, and 1 at the end of each weighing session	±5 µg/filter change from last weighing session
Tare Filter	1 at the beginning, 1 in the middle, and 1 at the end of each weighing session	±5 µg/filter change from last weighing session
Field Blanks	All sampling events, 5 blanks per sampling event	±20 µg between weighings
Lab Blanks	All sampling events, 3 blanks per sampling event	±10 µg between weighings
Lab duplicate (reweigh)	2 filters in each sampling session	±10 µg between weighings

Balance room temperature	Check record for 24 hours prior to weighing	Mean temperature 20-23°C, ± 2 °C over 24 hours
Balance room relative humidity	Check record for 24 hours prior to weighing	Average relative humidity 35% , ± 5% over 24 hours

A-7 Site Data Collection

All PM sampling was made under actual and normal field conditions, and no attempt was made to modify normal or typical field operation or activity. Site data includes filters, soil samples, meteorological data and the related local information to characterize the sampling site as required by AEMOD.

A-7-1 Soil Samples

Soil surface temperature (around 4 inches below the soil surface) was monitored and logged continuously during the PM sampling using thermocouples (Model TCAV, Campbell Scientific). Representative soil surface was examined for residue contents and soil samples from top few inches of soil surface were collected at each PM sampling site. Soil samples were sealed in plastic bags and transported to the Graduate Laboratory (CSU Fresno) for moisture content (ASTM D2216), dry sieving as described in EPA AP-42 (ASTM C-136), and wet sieving (particle size analysis).

Soil moisture at the time of field testing

Sample Date:	Agricultural operation	Sample No.	Location	Depth	% moisture
8/10/2009	Disk 1	29	Dakota/Lake	2-4"	2.11%
8/10/2009	Disk 2	30	Dakota/Lake	2-4"	5.19%
8/11/2009	Disk 1	31	Dakota/Lake	2-4"	7.73%
8/11/2009	Disk 2	32	Dakota/Lake	2-4"	7.17%
8/12/2009	Disk 1	33	Dakota/Lake	2-4"	3.48%
8/12/2009	Disk 2	34	Dakota/Lake	2-4"	4.47%
8/13/2009	Terracing 1	35	Dakota/Lake	2-4"	2.53%
8/13/2009	Terracing 2	36	Dakota/Lake	2-4"	2.21%
8/13/2009	Terracing 3	37	Dakota/Lake	2-4"	1.80%
9/10/2009	Harvesting 1	38	Trinity/Dakota	2-4"	3.14%
9/17/2009	Harvesting 2	39	Grantland/Nebraska	2-4"	0.57%
9/17/2009	Harvesting 3	40	Grantland/Nebraska	2-4"	0.74%
10/6/2009	Back Terracing 1	41	Clinton/Humbolt	2-4"	0.47%
10/6/2009	Back Terracing 2	42	Clinton/Humbolt	2-4"	1.34%
10/6/2009	Back Terracing 3	43	Clinton/Humbolt	2-4"	1.28%
10/12/2009	DOV	41	Yuba/Clinton	2-4"	0.47%
10/12/2009	DOV	42	Yuba/Clinton	2-4"	1.34%

7-3 Meteorological data
EPA AERMOD requires meteorological data and 3 surface characteristics: surface roughness length, albedo, and Bowen ratio. An advanced portable weather station was placed upwind and used to collect representative site specific meteorological data in all field sampling events. Surface (local) meteorological data includes air temperature, relative humidity, wind speed and direction, barometric pressure, and radiant flux. Another weather station was placed downwind to collect air temperature, relative humidity, wind speed and direction. Upper layer meteorological data were taken from representative stations, depending upon the location of field sampling. Surface characteristics of the sampling site (weather station) ware assessed using EPA recommendations. List of main sensors of the weather stations is given below.

Sensors	Model	Manufacturer
Measurement & Control Datalogger	CR5000	Campbell Scientific
Pyranometer	CMP 6	Kipp & Zonen
Pyranometer	CMP 22	Kipp & Zonen
3-D Sonic Anemometer	CSAT3	Campbell Scientific
2-D Sonic Anemometers (2 units)	WINDSONIC1-L	Gill Instruments
Wind Monitor, Speed and Direction (2 units)	5305	RM Young
Temperature & Humidity (2 units)	HMP50	Vaisala
Barometric Pressure	CS100	Setra as Model 278

7-4 Training and Safety
To obtain reliable and comparable PM data required in this study, personnel involved in the field and laboratory work received adequate education and training. To prevent personal injury, personnel involved in this study were trained to observe any warnings that are associated with PM samplers, microbalance, instrument download and upload, and any supporting supplies and equipment in the field and laboratory.

All personnel (including students) received training on how to operate the equipment safely. This training wasprovided by their supervisor. Moreover, all student and personnel watched a general video safety training course on shop safety as part of university employment requirements.

A-8 References:

AERMOD Implementation Guide- AERMOD Implementation Workgroup, Last Revised: January 9, 2008

California Air Resources Board. 2002. SOP MLD 055. Standard Operating Procedure for the Determination of $PM_{2.5}$ mass in Ambient Air by Gravimetric Analysis. Northern Laboratory branch, Monitoring and Laboratory Division.

U.S. Environmental Protection Agency (EPA) 1997. 40 CFR Part 50, Appendix L—Reference Method for the Determination of Fine Particulate Matter as PM2.5 in the Atmosphere

U.S. Environmental Protection Agency (EPA) 02/27/98, Summary of Guidance. Filter Conditioning and Weighing Facilities and procedures for PM2.5 reference and Class I Equivalent Methods.

U.S. Environmental Protection Agency (EPA) November 1998. Quality Assurance Guidance Document 2.12. Monitoring PM in 2.5 Ambient Air Using Designated Reference or Class I Equivalent Methods.

This page intentionally left blank

California State University, Fresno Foundation,
a recognized Auxiliary Corporation of California State University, Fresno

Misting: A Viable Conservation Management Practice (CMP)
For
Reducing PM10 Generated by Disking

Appendix B

AERMOD Air Quality Modeling

B-1 Introduction

Fresno State was awarded a contract to investigate Particulate Matter (PM) mitigation potential of an existing Dust Control Unit (DCU) attached to a common agricultural disk during field operations. This part of the report describes the air quality modeling components of the project. The main goal of the project is to estimate PM10 emissions during field disking operations when the DCU is 'on' and 'off'. PM10 is defined as airborne particles with aerodynamic diameters equal to or less than 10 micrometers. The PM mitigation potential of DCU on disking operations maybe better understood by measuring PM10 concentration near the field and applying an air quality model.

The standard U.S. Environmental Protection Agency (EPA) regulatory air quality model (AERMOD) has been used in this project to evaluate the relationship between ambient PM10 concentrations and emission rates. Filter-based PM10 mass balance of co-located samplers near the source of various disking operations and dispersion modeling approach has been applied in this project. This will enable comparisons among various disking operations with the DCU 'on' and 'off'. Air dispersion modeling in this project is a mathematical approximation of atmospheric processes that predicts ambient concentrations of PM10 based on the emission rates and prevailing site and meteorological data.

The modeling system used in this flat project consists of meteorological and surface characteristics programs and the AERMOD itself. Meteorological inputs for AERMOD were generated using EPA guidelines. Section B-2 describes meteorological data collected at the time of PM10 monitoring at the field sites. The EPA AERSURFACE processor was used as a tool to produce the required surface characteristics data. Field site meteorological data were collected at the time of sampling only. To show how the short-term field site data compare to the diurnal climate data, the AERMOD surface files of Fresno airport, National Climatic Data Center (NCDC), were used for demonstration purposes. Graphs of important AERMOD surface file variables are shown at the end of this Appendix.

AERMOD modeling options are presented in Section B-3 and AERMOD modeling results are presented in Section B-4. Results of the AERMOD were compared with the filter-based concentration data collected at the field sites. Section B-5 evaluates the performance of the AERMOD in predicting PM10 concentrations of various disking operations. Section B-6 presents summary and conclusion, Section B-7 provides citations for references used in this report, and Section B-8 presents graphs of AERMOD surface files for the field sites and Fresno airport weather station.
The goal of this part of the report is to show how AERMOD modeling is utilized in this project thus the results can be compared to similar projects. 2

B-2 Meteorological Data Preparation

AERMOD requires two meteorological input files: surface and upper air. The weather station at the field site and Oakland (California) station were used to provide the required meteorological data for surface and upper air. Input variables for surface and upper air files are given at the end of this Section.

The meteorological data were collected with sensors on a tower near the PM10 samplers at the time of sampling at the field sites. 5-minute averaging period was used in the calculation of all the meteorological parameters. Periods of 5-minute averages were used as hourly data in the AERMOD.

Wind speed and direction were measured with a RM Young monitor (model 5305). Ambient air temperature and humidity were measured with a Vaisala sensor (model HMP50). Solar radiation was measured with two Kipp & Zonen pyranometers (models CMP 22 and CMP 6). Barometric pressure was measured with a Setra sensor (model CS100).

The EPA guidelines (EPA 2004b) were used to calculate the required meteorological parameters as discussed below. The meteorological data were pre-processed to produce the required inputs for the model.

Sensible heat flux (*H*) was estimated with the following equation using net radiation (*Rn*) and Bowen ratio (*Bo*):

$$H = \frac{0.9R_n}{(1+\frac{1}{B_o})} \quad (1)$$

Rn was estimated from the following equation:

$$R_n = \frac{(1-A)R + c_1T^6 - \sigma_{SB}T^4 + c_2 n}{1+c_3} \quad (2)$$

where
A is albedo,
R is incoming shortwave solar radiation,
T is ambient air temperature at the reference height,
n is fractional cloud cover (assumed 0.5),
σ_{SB} is Stefan Boltzman constant (5.67x10-8 W m-2 K-4),
c_1=5.31x10-13,
c_2 = 60 W m-2, and
c_3 = 0.12. 3

Using sensible heat flux (Equation 1), the surface friction velocity (u*) and Monin-Obukhov Length (L) for the convective boundary layer were estimated through an iterative procedure and the following equations:

$$u_* = \frac{ku}{\ln\left(z_{ref}/z_o\right) - \psi_m\left(z_{ref}/L\right) + \psi_m\left(z_o/L\right)} \qquad (3)$$

$$L = -\frac{\rho c_p T u_*^3}{kgH} \qquad (4)$$

where
k is the von Karman constant (0.4),
u is the wind speed at reference height,
$zref$ is the reference height for wind speed and direction,
zo is the surface roughness length,
is the density of dry air,
cp is the specific heat capacity of air,
T is ambient temperature, and
g is the acceleration due to gravity.

ψ terms are given by:

$$\psi_m\left(z_{ref}/L\right) = 2\ln\left(\frac{1+u}{2}\right) + \ln\left(\frac{1+u^2}{2}\right) - 2tan^{-1}(u) + \frac{\pi}{2} \qquad (5)$$

$$\psi_m\left(z_o/L\right) = 2\ln\left(\frac{1+u_o}{2}\right) + \ln\left(\frac{1+u_o^2}{2}\right) - 2tan^{-1}(u_o) + \frac{\pi}{2} \qquad (6)$$

$$u = \left(1 - 16z_{ref}/L\right)^{1/4} \qquad (7)$$

$$u_o = (1 - 16z_o/L)^{1/4} \qquad (8)$$

The convective mixing height (z_{ic}) and the mechanical mixing height (z_{im}) were estimated using the following equations:

$$z_{ic}\theta(z_{ic}) - \int_0^{z_{ic}} \theta(z)dz = (1 + 2A)\int_0^t \frac{H(t')}{\rho c_p} dt' \qquad (9)$$

$$z_{im}(t + \Delta t) = z_{im}(t)e^{(-\Delta t/\tau)} + z_{ie}(t + \Delta t)[1 - e^{(-\Delta t/\tau)}] \qquad (10)$$

$$z_{ie} = 2300u_*^{3/2} \qquad (11)$$

$$\tau = \frac{z_{im}(t)}{\beta_\tau u_*(t+\Delta t)} \qquad (12)$$

where
θ is the potential temperature,
A is set equal to 0.20,
τ is the time scale,
β_τ is set equal to 2.0, and
Z_{ie} is equilibrium mechanical mixing height.

Finally, the convective velocity scale (w_*) was calculated as:

$$w_* = \left[\frac{gHz_{ic}}{\rho c_p T}\right]^{1/3} \qquad (13)$$

Surface characteristics that need to be determined for AERMOD include surface roughness length (z_o), albedo (A), and Bowen ratio (B_o). The surface roughness represents the height at which the mean horizontal wind speed is assumed zero. The albedo is the measure of reflectivity and is the fraction of total incoming solar radiation reflected back into space without absorption. The Bowen ratio is an indicator of surface moisture and it is the ratio of sensible heat flux to latent heat flux.

The EPA AERSURFACE (EPA 2008) and EPA recommendations (EPA 2009) were used to process land-use data to estimate appropriate surface characteristics in eight sectors centered on the weather station of the field site. Typical values for surface characteristics used in this project are:

Surface roughness length: 0.3
Bowen ratio: 0.5
Noontime Albedo: 0.18

The meteorological station was placed in the test plot before the sampling and removed from the plot after the sampling. Thus, field meteorological data for different field plots are available for the period of sampling only. To provide perspectives on how these short-term meteorological data compare to long-term well-established meteorological stations, important variables of AERMOD surface files are graphed at the end of this Appendix (Section A-8) for all the field sites, CIMIS at Fresno State, Fresno airport and at Five Points. AERMET was used to prepare the surface file for CIMIS using similar field surface characteristics. For Fresno airport, the AERMOD ready surface file was downloaded from the web site of San Joaquin Valley Air Pollution Control District (http://valleyair.org/).

List of input variables for surface file:

1. Year
2. Month (1-12)
3. Day (1-31)
4. Julian day (1-366)
5. Hour (1-24)
6. Sensible heat flux, *H* (Watts/meter2)
7. Surface friction velocity, *u** (meters/second)
8. Convective velocity scale, w* (meters/second)
9. Laps rate in the 500 m layer above the planetary boundary layer (K/meter)
10. Convective mixing height, *Zic* (meters)
11. Mechanical mixing height, *Zim* (meters)
12. Monin-Obukhov length, *L* (meters)
13. Surface roughness length, *z0* (meters)
14. Bowen ratio, *Bo*
15. Albedo, *A*
16. Reference wind speed (meters/second)
17. Reference wind direction (degrees)
18. Height of reference wind speed (meters)
19. Reference ambient temperature (degrees Kelvin)
20. Height of reference temperature (meters)
21. Precipitation code
22. Precipitation rate (millimeter per hour)
23. Relative humidity (percent)
24. Surface pressure (millibars)
25. Cloud cover (tenths)

List of input variables for upper air file:
1. Year
2. Month (1-12)
3. Day (1-31)
4. Hour (1-24)
5. Measurement height (meters)
6. Height flag (Flag = 1 for top measurement level)
7. Wind direction (degrees)
8. Wind speed (meters/second)
9. Ambient temperature (Celsius)
10. Standard deviation of the wind direction (degrees)
11. Standard deviation of the vertical wind speed (meters/second) [6]

B-3 AERMOD Modeling Options

AERMOD has been developed by the American Meteorological Society (AMS) and the EPA. AMS/EPA regulatory model (AERMOD) is a steady-state Gaussian plume dispersion model that could be used to assess and compare PM10 concentrations from the DCU unit with the misting system ‘on’ and ‘off’ on various disking operations. Current AERMOD version (09292) was used in this study and AERMOD VIEW (version 6.7.1. Lakes Environmental) was used as interface for the AERMOD.

The AERMOD model requires well-defined PM10 source-receptor locations. These locations were identified on-site using Global Positioning System (GPS) and were used as inputs in AERMOD application.

All test sites in this project were flat and bare agricultural fields except one field. In this field, vines were planted on 3.65 meters (12-foot) row spacing and had about 200 meters (660 feet) row length. Number of rows (tractor passes) that were monitored at each sampling event ranged from 12 to 15 rows (passes), except in raisin which was 10 rows. Each pass was 3.65 meters (12 feet) wide and about 80 meters (260 feet) to 190 meters (620 feet) long, depending upon the field conditions.

