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