Downwind PM10 samplers were located near the middle of field and 5 meters downwind of the first sampling row (tractor pass). The prevailing wind direction at the time of field sampling (usually around noon and early afternoon) in the San Joaquin Valley is from north-west. The heights of all PM10 inlet heads were 2 meters from ground elevation.

AERMOD is a mathematical program that utilizes source characteristics and atmospheric conditions to simulate pollutant concentration. AERMOD accepts a variety of source options such as point, volume, area, and line sources (EPA 1995; EPA 2004a; EPA 2005). In this project, the DCU with the misting ‘off’ and ‘on’ was tested in every other row (pass) to reduce any possible soil variations that could affect the generation of PM10. Thus, line source modeling option was employed in this analysis to compare the DCU in ‘off’ and ‘on’ positions.

Line source characteristics used in the AERMOD modeling include emission rate, release height, length of side, and vertical dimension. Identical emission rate of 1.0 gram per second was used in all modeling for comparison purposes. Height of release was assumed zero in all bare fields and 0.50 meters (1.5 feet) in the raisin field. Length of side was 3.65 meters (12 feet) in all modeling runs. Vertical dimension was assumed zero in all bare fields and 1.0 meter (3 feet) in the raisin field.

B-4 AERMOD Modeling Results

The output of AERMOD dispersion modeling in this study is average for the period of field testing. This output is the ambient PM10 concentration (micrograms per cubic meter) for the initial (nominal) emission rate of one (1) gram per second in each field test. Net downwind (i.e., downwind minus upwind) concentrations were used in AERMOD to back calculate the PM10 emission rate using the following relationship:

$$\frac{Q_1}{Q_2} = \frac{C_1}{C_2} \qquad (14)$$

where
Q1 is AERMOD nominal emission rate (g/s),
Q2 is back-calculated emission rate for a given condition and location (g/s),
C1 is modeled concentration (□g/m3), and
C2 is measured concentration (□g/m3).

At each field testing, a total of 4 co-located PM10 samplers were used to measure particulates: 2 Federal Reference Method (FRM) PM10 samplers, and 2 Texas A&M (TAMU) PM10 samplers. Table 1 below presents all the measured and back calculated (modeled) concentrations of individual PM10 samplers for all the disking operations.

Table 1- Measured and modeled PM10 concentrations for all field testings

Sampler Type	Date	TREATMENT	Measured	Back Calculated
FRM PM10	6/22/2009	Mist 'OFF'	645	795
FRM PM10	6/22/2009	Mist 'OFF'	702	792
TAMU PM10	6/22/2009	Mist 'OFF'	828	809
TAMU PM10	6/22/2009	Mist 'OFF'	1,039	812
FRM PM10	6/22/2009	Mist 'ON'	446	778
FRM PM10	6/22/2009	Mist 'ON'	764	778
TAMU PM10	6/22/2009	Mist 'ON'	1,029	760
TAMU PM10	6/22/2009	Mist 'ON'	816	760
FRM PM10	6/23/2009	Mist 'OFF'	324	1,015
FRM PM10	6/23/2009	Mist 'OFF'	953	1,022
TAMU PM10	6/23/2009	Mist 'OFF'	1,465	1,002
TAMU PM10	6/23/2009	Mist 'OFF'	1,306	1,014
FRM PM10	6/23/2009	Mist 'ON'	542	793
FRM PM10	6/23/2009	Mist 'ON'	835	797
TAMU PM10	6/23/2009	Mist 'ON'	966	769
TAMU PM10	6/23/2009	Mist 'ON'	783	773
FRM PM10	6/24/2009	Mist 'OFF'	1,003	1,428
FRM PM10	6/24/2009	Mist 'OFF'	1,997	1,420

TAMU PM10	6/24/2009	Mist 'OFF'	1,286	1,513
TAMU PM10	6/24/2009	Mist 'OFF'	1,571	1,509
FRM PM10	6/24/2009	Mist 'ON'	810	1,237
FRM PM10	6/24/2009	Mist 'ON'	1,103	1,235
TAMU PM10	6/24/2009	Mist 'ON'	1,423	1,204
TAMU PM10	6/24/2009	Mist 'ON'	1,526	1,202
FRM PM10	7/1/2009	Mist 'OFF'	1,304	1,703
FRM PM10	7/1/2009	Mist 'OFF'	2,010	1,717
TAMU PM10	7/1/2009	Mist 'OFF'	1,802	1,694
TAMU PM10	7/1/2009	Mist 'OFF'	1,705	1,696
FRM PM10	7/1/2009	Mist 'ON'	1,684	1,714
FRM PM10	7/1/2009	Mist 'ON'	1,633	1,710
TAMU PM10	7/1/2009	Mist 'ON'	1,588	1,664
TAMU PM10	7/1/2009	Mist 'ON'	1,840	1,661
FRM PM10	7/6/2009	Mist 'OFF'	2,222	2,491
FRM PM10	7/6/2009	Mist 'OFF'	2,003	2,469
TAMU PM10	7/6/2009	Mist 'OFF'	2,953	2,487
TAMU PM10	7/6/2009	Mist 'OFF'	2,740	2,470
FRM PM10	7/6/2009	Mist 'ON'	1,093	1,552
FRM PM10	7/6/2009	Mist 'ON'	1,115	1,544
TAMU PM10	7/6/2009	Mist 'ON'	2,112	1,507
TAMU PM10	7/6/2009	Mist 'ON'	1,756	1,499
FRM PM10	7/7/2009	Mist 'OFF'	590	1,014
FRM PM10	7/7/2009	Mist 'OFF'	972	1,020
TAMU PM10	7/7/2009	Mist 'OFF'	1,147	1,004
TAMU PM10	7/7/2009	Mist 'OFF'	1,326	1,004
FRM PM10	7/7/2009	Mist 'ON'	1,366	1,372
FRM PM10	7/7/2009	Mist 'ON'	1,089	1,374
TAMU PM10	7/7/2009	Mist 'ON'	1,415	1,321
TAMU PM10	7/7/2009	Mist 'ON'	1,510	1,324
FRM PM10	7/9/2009	Mist 'OFF'	606	2,846
FRM PM10	7/9/2009	Mist 'OFF'	3,487	2,906
TAMU PM10	7/9/2009	Mist 'OFF'	3,519	2,940
TAMU PM10	7/9/2009	Mist 'OFF'	3,991	2,871
FRM PM10	7/9/2009	Mist 'ON'	1,786	1,454
FRM PM10	7/9/2009	Mist 'ON'	1,293	1,442
TAMU PM10	7/9/2009	Mist 'ON'	1,301	1,414
TAMU PM10	7/9/2009	Mist 'ON'	1,338	1,402
FRM PM10	7/20/2009	Mist 'OFF'	2,886	2,624
FRM PM10	7/20/2009	Mist 'OFF'	2,047	2,659

TAMU PM10	7/20/2009	Mist 'OFF'	3,305	2,807
TAMU PM10	7/20/2009	Mist 'OFF'	2,676	2,809
FRM PM10	7/20/2009	Mist 'ON'	952	1,245
FRM PM10	7/20/2009	Mist 'ON'	584	1,221
TAMU PM10	7/20/2009	Mist 'ON'	1,718	1,205
TAMU PM10	7/20/2009	Mist 'ON'	1,570	1,180
FRM PM10	7/21/2009	Mist 'OFF'	724	884
FRM PM10	7/21/2009	Mist 'OFF'	950	886
TAMU PM10	7/21/2009	Mist 'OFF'	976	925
TAMU PM10	7/21/2009	Mist 'OFF'	975	925
FRM PM10	7/21/2009	Mist 'ON'	1,041	1,451
FRM PM10	7/21/2009	Mist 'ON'	1,805	1,449
TAMU PM10	7/21/2009	Mist 'ON'	1,438	1,394
TAMU PM10	7/21/2009	Mist 'ON'	1,401	1,394
FRM PM10	7/22/2009	Mist 'OFF'	765	1,529
FRM PM10	7/22/2009	Mist 'OFF'	1,660	1,543
TAMU PM10	7/22/2009	Mist 'OFF'	1,925	1,573
TAMU PM10	7/22/2009	Mist 'OFF'	1,866	1,555
FRM PM10	7/22/2009	Mist ‘ON’	395	658
FRM PM10	7/22/2009	Mist 'ON'	551	650
TAMU PM10	7/22/2009	Mist 'ON'	959	637
TAMU PM10	7/22/2009	Mist 'ON'	657	629
FRM PM10	10/29/2009	Mist 'OFF'1	40	78
FRM PM10	10/29/2009	Mist 'OFF'1	63	78
TAMU PM10	10/29/2009	Mist 'OFF'1	126	77
TAMU PM10	10/29/2009	Mist 'OFF'1	81	77
FRM PM10	10/29/2009	Mist 'OFF'2	48	44
FRM PM10	10/29/2009	Mist 'OFF'2	46	43
TAMU PM10	10/29/2009	Mist 'OFF'2	55	43
TAMU PM10	10/29/2009	Mist 'OFF'2	26	43
FRM PM10	10/29/2009	Mist 'ON'1	67	98
FRM PM10	10/29/2009	Mist 'ON'1	76	98
TAMU PM10	10/29/2009	Mist 'ON'1	159	98
TAMU PM10	10/29/2009	Mist 'ON'1	90	98
FRM PM10	10/29/2009	Mist 'ON'2	73	92
FRM PM10	10/29/2009	Mist 'ON'2	43	92
TAMU PM10	10/29/2009	Mist 'ON'2	108	91
TAMU PM10	10/29/2009	Mist 'ON'2	141	91
FRM PM10	9/1/2010	Mist 'OFF'1	560	849
FRM PM10	9/1/2010	Mist 'OFF'1	491	826

TAMU PM10	9/1/2010	Mist 'OFF'1	1,435	822
TAMU PM10	9/1/2010	Mist 'OFF'1	829	811
FRM PM10	9/1/2010	Mist 'OFF'2	362	521
FRM PM10	9/1/2010	Mist 'OFF'2	380	522
TAMU PM10	9/1/2010	Mist 'OFF'2	595	518
TAMU PM10	9/1/2010	Mist 'OFF'2	742	519
FRM PM10	9/1/2010	Mist 'ON' 1	395	412
FRM PM10	9/1/2010	Mist 'ON'1	291	412
TAMU PM10	9/1/2010	Mist 'ON'1	512	410
TAMU PM10	9/1/2010	Mist 'ON'1	445	410
FRM PM10	9/1/2010	Mist 'ON'2	641	670
FRM PM10	9/1/2010	Mist 'ON'2	559	664
TAMU PM10	9/1/2010	Mist 'ON'2	788	662
TAMU PM10	9/1/2010	Mist 'ON'2	661	654
FRM PM10	9/2/2010	Mist 'OFF'	162	628
FRM PM10	9/2/2010	Mist 'OFF'	756	626
TAMU PM10	9/2/2010	Mist 'OFF'	865	619
TAMU PM10	9/2/2010	Mist 'OFF'	711	626
FRM PM10	9/2/2010	Mist 'ON'	684	745
FRM PM10	9/2/2010	Mist 'ON'	339	749
TAMU PM10	9/2/2010	Mist 'ON'	1,183	730
TAMU PM10	9/2/2010	Mist 'ON'	740	734

Observed and back-calculated mean and standard deviation for DCU with misting system ‘off’ and ‘on’ are shown in Table 2. The modeled (back-calculated) concentrations were estimated by using average back-calculated emission rates obtained from initial model runs. The average back calculated emission rates for model calibration were obtained by averaging the measured and modeled values for each disk operation (field test). Taking one composite mean modeled-to-observed ratio, the data show mean values of close to 1.0 for both misting ‘off’ and misting ‘on’ in all disking operations. On average, the PM10 concentration of mist ‘off’ is 33% more than mist ‘on’ treatment for both measured and modeled values.

Table 2. Mean and standard deviation of observed and back-calculated PM10 concentrations for all field sites.

Harvest Operation	Observed Concentration, μgm^{-3}		Back-Calculated Concentration, μgm^{-3}	
	Mean	Standard Deviation	Mean	Standard Deviation
Mist 'OFF'	1244	982	1243	867
Mist 'ON'	934	552	936	498
Total	1089	809	1089	721

B-5 AERMOD Performance Evaluation

Air quality models can be evaluated for physical algorithm, regulatory, operation, or statistical comparison between observed and predicted data. The focus of this part of the report is on evaluation of AERMOD using field measurements and statistical performance measures for general applications only, not for regulatory applications. The evaluation goal is to test the ability of the AERMOD to replicate the PM10 concentration in this project. This Section evaluates the model's predictions against field observations.

Performance Measures

American Society for Testing and Materials guide (ASTM 2000), Chang and Hanna (2004), and Perry et. al (2004) were used as the main references to define statistical performance measures and modeling skill. Even though it is vitally important to predict or estimate fugitive PM10 emissions from agricultural operations using air quality modeling, there is no government or scientific recommended performance measures or even guidelines for such activities.

Performance measures in this study include mean bias (*MB*), geometric mean bias (*MG*), fractional bias (*FB*), geometric mean variance (*VG*), normalized mean square error (*NMSE*), correlation coefficient (*R*), and factor of 2 (*FACT2*), which is the fraction of prediction within a factor of 2 of the observed values. The following equations were used to estimate the performance measures.

$$MB = \overline{(C_o - C_p)} \quad (15)$$

$$MG = \exp\left(\overline{ln\, C_o} - \overline{ln\, C_p}\right) \quad (16)$$

$$FB = \frac{(\overline{C_o} - \overline{C_p})}{0.5(\overline{C_o} + \overline{C_p})} \quad (17)$$

$$VG = \exp\left[\overline{\left(\ln C_o - \ln C_p\right)^2}\right] \quad (18)$$

$$NMSE = \frac{\overline{(C_o - C_p)^2}}{\overline{C_o C_p}} \quad (19)$$

$$R = \frac{\overline{(C_o - \overline{C_o})(C_p - \overline{C_p})}}{\sigma C_p \sigma C_o} \quad (20)$$

$$FACT2 : 0.5 \le \frac{C_p}{C_o} \le 2.0 \quad (21)$$

Where:
Co: field observations,

Cp: model predictions,
ρ*C*: standard deviation over the dataset, and
over bar is average over the dataset.

The relationships between predicted (modeled) and observed (measured) PM10 concentrations for various locations and disking operations are shown in Figure 1.

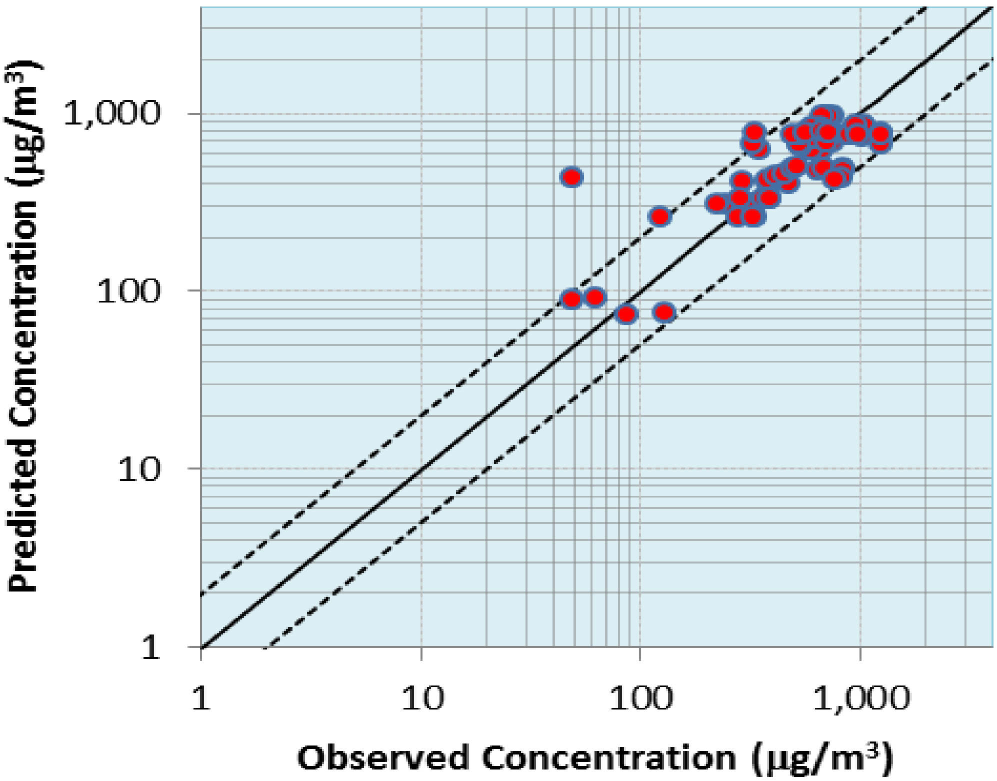


Figure 1- Scatter plot of predicted versus observed PM10 concentration

This scatter plot, which uses data paired in time and space, shows how the magnitude of the model estimate matches the measured values for different fields and disking operations. In this figure, the scatter of the observed and predicted points, which are diverging from the 45 degrees solid line, indicates the accuracy of AERMOD estimation and consistency at different dates and activities. The two dotted lines in these figures indicate a factor of two over- and under-prediction. Each data point represents paired model prediction (i.e., net measured concentration versus AERMOD prediction). The focus of this paired comparison is to examine how well AERMOD predicts ambient concentration of PM10 in various disking operations.

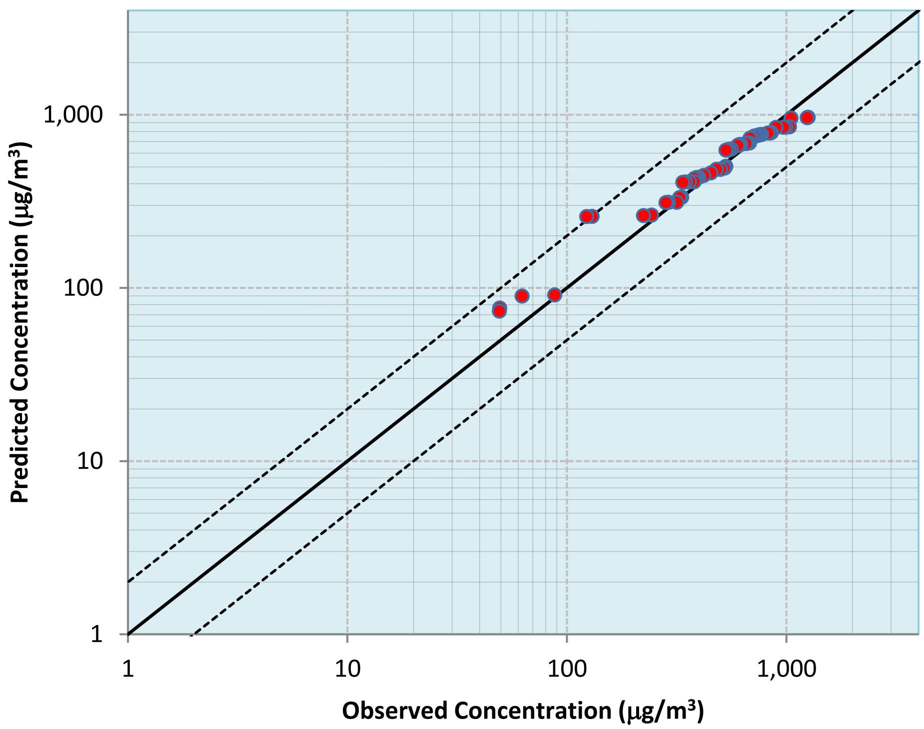


Figure 2- Q-Q plot of predicted versus observed PM10 concentration

Results of performance measures for all the paired field measurements and AERMOD predictions are shown in Table 3. Values for the “perfect” model are also shown in this Table. Nevertheless, air quality models cannot include all of the natural variability that affects measured concentrations, and values for the “perfect” model in this table are given for demonstration purposes only.

Table 3: Overall performance measures of AERMOD for various time and locations of disking operations.

Performance Measures	AERMOD	"Perfect" Model
Geometric Mean (MG)	0.95	1.0
Fractional Bias (FB)	0.00	0.0
Geometric Variance (VG)	1.14	1.0
Normalized Mean Square Error (NMSE)	0.11	0.0
Factor of 2 (FAC2)	0.95	1.0
Correlation Coefficient (R)	0.89	1.0

Geometric mean and fractional bias define mean biases, and geometric variance and normalized mean square error deal with scatter. Judging the AERMOD performance measures in this project is very challenging as there are no firm guidelines available for assessing “good” or “acceptable” performance in predicting PM10 from agricultural activities. However, based on the available literature, “acceptable” model in this study assumed to have the following performance measures to determine the reliability of AERMOD:

0.7 < Geometric mean bias < 1.3
-0.3 < Fractional bias < +0.3
1.00 < Geometric variance < 1.3
Normalized mean square error < 0.5
FAC2 Factor of two > 0.5

It seems that line source model of AERMOD provides satisfactory performance measures in this study.

B-6 Summary and Conclusions

This Appendix presents the manner that the AERMOD model was used in the project, and also evaluated the performance of the model for predicting the concentrations of PM10 emissions from disking operations at different locations with the DCU misting system in ‘off’ and ‘on’ position. Evaluating the performance of AERMOD was particularly challenging as no protocols or guidelines were available for fugitive PM10 emissions from near source agricultural activities.

AERMOD requires well defined meteorological data, surface characteristics, source types and modeling options that are presented in this report. All the measured data and model predictions are also presented.

The measured data and model predictions were processed to produce scatter plot to check how well observed and predicted concentrations match at different times and locations, and to produce Q-Q plot to see if distribution of the AERMOD predictions match those of measured values. Both scatter and Q-Q plots provided good agreement and satisfactory results.

Various performance measures were used to estimate the differences between measured and predicted PM10 emissions. These measures include geometric mean bias, fractional bias, geometric mean variance, normalized mean square error, correlation coefficient, and factor of 2. Overall, AERMOD appeared to match the ambient PM10 concentration fairly well.

The measured and modeled PM10 concentrations of the existing Dust Control Unit (DCU) attached to a common agricultural disk appeared lower when the misting system was ‘on’ versus misting system ‘off’, and on average, the PM10 concentrations were reduced by 33% with the misting system ‘on’.

B-7 References

ASTM 2000. Designation D6589-05 (2010). Standard guide for statistical evaluation of atmospheric dispersion model performance. American Society for Testing and Materials, Published July 2010.

Chang , J. C., and Hanna, S. R. 2004. Air quality model performance evaluation. Meteorol Atmos Phys 87, 167–196 (2004).

Perry, S.T., A.J., Cimorelli, R.J. Paine, R.W. Brode, J.C. Well, A. Venkatram, and R.B. Wilson. 2004. AERMOD: A Dispersion Model for Industrial Source Applications. Part II: Model Performance against 17 Field Study Databases. JOURNAL OF APPLIED METEOROLOGY, Volume 44: 694-708.

EPA 1995. User's Guide for the Industrial Source Complex (ISC3) Dispersion Models. Volume II, Description of the Model Algorithms. EPA-454/B-95-003b, September 1995.

EPA 2004a. User's Guide for the AMS/EPA Regulatory Model- AERMOD. EPA-454/B-03-001, September 2004, ADDENDUM – Updated October 2009.

EPA 2004b. User's Guide for the AERMOD Meteorological Preprocessor (AERMET). EPA-454/B-03-002, November 2004.

EPA 2005. Guideline on Air Quality Models. 40 CFR Part 51, Appendix W. Published in the *Federal Register*, Vol. 70, No. 216, November 9, 2005.

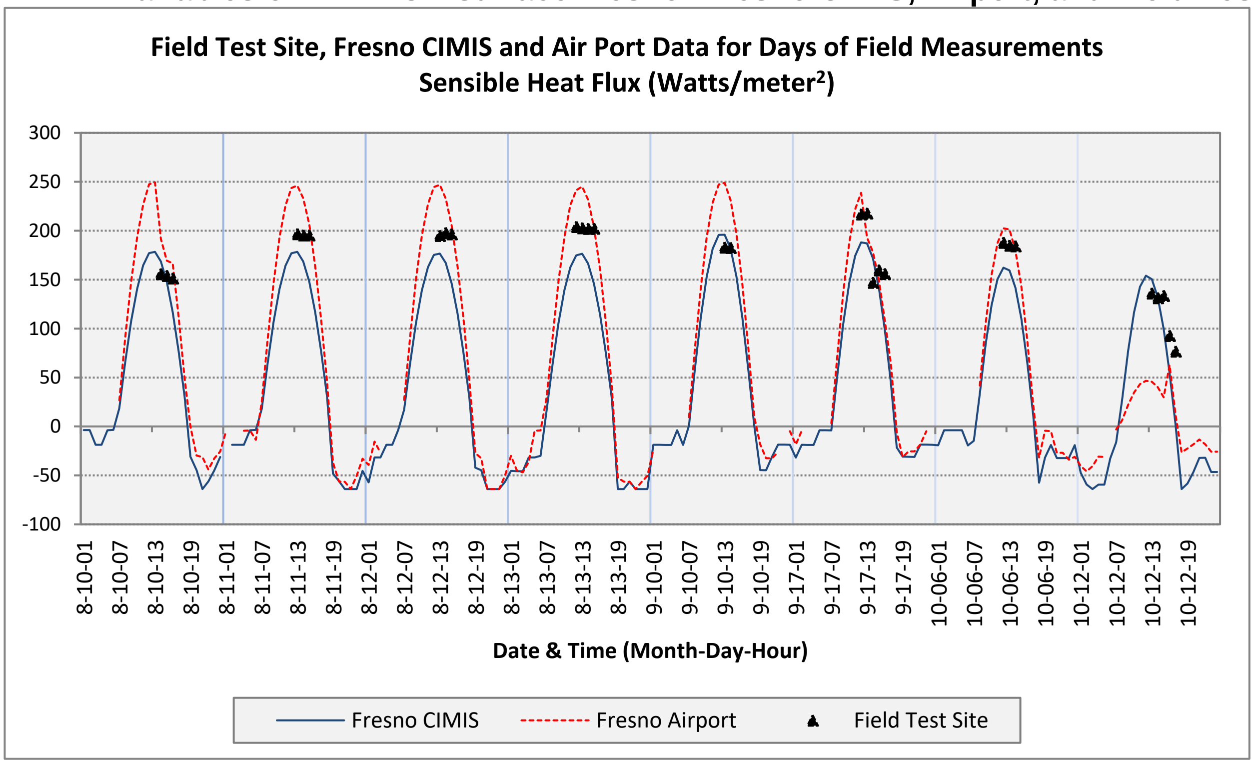
EPA 2008. AERSURFACE User's Guide. EPA-454/B-08-001. January 2008.

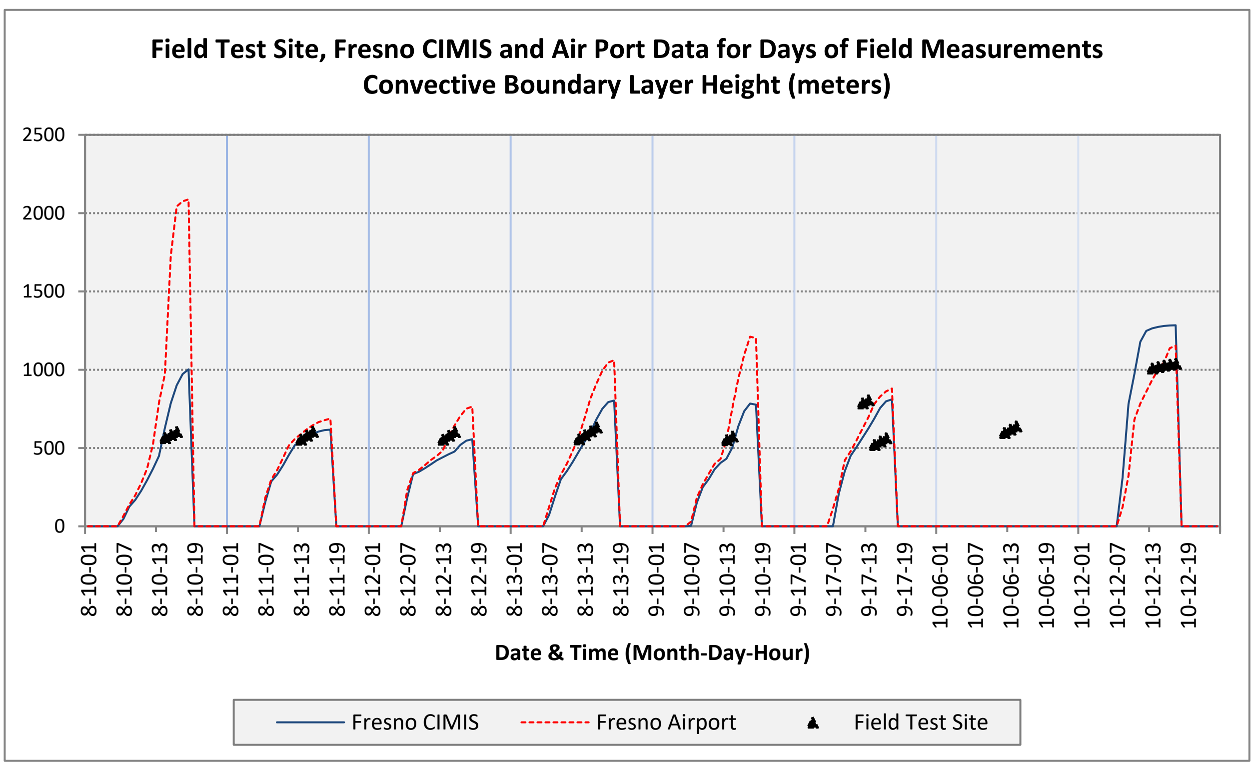
EPA 2009. AERMOD Implementation Guide. AERMOD Implementation Workgroup. Last Revised: March 19, 2009.

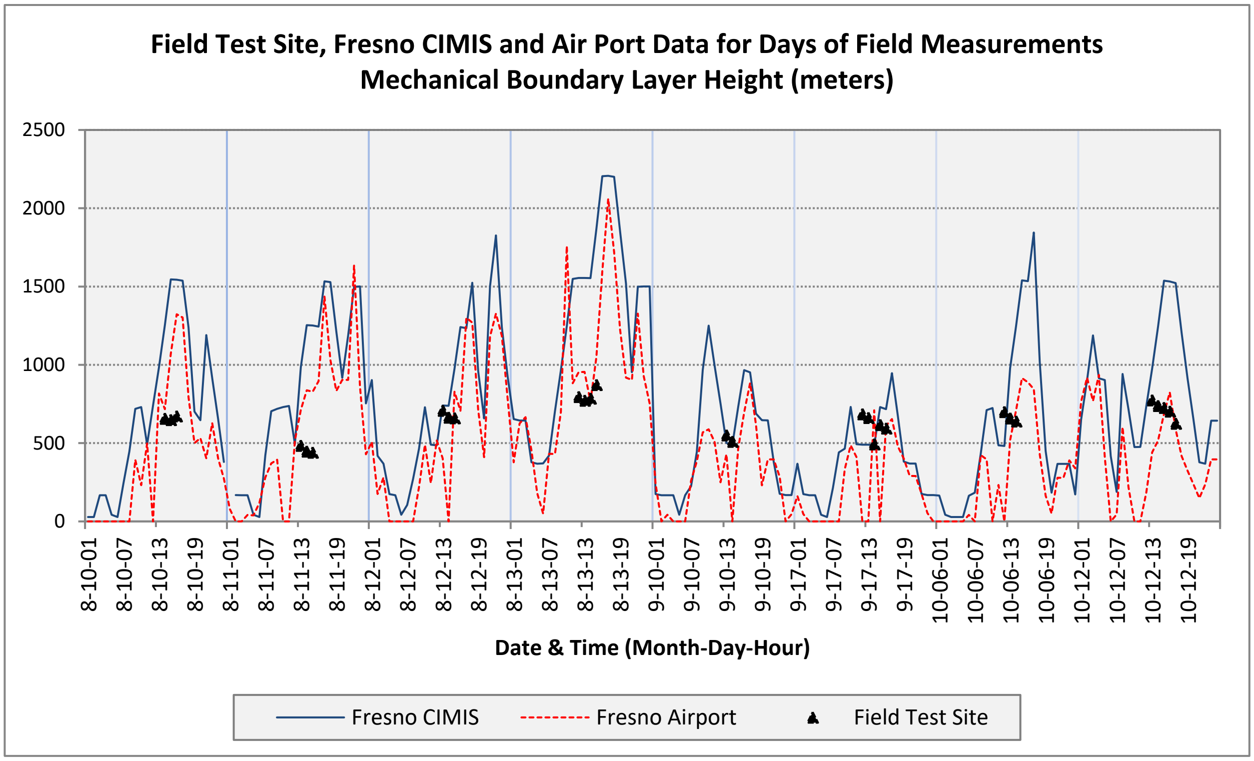
Lakes Environmental 2009. AERMOD View. Interface for the U.S. EPA ISC and AERMOD Models.

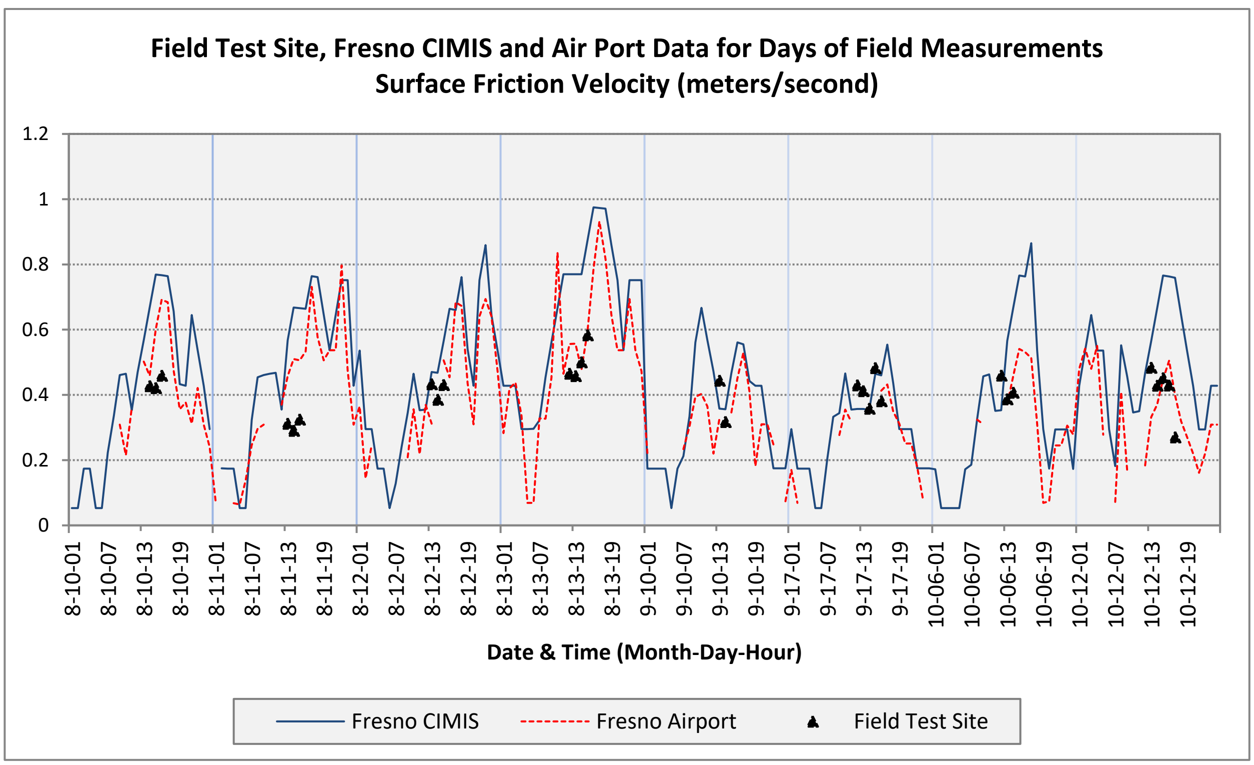
B-8 Graphs- Variables of AERMOD surface files

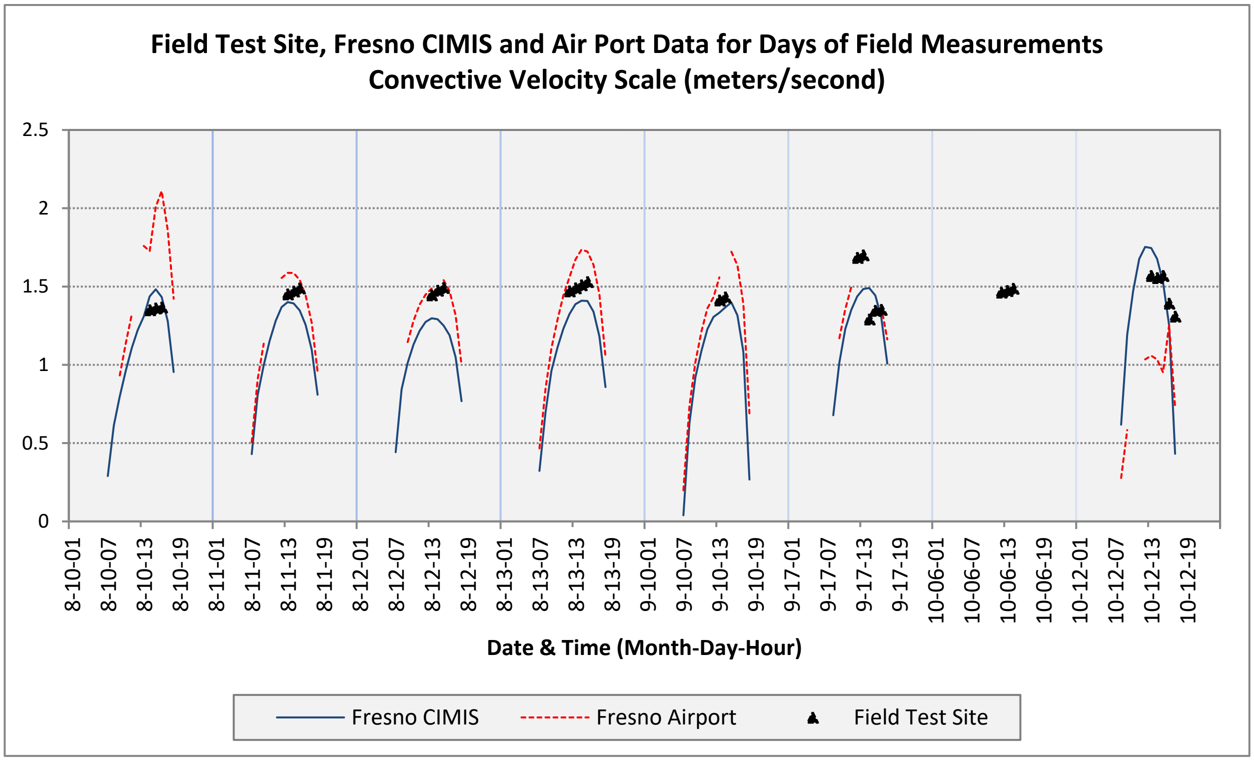
Variables of AERMOD surface files for Fresno CIMIS, Airport, and Field Test Site

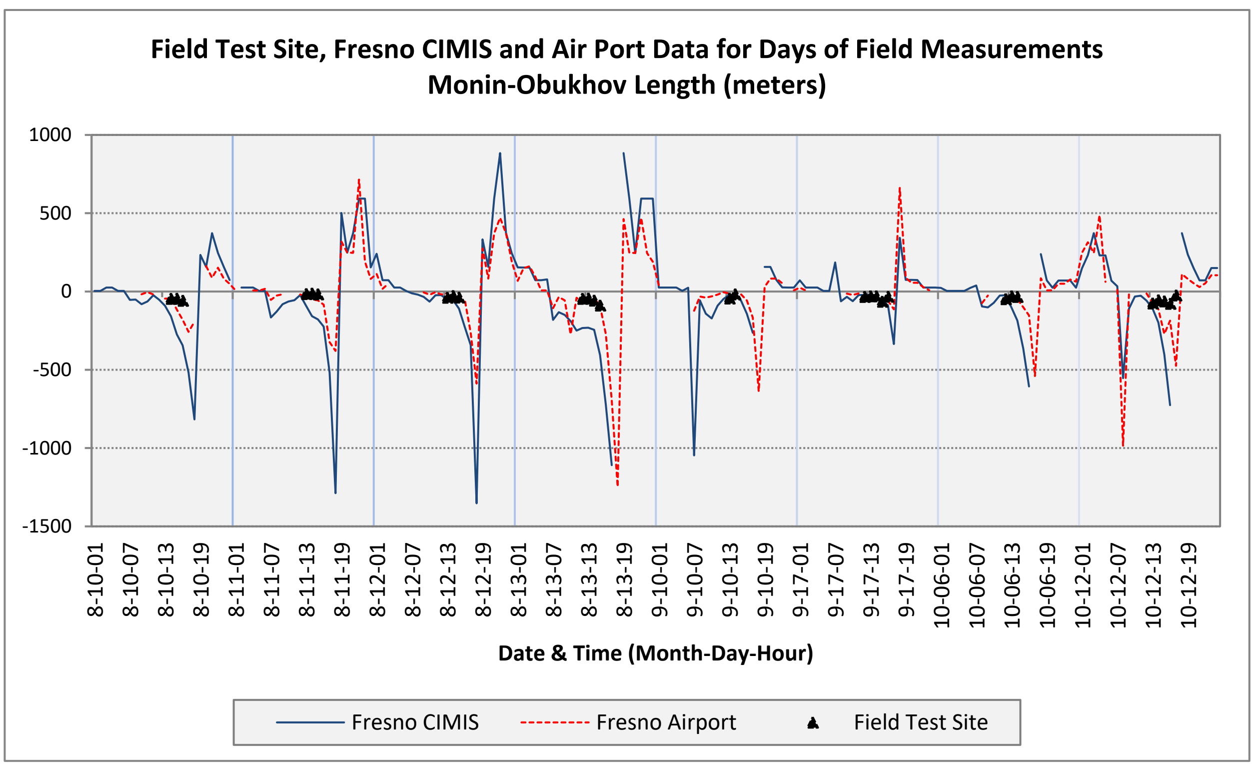


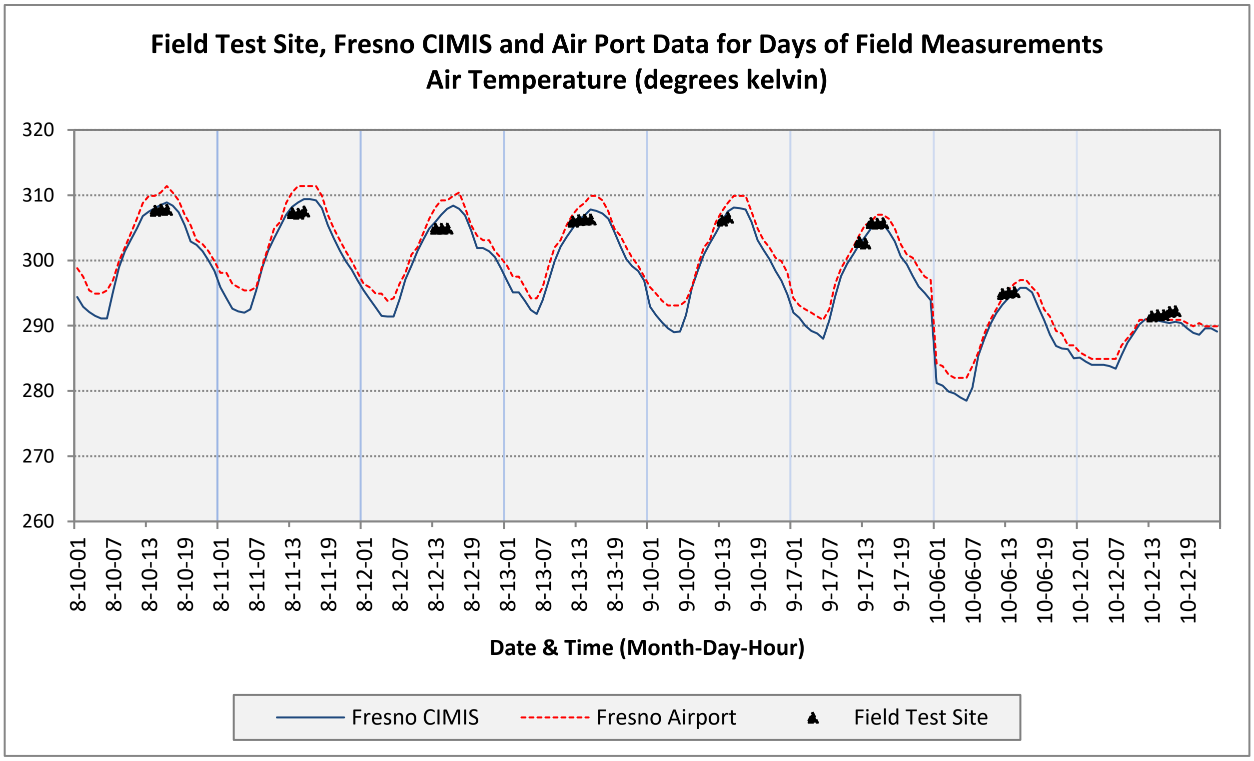


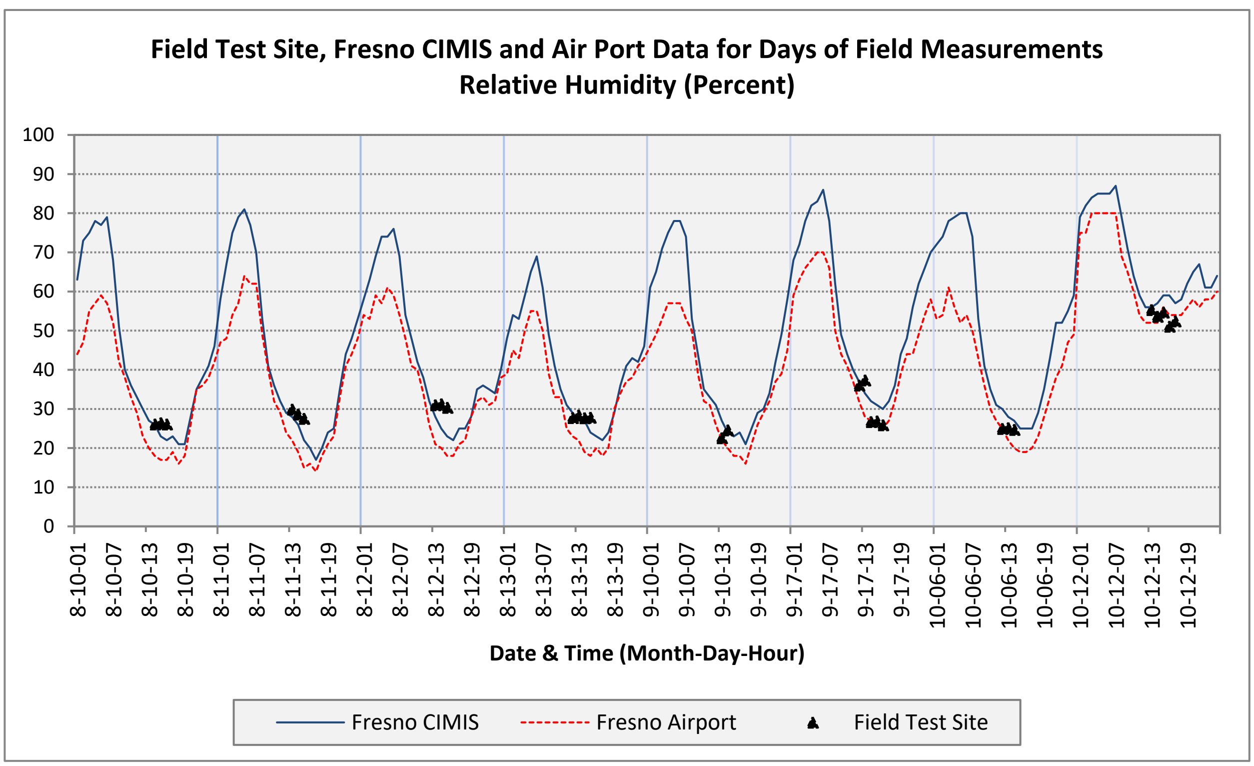

Field Test Site, Fresno CIMIS and Air Port Data for Days of Field Measurements
Mechanical Boundary Layer Height (meters)
2500
2000
1500
1000
500
0
8-10-01
8-10-07
8-10-13
8-10-19
8-11-01
8-11-07
8-11-13
8-11-19
8-12-01
8-12-07
8-12-13
8-12-19
8-13-01
8-13-07
8-13-13
8-13-19
9-10-01
9-10-07
9-10-13
9-10-19
9-17-01
9-17-07
9-17-13
9-17-19
10-06-01
10-06-07
10-06-13
10-06-19
10-12-01
10-12-07
10-12-13
10-12-19
Date & Time (Month-Day-Hour)
Fresno CIMIS
Fresno Airport
Field Test Site


Field Test Site, Fresno CIMIS and Air Port Data for Days of Field Measurements
Surface Friction Velocity (meters/second)
1.2
1
0.8
0.6
0.4
0.2
0
8-10-01
8-10-07
8-10-13
8-10-19
8-11-01
8-11-07
8-11-13
8-11-19
8-12-01
8-12-07
8-12-13
8-12-19
8-13-01
8-13-07
8-13-13
8-13-19
9-10-01
9-10-07
9-10-13
9-10-19
9-17-01
9-17-07
9-17-13
9-17-19
10-06-01
10-06-07
10-06-13
10-06-19
10-12-01
10-12-07
10-12-13
10-12-19
Date & Time (Month-Day-Hour)
Fresno CIMIS
Fresno Airport
Field Test Site


Field Test Site, Fresno CIMIS and Air Port Data for Days of Field Measurements
Convective Velocity Scale (meters/second)
2.5
2
1.5
1
0.5
0
8-10-01
8-10-07
8-10-13
8-10-19
8-11-01
8-11-07
8-11-13
8-11-19
8-12-01
8-12-07
8-12-13
8-12-19
8-13-01
8-13-07
8-13-13
8-13-19
9-10-01
9-10-07
9-10-13
9-10-19
9-17-01
9-17-07
9-17-13
9-17-19
10-06-01
10-06-07
10-06-13
10-06-19
10-12-01
10-12-07
10-12-13
10-12-19
Date & Time (Month-Day-Hour)
Fresno CIMIS
Fresno Airport
Field Test Site


Field Test Site, Fresno CIMIS and Air Port Data for Days of Field Measurements
Monin-Obukhov Length (meters)
1000
500
0
-500
-1000
-1500
8-10-01
8-10-07
8-10-13
8-10-19
8-11-01
8-11-07
8-11-13
8-11-19
8-12-01
8-12-07
8-12-13
8-12-19
8-13-01
8-13-07
8-13-13
8-13-19
9-10-01
9-10-07
9-10-13
9-10-19
9-17-01
9-17-07
9-17-13
9-17-19
10-06-01
10-06-07
10-06-13
10-06-19
10-12-01
10-12-07
10-12-13
10-12-19
Date & Time (Month-Day-Hour)
Fresno CIMIS
Fresno Airport
Field Test Site


Field Test Site, Fresno CIMIS and Air Port Data for Days of Field Measurements
Air Temperature (degrees kelvin)
320
310
300
290
280
270
260
8-10-01
8-10-07
8-10-13
8-10-19
8-11-01
8-11-07
8-11-13
8-11-19
8-12-01
8-12-07
8-12-13
8-12-19
8-13-01
8-13-07
8-13-13
8-13-19
9-10-01
9-10-07
9-10-13
9-10-19
9-17-01
9-17-07
9-17-13
9-17-19
10-06-01
10-06-07
10-06-13
10-06-19
10-12-01
10-12-07
10-12-13
10-12-19
Date & Time (Month-Day-Hour)
Fresno CIMIS
Fresno Airport
Field Test Site


Field Test Site, Fresno CIMIS and Air Port Data for Days of Field Measurements
Relative Humidity (Percent)
100
90
80
70
60
50
40
30
20
10
0
8-10-01
8-10-07
8-10-13
8-10-19
8-11-01
8-11-07
8-11-13
8-11-19
8-12-01
8-12-07
8-12-13
8-12-19
8-13-01
8-13-07
8-13-13
8-13-19
9-10-01
9-10-07
9-10-13
9-10-19
9-17-01
9-17-07
9-17-13
9-17-19
10-06-01
10-06-07
10-06-13
10-06-19
10-12-01
10-12-07
10-12-13
10-12-19
Date & Time (Month-Day-Hour)
Fresno CIMIS
Fresno Airport
Field Test Site

California State University, Fresno Foundation,
a recognized Auxiliary Corporation of California State University, Fresno

Misting: A Viable Conservation Management Practice (CMP)
For
Reducing PM10 Generated by Disking

APPENDIX C

Meteorological Data

Wind velocity during testing. Data were collected in situ (SI units).

Operation	Min. Wind Speed (m/s)	Max. Wind Speed	Avg. Wind Speed
Mist off (6-22-2009)	2.04	2.76	2.41
Mist on (6-22-2009)	1.64	2.53	2.24
Mist off (6-23-2009)	0.79	2.56	1.68
Mist on (6-23-2009)	1.44	1.74	1.65
Mist off (6-24-2009)	1.41	2.44	1.84
Mist on (6-24-2009)	1.83	2.87	2.48
Mist off (7-01-2009)	1.66	2.08	1.91
Mist on (7-01-2009)	1.86	2.74	2.27
Mist off (7-06-2009)	2.30	3.22	2.97
Mist on (7-06-2009)	2.47	3.27	2.94
Mist off (7-07-2009)	1.37	1.97	1.62
Mist on (7-07-2009)	1.30	2.34	1.81
Mist off (7-08-2009)	2.98	3.24	3.10
Mist on (7-08-2009)	2.94	3.94	3.39
Mist off (7-09-2009)	1.20	1.53	1.33
Mist on (7-09-2009)	1.68	2.47	2.19
Mist off (7-20-2009)	2.74	3.14	2.99
Mist on (7-20-2009)	3.24	4.68	4.11
Mist off (7-21-2009)	1.68	2.51	2.23
Mist on (7-21-2009)	1.93	3.24	2.51
Mist off (7-22-2009)	1.84	2.54	2.09
Mist on (7-22-2009)	2.31	2.70	2.51
Mist off (10-29-2009)	0.43	0.99	0.75
Mist on (10-29-2009)	0.41	0.97	0.69
Mist off 2 (10-29-2009)	0.22	0.79	0.49
Mist on 2 (10-29-2009)	0.27	1.04	0.72
Mist off (9-01-2010)	2.54	3.79	3.28
Mist on (9-01-2010)	2.07	3.60	2.83
Mist off 2 (9-01-2010)	2.02	3.26	2.69
Mist on 2 (9-01-2010)	2.56	4.36	3.59
Mist off (9-02-2010)	3.43	4.01	3.65
Mist on (9-02-2010)	2.81	3.09	2.95

Wind velocity during testing. Data were collected in situ (Imperial units).

Operation	Min. Wind Speed (mph)	Max. Wind Speed	Avg. Wind Speed
Mist off (6-22-2009)	4.56	6.17	5.39
Mist on (6-22-2009)	3.67	5.66	5.01
Mist off (6-23-2009)	1.77	5.73	3.76
Mist on (6-23-2009)	3.22	3.89	3.69
Mist off (6-24-2009)	3.15	5.46	4.12
Mist on (6-24-2009)	4.09	6.42	5.55
Mist off (7-01-2009)	3.71	4.65	4.27
Mist on (7-01-2009)	4.16	6.13	5.08
Mist off (7-06-2009)	5.14	7.20	6.64
Mist on (7-06-2009)	5.53	7.31	6.58
Mist off (7-07-2009)	3.06	4.41	3.62
Mist on (7-07-2009)	2.91	5.23	4.05
Mist off (7-08-2009)	6.67	7.25	6.93
Mist on (7-08-2009)	6.58	8.81	7.58
Mist off (7-09-2009)	2.68	3.42	2.98
Mist on (7-09-2009)	3.76	5.53	4.90
Mist off (7-20-2009)	6.13	7.02	6.69
Mist on (7-20-2009)	7.25	10.47	9.19
Mist off (7-21-2009)	3.76	5.61	4.99
Mist on (7-21-2009)	4.32	7.25	5.61
Mist off (7-22-2009)	4.12	5.68	4.68
Mist on (7-22-2009)	5.17	6.04	5.61
Mist off (10-29-2009)	0.96	2.21	1.68
Mist on (10-29-2009)	0.92	2.17	1.54
Mist off 2 (10-29-2009)	0.49	1.77	1.10
Mist on 2 (10-29-2009)	0.60	2.33	1.61
Mist off (9-01-2010)	5.68	8.48	7.34
Mist on (9-01-2010)	4.63	8.05	6.33
Mist off 2 (9-01-2010)	4.52	7.29	6.02
Mist on 2 (9-01-2010)	5.73	9.75	8.03
Mist off (9-02-2010)	7.67	8.97	8.16
Mist on (9-02-2010)	6.29	6.91	6.60

This page intentionally left blank

Misting: A Viable Conservation Management Practice (CMP) For Reducing PM10 Generated by Disking

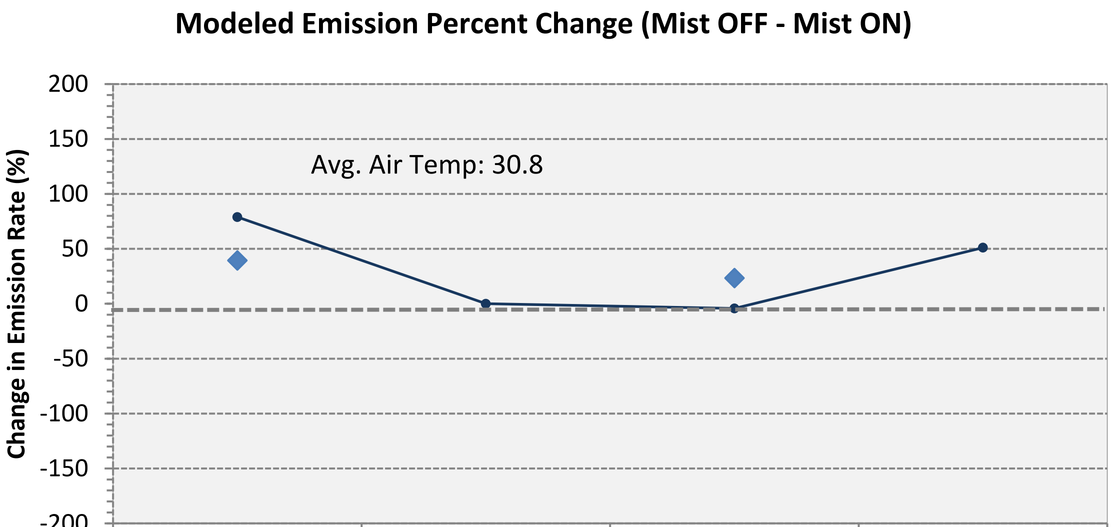
APPENDIX D

Modeled emission percent change

MISTING: A Viable Conservation Management Practice For Reducing PM10 Generated by Disking

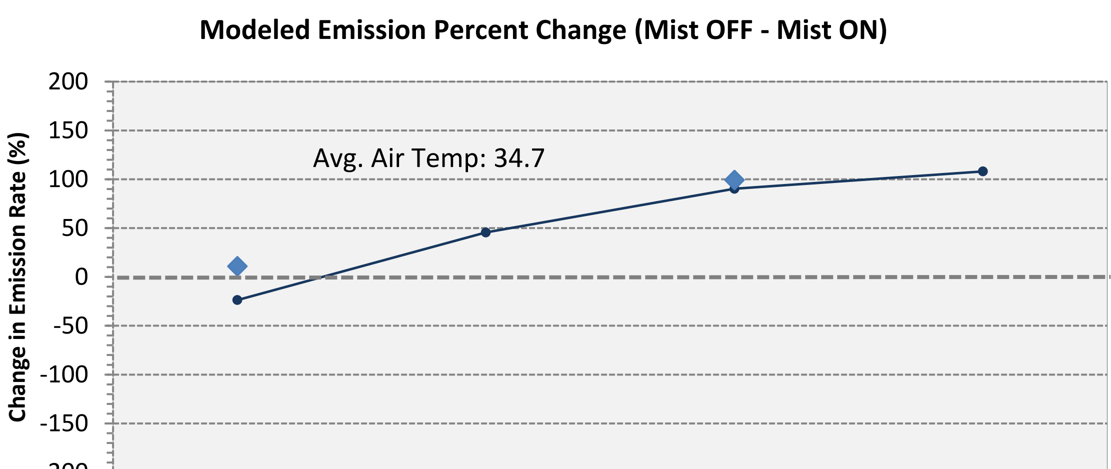
PM 10 Emission Rates (grams per second)

Location: N CWI Soil Type: Sandy Loam Test Date: 6/22/2009



	FRM PM10	FRM PM10	TAMU PM10	TAMU PM10
PM 10	78.99	0.00	-4.27	51.06
Average	39.50		23.40	

Location: N CWI Soil Type: Sandy Loam Test Date: 6/23/2009



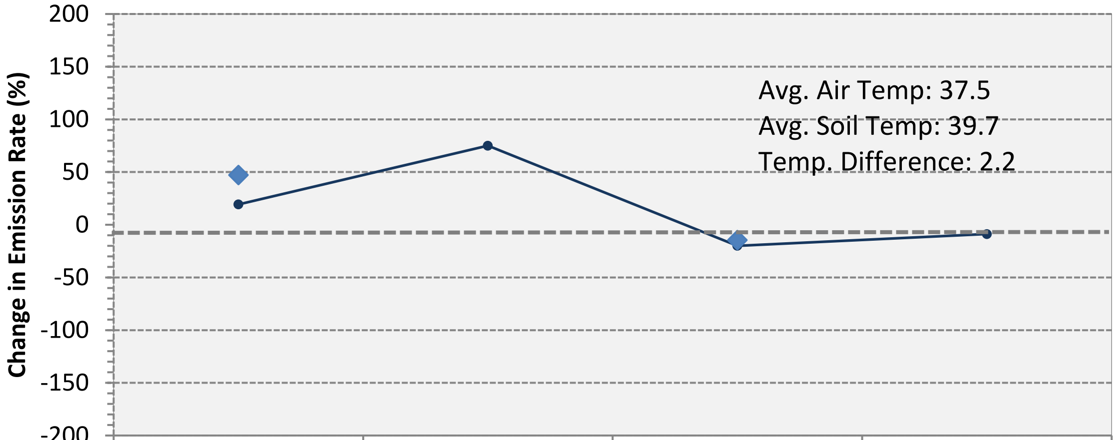
	FRM PM10	FRM PM10	TAMU PM10	TAMU PM10
PM 10	-23.71	45.52	90.29	108.03
Average	10.90		99.16	

MISTING: A Viable Conservation Management Practice For Reducing PM10 Generated by Disking

PM 10 Emission Rates (grams per second)

Location: N CWI Soil Type: Sandy Loam Test Date: 6/24/2009

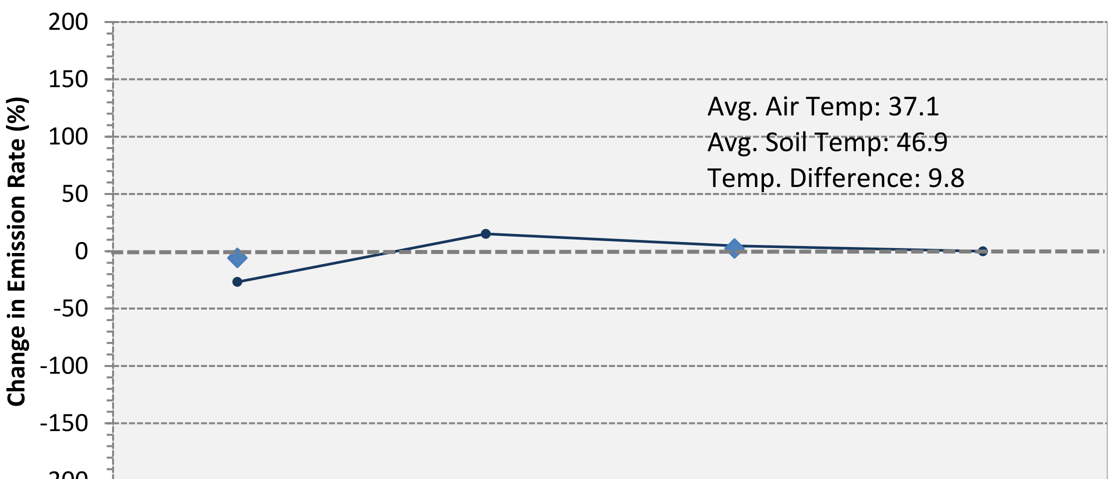
Modeled Emission Percent Change (Mist OFF - Mist ON)



	FRM PM10	FRM PM10	TAMU PM10	TAMU PM10
PM 10	19.31	75.05	-19.99	-8.83
Average	47.18		-14.41	

Location: E CWI Soil Type: Sandy Loam Test Date: 7/1/2009

Modeled Emission Percent Change (Mist OFF - Mist ON)

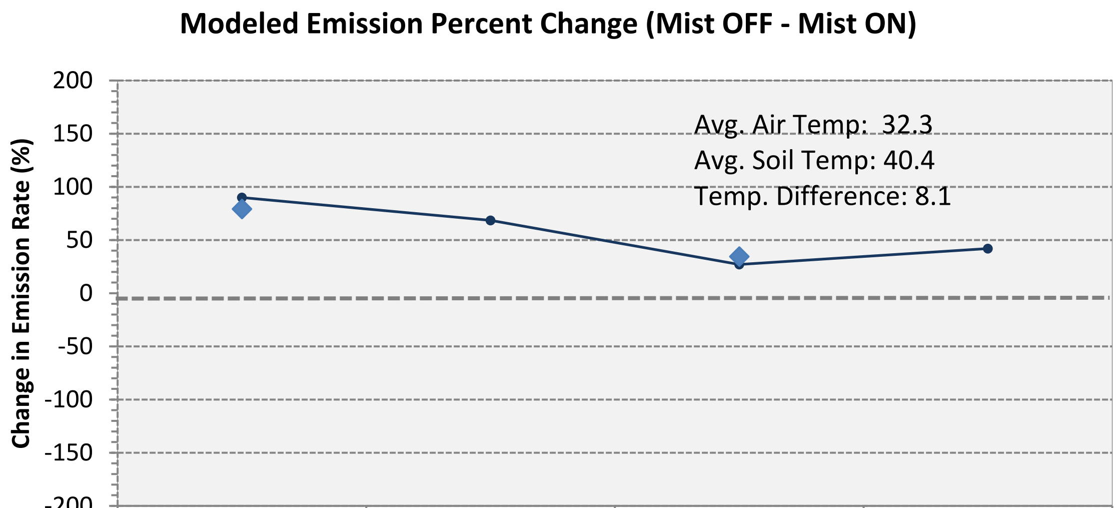


	FRM PM10	FRM PM10	TAMU PM10	TAMU PM10
PM 10	-26.77	15.22	4.78	0.00
Average	-5.78		2.39	

MISTING: A Viable Conservation Management Practice For Reducing PM10 Generated by Disking

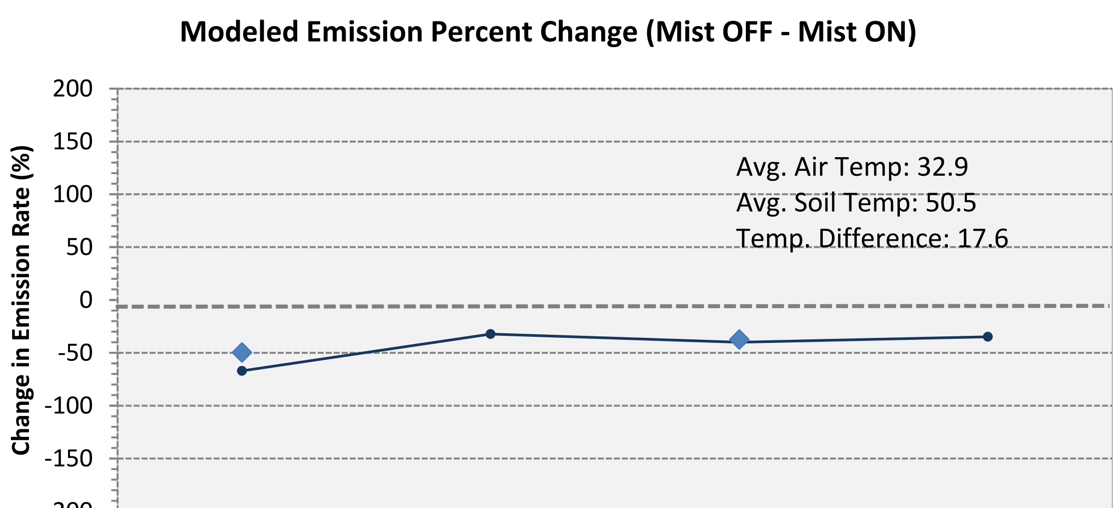
PM 10 Emission Rates (grams per second)

Location: E CWI Soil Type: Sandy Loam Test Date: 7/6/2009



	FRM PM10	FRM PM10	TAMU PM10	TAMU PM10
PM 10	89.99	68.49	27.04	41.97
Average	79.24		34.51	

Location: E CWI Soil Type: Sandy Loam Test Date: 7/7/2009



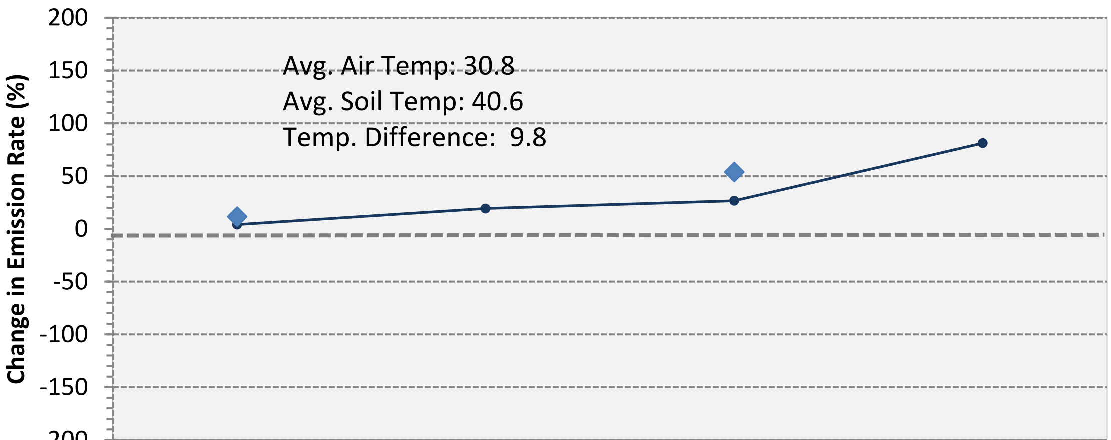
	FRM PM10	FRM PM10	TAMU PM10	TAMU PM10
PM 10	-67.04	-32.22	-39.91	-34.76
Average	-49.63		-37.34	

MISTING: A Viable Conservation Management Practice For Reducing PM10 Generated by Disking

PM 10 Emission Rates (grams per second)

Location: E CWI Soil Type: Sandy Loam Test Date: 7/8/2009

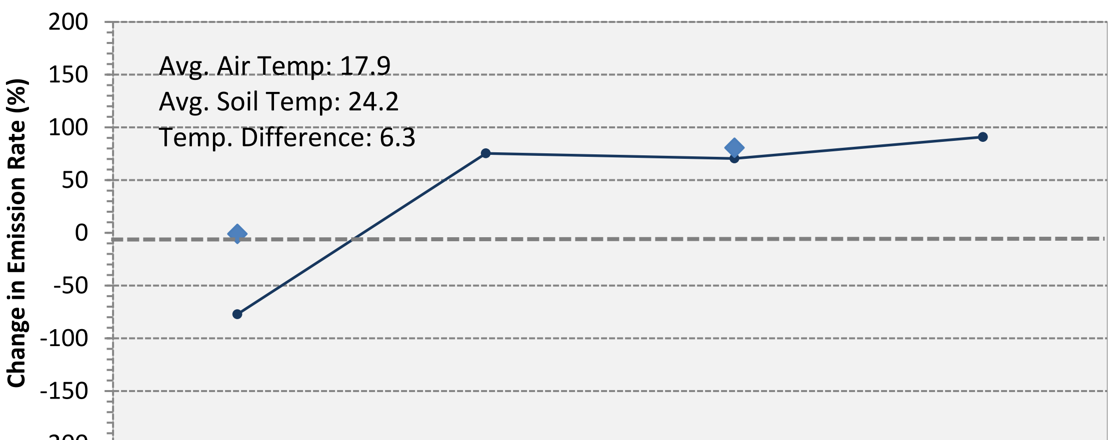
Modeled Emission Percent Change (Mist OFF - Mist ON)



	FRM PM10	FRM PM10	TAMU PM10	TAMU PM10
PM 10	4.08	19.28	26.63	81.17
Average	11.68		53.90	

Location: N CWI Soil Type: Sandy Loam Test Date: 7/9/2009

Modeled Emission Percent Change (Mist OFF - Mist ON)



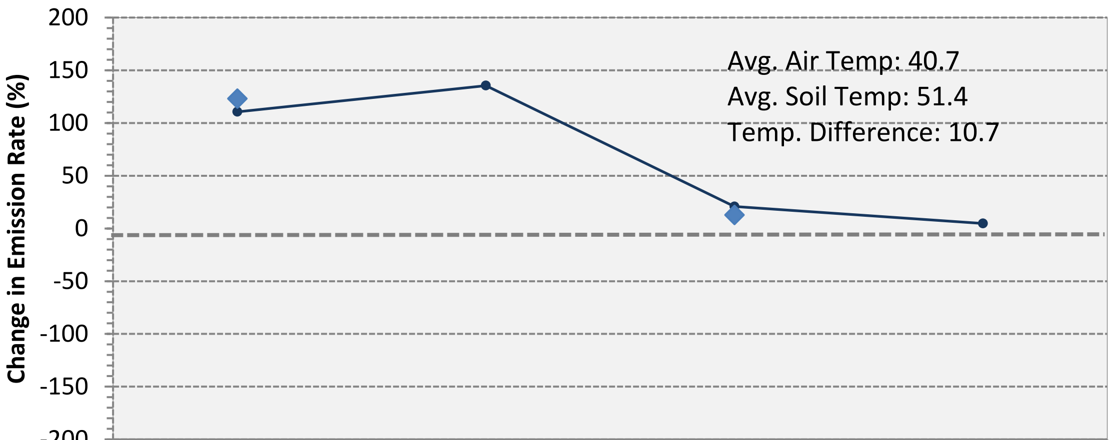
	FRM PM10	FRM PM10	TAMU PM10	TAMU PM10
PM 10	-77.25	75.38	70.51	90.88
Average	-0.94		80.70	

MISTING: A Viable Conservation Management Practice For Reducing PM10 Generated by Disking

PM 10 Emission Rates (grams per second)

Location: S CIT Soil Type: Sandy Loam Test Date: 7/20/2009

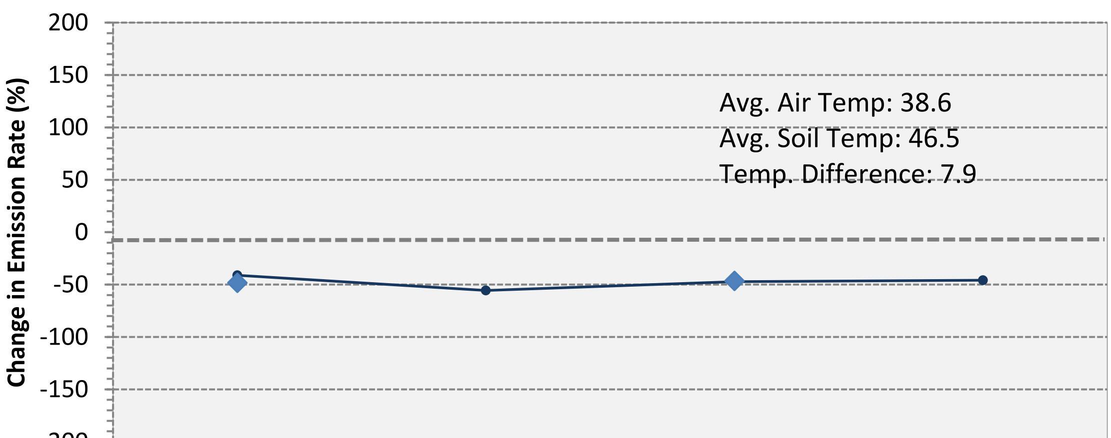
Modeled Emission Percent Change (Mist OFF - Mist ON)



	FRM PM10	FRM PM10	TAMU PM10	TAMU PM10
PM 10	110.59	135.43	20.80	4.73
Average	123.01		12.76	

Location: S CIT Soil Type: Sandy Loam Test Date: 7/21/2009

Modeled Emission Percent Change (Mist OFF - Mist ON)



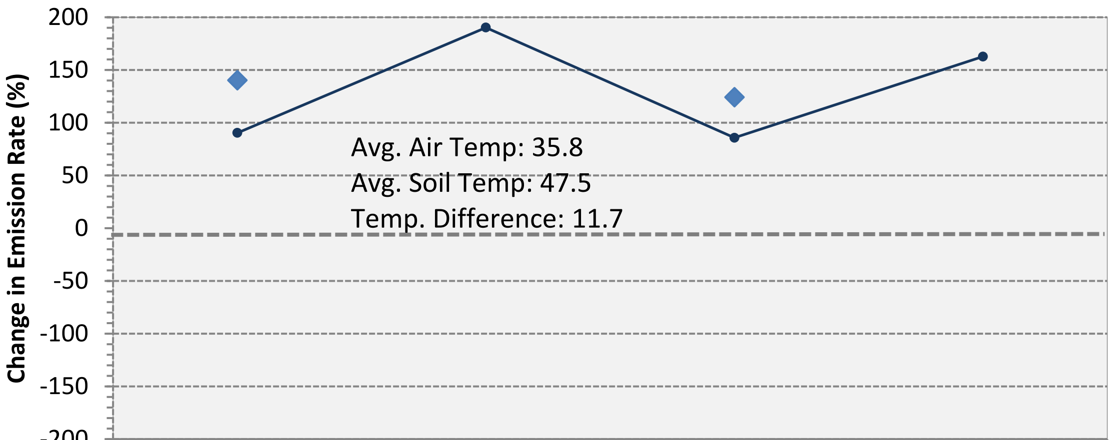
	FRM PM10	FRM PM10	TAMU PM10	TAMU PM10
PM 10	-41.13	-55.62	-47.20	-45.90
Average	-48.38		-46.55	

MISTING: A Viable Conservation Management Practice For Reducing PM10 Generated by Disking

PM 10 Emission Rates (grams per second)

Location: S CIT Soil Type: Sandy Loam Test Date: 7/22/2009

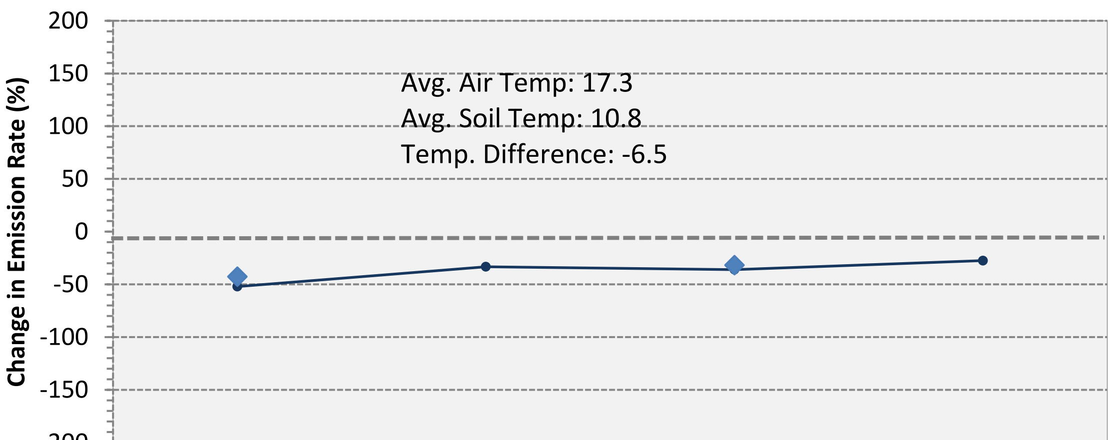
Modeled Emission Percent Change (Mist OFF - Mist ON)



	FRM PM10	FRM PM10	TAMU PM10	TAMU PM10
PM 10	90.32	190.19	85.74	162.73
Average	140.25		124.23	

Location: Orchard Soil Type: Loamy Sand Test Date: 10/29/2009

Modeled Emission Percent Change (Mist OFF - Mist ON)

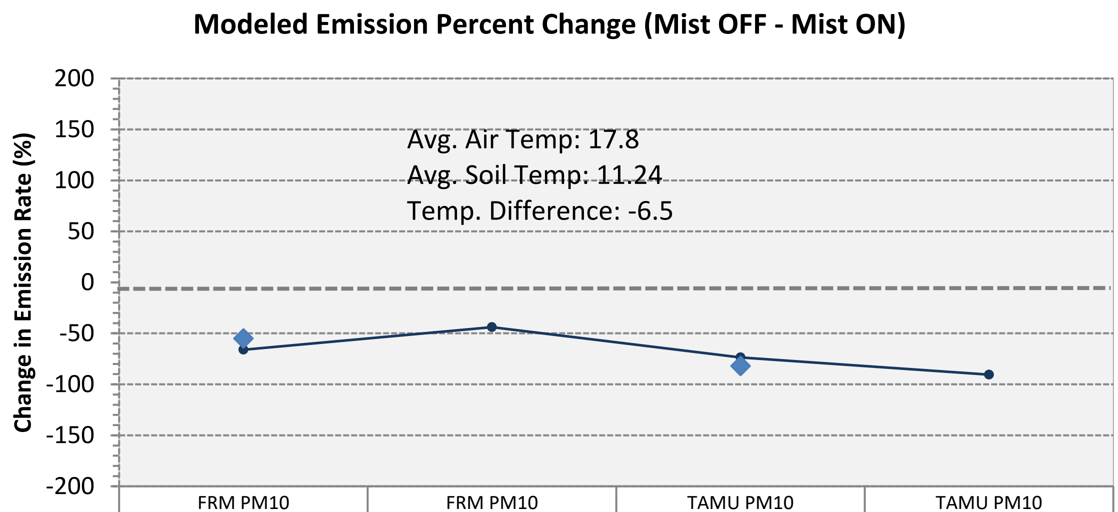


	FRM PM10	FRM PM10	TAMU PM10	TAMU PM10
PM 10	-52.08	-33.29	-35.97	-27.43
Average	-42.68		-31.70	

MISTING: A Viable Conservation Management Practice For Reducing PM10 Generated by Disking

PM 10 Emission Rates (grams per second)

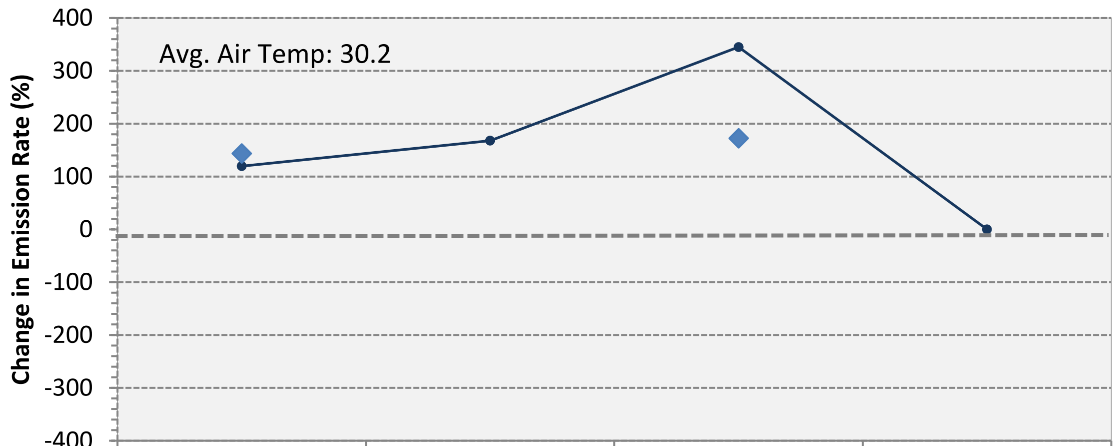
Location: Orchard Soil Type: Loamy Sand Test Date: 10/29/2009 (**2**)



	FRM PM10	FRM PM10	TAMU PM10	TAMU PM10
PM 10	-66.06	-43.94	-73.61	-90.48
Average	-55.00		-82.05	

Location: San Diego/Manning Soil Type: Clay Test Date: 9/1/2010

Modeled Emission Percent Change (Mist OFF - Mist ON)



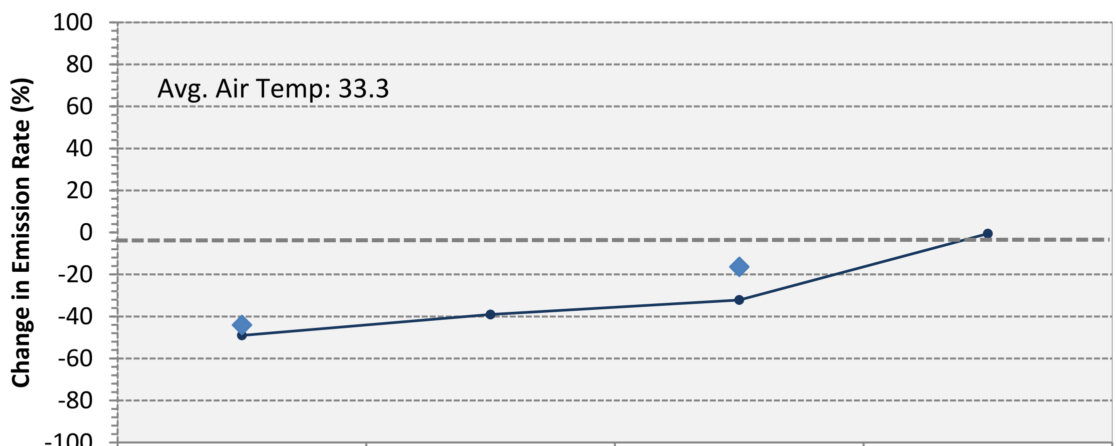
	FRM PM10	FRM PM10	TAMU PM10	TAMU PM10
PM 10	119.71	167.78	345.01	0.00
Average	143.74		172.51	

MISTING: A Viable Conservation Management Practice For Reducing PM10 Generated by Disking

PM 10 Emission Rates (grams per second)

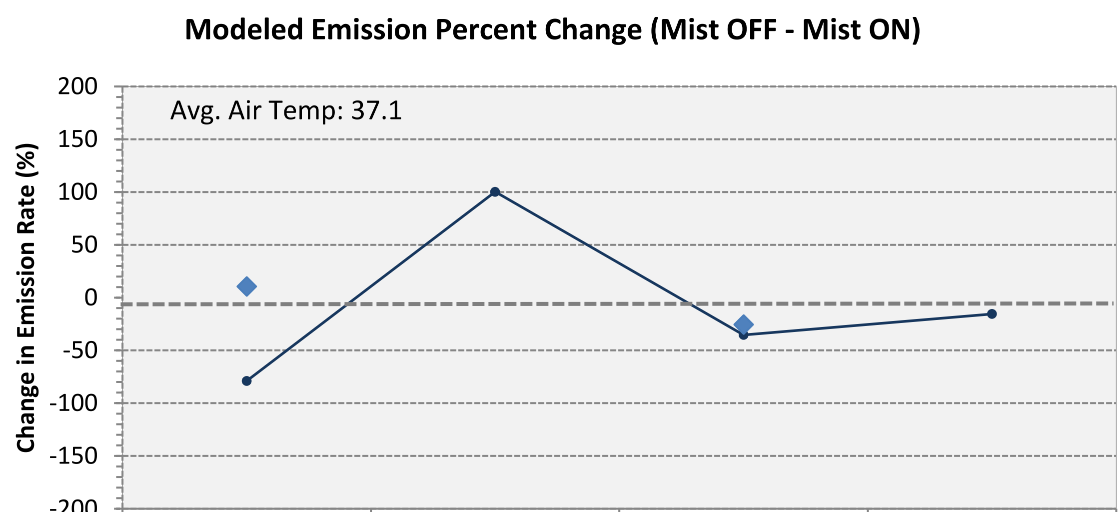
Location: San Diego/Manning Soil Type: Clay Test Date: 9/1/2010

Modeled Emission Percent Change (Mist OFF - Mist ON 2)



	FRM PM10	FRM PM10	TAMU PM10	TAMU PM10
PM 10	-49.03	-39.08	-32.15	-0.57
Average 2	-44.05		-16.36	

Location: South/Washoe Soil Type: Clay Loam Test Date: 9/2/2010



	FRM PM10	FRM PM10	TAMU PM10	TAMU PM10
PM 10	-78.92	100.24	-35.37	-15.49
Average	10.66		-25.43	

Misting: A Viable Conservation Management Practice (CMP)
For
Reducing PM10 Generated by Disking

APPENDIX E

Communications with the SJVACDP

California State University, Fresno Foundation,
a recognized Auxiliary Corporation of California State University, Fresno

San Joaquin Valley Air Pollution Control District

Approval of New Conservation Management Practices (CMPs)

Approved By: ______________________ David Warner, Director of Permit Services	Date Signed: __________

Purpose: To outline the procedures for the approval of new CMPs proposed by owners/operators to be used for compliance with the requirements of Rule 4550 Conservation Management Practices.

I. Applicability

This policy uses the Conservation Management Practice List (CMP List) approved by the District Board on May 20, 2004 as a baseline. The CMP List is posted on the District's website.

A practice not on the CMP list may be proposed by an owner or operator to be accepted as a CMP to comply with the requirements of Rule 4550.

The two sections of the rule that are applicable to proposed agricultural activities are:

- Section 6.2.3.1: An owner/operator may identify or develop a new CMP not on the CMP list to be used to comply with the requirements of this rule. Prior to use of the new CMP the owner/operator must obtain the interim approval of the APCO to use a new CMP to meet the requirements of Section 6.2. The owner/operator shall demonstrate that the new CMP achieves PM10 emission reductions that are at least equivalent to other CMPs on the CMP list that could be selected for the applicable operation.
- Section 6.2.3.2: The APCO will perform an independent analysis of proposed CMPs to determine that they achieve PM10 emission reductions that are at least equivalent to other CMPs on the CMP list that could be selected for the applicable operation. This analysis shall be made using the most recent emission factors provided by EPA or CARB when available. CMPs that are not shown to achieve equivalent emission reductions will be disapproved. The

DRAFT

District shall maintain a list of CMPs determined to be equivalent under this section.

II. Evaluation Process

The CMP Program incorporates the involvement of the District's Agricultural Technical Advisory (AgTech) committee. This AgTech committee will be part of the review team for the evaluation of practices/measures demonstrating capability to reduce particulate emissions for inclusion in the CMP List. Organizations participating in the AgTech committee includes the United States Department of Agriculture, Natural Resource Conservation Services, Resource Conservation District, California Department of Food and Agriculture, University of California, educational institutions, Agricultural Extension Services, agricultural associations, growers/stakeholders, District, EPA, ARB, and other governmental organizations. The other participant is the District Air Pollution Control Officer (APCO) who is responsible to make the final approval of the proposed practice.

Diagram 1 below presents a process for evaluating proposed agricultural practices. An owner/operator submits the proposed practice(s) and supporting documentation to the District who in turn will do an independent analysis before presenting the practice(s) to the AgTech committee. The AgTech committee will review and forward their recommendation to the APCO for approval or disapproval. If approved, the proposed practice will then be added as a new CMP to the CMP List.

The timeframe for each step is to be determined as the process becomes established.

III. CMP Approval Criteria

The reviewing contributors should use the following factors to consider when determining acceptability:

1. Equivalent emission reduction to existing CMP in comparable CMP Category.
2. Availability and quality of research or manufacturer's data sheet demonstrating the effectiveness of PM emissions reduction.
3. State or Federal new regulations affecting the CMP List (e.g.: ag. burn restriction).
4. Potential negative impacts of the practice on the environment or animal health.

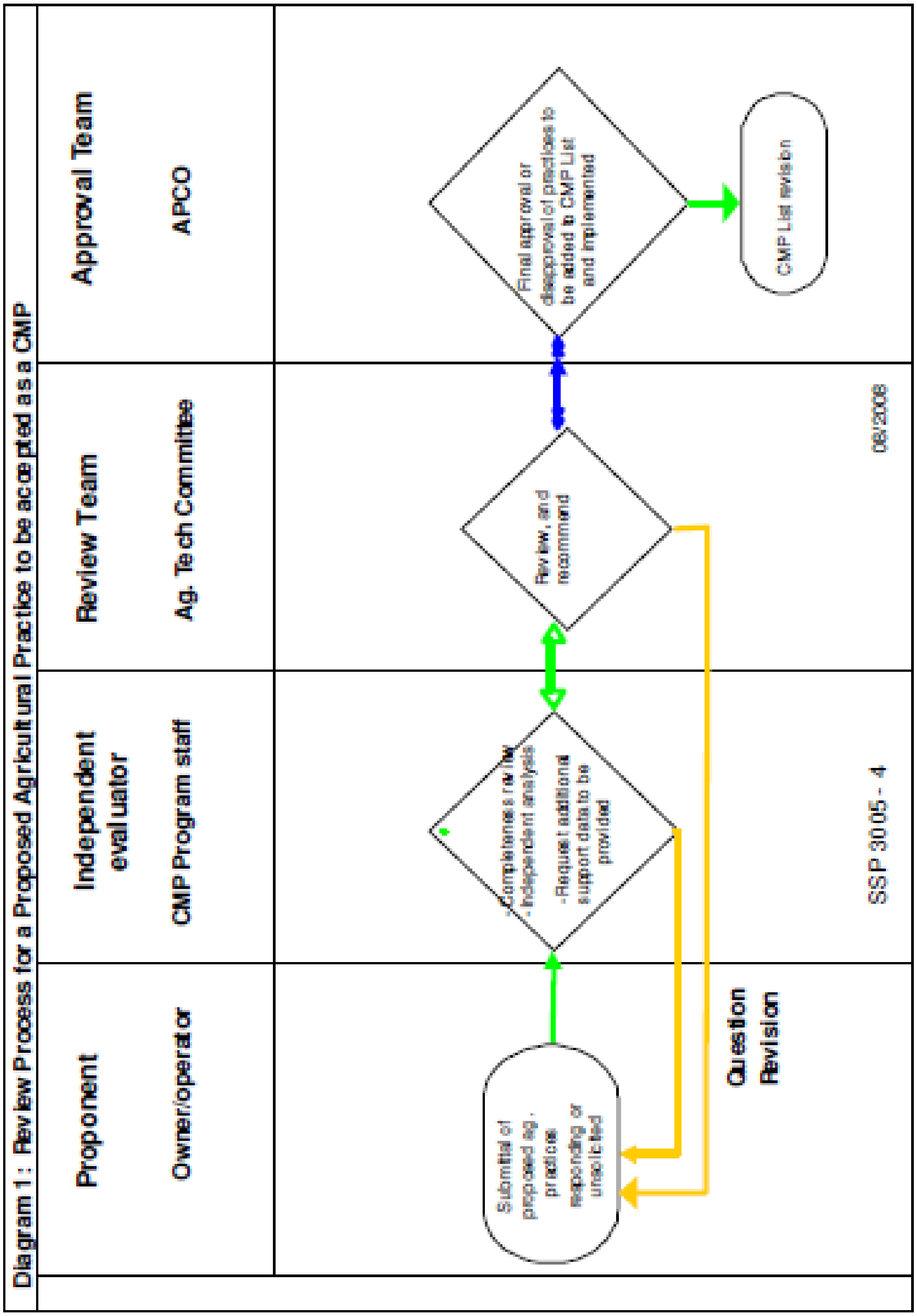
The list of criteria is not all-inclusive. It is to be further refined by the AgTech Committee.

DRAFT

IV. CMP List Update

Practices suggested by an owner or operator will be reviewed through an established CMP evaluation process and added to the CMP List if accepted. The CMP list will be updated accordingly.

DRAFT



Response on May 28, 2010

California State University, Fresno Foundation,
a recognized Auxiliary Corporation of California State University, Fresno

Trevor,
Could you please pass the following comment to Jim?
The draft policy on section 6.3.2.1, states that "The owner/operator shall demonstrate that the new CMP achieves PM10 emission reductions that are at least equivalent to other CMPs on the CMP list that could be selected for the applicable operation". Do the existing CMPs have documented PM10 reductions? If the percentage reduction for an existing CMP is not documented, how the reductions of the new CMP will be compared with existing CMPs that could be selected for the applicable operation?
I would suggest a baseline (reference point) with which a new technique will be compared. Perhaps the baseline will be an applicable management practice where no CMP is practiced. This information could be derived from existing data used in ARB (Agricultural Area Source Methodologies) or perhaps by running a comparative study. The study could compare PM10 emissions when the CMP in question is practiced and when no CMP is practiced and compare the results. Under this approach a cut off limit should be established which may be for example a 20% reduction in PM10 emissions.

Thank you,

Alex

--
A. Alexandrou, Ph.D.
Mechanized Agriculture
Associate Professor
Department of Plant Science
California State University - Fresno
2415 San Ramon Av. M/S AS72
Fresno, California 93740-8033
Phone: (559) 278 8824
Fax: (559) 278 7413

California State University, Fresno Foundation,
a recognized Auxiliary Corporation of California State University, Fresno

Misting: A Viable Conservation Management Practice (CMP) For Reducing PM10 Generated by Disking

APPENDIX F

Particulate Matter measurements at 25 meters

For the purposes of this study, the PM samplers were placed at 5 meters from the nearest pass of the tractor or harvester. The research team also placed PM samplers at 25 meters from the disk's nearest pass. The number and type of samplers used is shown in Table 1. The 25 meter samplers were used for every disking operation.

Number and type of PM samplers placed at 25 meters.

Sampling Method	Downwind Samplers (25 meters)		
	$PM_{2.5}$	PM_{10}	TSP
Texas A&M University Method (TAMU)	1	1	1

PM filters collected from the above mentioned samplers were analyzed the same way as the filters from the 5 meter samplers and emission rates were generated from these filters using AERMOD. The research team expected that the emission rates generated by the 25 meter samplers would not be statistically different from the emission rates generated from the 5 meter samplers. This expectation was based on the facts that the same event was monitored in both locations and that the air dispersion model takes into account the distance from the source when generates the emissions rate. However this was not the case. Emission rates from the 25 and 5 meter locations were statistically different.

The research team recognizes that the number of PM samplers located at 25 meters was insufficient to draw scientific conclusions. Moreover, the study was not designed to evaluate AERMOD and its performance when monitoring agricultural field operations. On the other hand the model is used for evaluating emissions from agricultural field operations and there is currently no protocol widely accepted for its use. The above mentioned finding created questions as to the applicability of this model for these types of operations. The research team recommends that more research should be carried out to evaluate the performance of AERMOD when it is used to monitor agricultural field operations.

TECHNOLOGY REVIEW CRITERIA

A description of the technology (process, method, equipment, or proprietary item) or measure.

Misting – as used in the reduction of particulate matter in the air - is all about energy budgets. Identifying the energy sources that exist in the phenomenon of particulate matter getting into the atmosphere is required to be able to reduce atmospheric dust. Dust reduction is about reducing the energy required to move soil particles from a stationary existence on the soil surface to being lifted into the air. Energy is necessary to counteract the force due to gravity (gravitational energy) that keeps the dust on the ground. Heretofore, methods to reduce dust have taken the form of:

1. wetting the soil,
2. planting vegetation either as ground cover or windbreaks
3. spreading or maintaining mulches and residues on the soil surface, and
4. reducing the number of passes of agricultural equipment

Very little effort has been applied to reducing the dust after it has already gotten into the air. Volumetrically, it seems to be an impractical control point. However, a careful identification of energy sources reveals that a little-recognized energy source is capable of being reduced - the heat energy that causes dust plume to rise.

Heat can be reduced by the application of the principle of the enthalpy of vaporization; also known as the heat of vaporization or heat of evaporation. For example, an evaporative cooler (also known as a swamp cooler, desert cooler, or wet air cooler) is a device that cools air through the evaporation of water. Evaporative cooling works by employing water's large enthalpy of vaporization. The temperature of dry air can be dropped significantly through the phase transition of liquid water to water vapor.

In thermo-chemistry, latent heat is the amount of energy in the form of heat released or absorbed by a substance during a change of phase (i.e., from a solid to a liquid or a liquid to a gas), also called a phase transition. Two of the more common forms of latent heat (or enthalpies or energies) encountered are latent heat of fusion (melting or freezing) and latent heat of vaporization (boiling or condensing). These names describe the direction of energy flow when changing from one phase to the next: again, from solid to liquid and a liquid to a gas. In both cases, the change is endothermic, meaning that the system absorbs energy on going from solid to liquid to gas. The change is exothermic (the process releases energy) for the opposite direction. For example, in the atmosphere, when a molecule of water evaporates from the surface of any body of water, energy is transported by the water molecule into a lower temperature air parcel that contains less water vapor than its surroundings. Because energy is needed to overcome the molecular forces of attraction between water particles, the process of transition from a parcel of water to a parcel of vapor requires the input of energy causing a drop in temperature in its surroundings. If the water vapor condenses back to a liquid or solid phase onto a surface, the latent energy absorbed during evaporation is released as sensible heat onto the surface. The terms *sensible heat* and *latent heat* are not special forms of energy, instead they characterize the same form of energy, heat, in terms of their effect on a material or a thermodynamic system. Heat is thermal energy in the process of transfer between a system and its surroundings or between two systems with a different temperature.

Soil temperature varies from month to month as a function of incident solar radiation, rainfall, irrigation, seasonal swings in overlying air temperature, local vegetation cover, type of soil, and depth. Due to the much higher heat capacity of soil relative to air, bare soil (i.e., soil without the thermal insulation provided by vegetation or a heavy mulch cover) will heat up faster and attain a higher temperature than the ambient air temperature. As the soil temperature rises above that of the ambient air, any dust plume generated from the hotter soil by an agricultural implement also rises. The heated dust plume rises into the air due to the plume being hotter than the ambient air - "hot air rises." Not only does hot air rise but it carries with it any soil particles light enough for their heat energy to overcome gravitational forces. The vaporization of a fine water mist requires heat and that heat comes from the heated dust plume. As the temperature of the dust plume is lowered by the evaporation of the mist, the dust particles no longer have enough energy to counteract the force due to gravity and the dust settles back to the ground.

The equipment (called a Dust Control Unit – DCU) that facilitates this heat transfer consists of a water tank, an electric pump, filters, booms, pressure control valve, pipes, and spray nozzles.

An explanation of how this technology or measure will accomplish one or more of the purposes of an existing standard.

Misting and the principle of latent heat of evaporation is applicable in any situation where a dust plume is generated whose temperature is hotter than the ambient air temperature. The DCU can be configured to many different pieces of equipment not only tillage equipment but also individual tractors, bulldozers, and backhoes working without an auxiliary piece of equipment. Below is a list of conservation practices that may need to address the air quality element of SWAPAH.

Alley Cropping (311)
Bedding (310)
Brush Management (314)
Clearing and Snagging (326)
Conservation Cover (327)
Conservation Crop Rotation (328)
Contour Buffer Strips (332)
Contour Farming (330)
Contour Orchard and Other Perennial Crops (331)
Cover Crop (340)
Critical Area Planting (342)
Cross Wind Ridges (588)
Cross Wind Trap Strips (589C)
Deep Tillage (324)
Dust Control from Animal Activity (375)
Filter Strips (393)
Firebreak (394)
Forage and Biomass Planting (512)
Forage Harvest Management (511)
Forest Site Preparation (490)
Forest Stand Improvement (666)
Forest Trails and Landings (655)
Fuel Break (383)
Heavy Use Protection (561)
Hedgerow Planting (422)
Herbaceous Weed Control (315)
Herbaceous Wind Barriers (603)
Hillside Ditch (423)
Irrigation Canal or Lateral (320)
Irrigation Field Ditch (388)
Irrigation Land Leveling (464)

Irrigation Reservoir (436)
Land Clearing (460)
Land Reclamation - Abandoned Mine Land (543)
Land Reclamation – Currently Mined Land (544)
Land Reclamation – Landslide Treatment (453)
Land Smoothing (466)
Obstruction Removal (500)
Open Channel (582)
Pipeline (516)
Pond (378)
Pond Sealing or Lining – Bentonite Sealant (521C)
Pond Sealing or Lining - Compacted Clay Treatment (521D)
Pond Sealing or Lining - Soil Cement (740)
Pond Sealing or Lining – Soil Dispersant (521B)
Precision Land Forming (462)
Range Planting (550)
Recreation Area Improvement (562)
Recreation Land Grading and Shaping (566)
Residue and Tillage Management, Mulch Till (345)
Residue and Tillage Management, No Till/Strip Till/Direct Seed (329)
Residue and Tillage Management, Ridge Till (346)
Residue Management (344)
Road/Landing/Trail Closure and Treatment (654)
Salinity and Sodic Soil Management (610)
Sediment Basin (350)
Shallow Water Development and Management (646)
Spoil Spreading (572)
Stripcropping (585)
Subsurface Drain (606)
Surface Drain, Field Ditch (607)
Surface Drain, Main or Lateral (608)
Surface Roughening (609)
Terrace (600)
Trails and Walkways (568)
Underground Outlet (620)
Vegetated Treatment Area (635)
Vegetative Barrier (601)
Vertical Drain (630)
Waste Storage Facility (313)
Waste Transfer (634)
Waste Treatment (629)
Waste Treatment Lagoon (359)
Waste Utilization (633)
Water and Sediment Control Basin (638)
Water harvesting Catchment (636)
Wetland Creation (658)
Windbreak – Shelterbelt Establishment (380)

Process monitoring and control system requirements, if applicable.

A visual determination of the DCU in operation in the field/vineyard will be required to substantiate its being used.

An example of warranties on all construction materials, equipment, or applied processes not covered by other NRCS Conservation Practice standards.

The manufacturer guarantees all materials and labor for one year against normal wear and tear.

An operation and maintenance plan that includes performance monitoring requirements and a replacement schedule for components that will not last for the practice lifespan.

The operation and maintenance plan consists of:

1. Visual inspection of nozzles before operating the system for proper spray pattern (between 180^0 and 300^0 depending on nozzle)
2. Check water pressure; if below 20 psi, remove and clean filter. Change filter when inspection indicates need.
3. If consumption of water – as determined by monitoring water level in the tank – falls below 3 gallons/nozzle/hour, check for plugged nozzles and proper working water pressure.
4. Spray should be fine enough to totally evaporate before reaching ground level
5. Auxiliary spray boom will automatically come on when electronic sensor senses a denser dust plume.

Estimated installation and annual operation cost.

Cost of DCU is variable depending on system design; field models will be larger and costlier than vineyard models.

Contact information for individuals that have implemented this technology successfully.

Vaughn Easter
Kern Ridge Growers
P O Box 455
Arvin, Ca. 93203
(661) 854-3141

Ross Spitzer
Top Hat Produce
13649 Weedpatch Hwy
Lamont, Ca. 93307
(661) 845-7844

Craig Poochigan
High Caliber Farms
2719 Panorama Dr.
Bakersfield, Ca. 93306
(661) 871-2160

Independent, verifiable data demonstrating results for the use of the measure, equipment, facility, or process in other similar situations and locations.

See Final Report.

The credentials of the individual collecting the data along with a disclaimer of any conflict of interest on the part of the individual.

A team was put in place to carry out the study. The team consisted of Dr. A. Alexandrou, Dr. C. Krauter, S. Ashkan and D. Adhikari. Dr. Alexandrou is an agricultural engineer. His research interests include soil mechanics, soil implement interaction and mechanical weed control. The last five years at Fresno State, he has developed an interest in the area of air quality and energy issues as related to agriculture. In the area of air quality his research focuses in particulate matter (PM) emissions from agricultural operations and emissions from small engines. He also worked on energy budget for field crops. Sponsors of his research include federal agencies such as USDA and Natural Resources Conservation Service, state agencies such as California Air Resource Board and San Joaquin Valley Air Pollution Control District, industry such as Sun Maid and agricultural groups such as NISEI Farmers League.
Dr. Krauter is a soil scientist with extensive work in the area of air quality in agriculture. His research interests include irrigation, water-plant relations. The last fifteen years, he has developed an interest in the area of air quality. In the area of air quality his research focuses in particulate matter (PM) emissions from agricultural operations and VOC emissions from dairies and confined animal facilities. He has been successful in obtaining external funding for his research. Sponsors of his research include federal agencies such as USDA and Natural Resources Conservation Service, state agencies such as California Air Resource Board and San Joaquin Valley Air Pollution Control District, industry such as Sun Maid and agricultural groups such as NISEI Farmers League.

Mr. Ashkan is an air quality researcher in the Center for Irrigation Technology, California State University- Fresno. He earned a M.Sc. degree in agricultural engineering form University of Nebraska in 1979. Mr. Ashkan has been actively involved in collecting and analyzing gaseous emissions from dairies and PM emissions from agricultural farms in the San Joaquin Valley since 2006.
D. Adhikari is an irrigation and instrumentation specialist, and works at the Center for Irrigation Technology (CIT) California State University. He also serves as a faculty member for the Department of Industrial Technology at CSUF where he teaches classes on automation, design and process control. His areas of expertise and research are in the field of air quality; soil salinity, land reclamation; crop co-efficient (Kc), groundwater, protocol development and sensor networks. He has successfully secured grants from Agricultural Research Institute, Irrigation Association, Valley Clean Air Now and various other State, Federal and private entities.

Progress reports for this project have been submitted to the Ag Tech committee of the SJVAPCD. The committee advices the San Joaquin Valley Air District on regulatory and policy issues related to agriculture. Part of the analytical work carried out for this project, was carried out in Texas A&M University under the supervision of Dr. B. Faulkner. Fresno State used AERMOD to model the data. During the modeling process the research team contacted the modelers of the SJVAPCD for consultation.

Disclaimer:

The statements and conclusions in this report are those of the contractor and not necessarily those of the sponsor. The mention of commercial products, their source, or their use in connection with material herein is not to be construed as actual or implied endorsement of such products.

No members of the research team and individuals collecting data for this project have any interest, financial or otherwise, direct or indirect, or engage in any business or transaction with the manufacturer of the DCU. All CSU Fresno employees participating in this project conform to all applicable conflict of interest policies.

Contact information for the technology provider (manufacturer).

Mr. Lynn Embry
Diamond E Manufacturing
3109 Jackie Court
Bakersfield, CA 93313-3719
661-632-6507
lynn@diamondemfg.com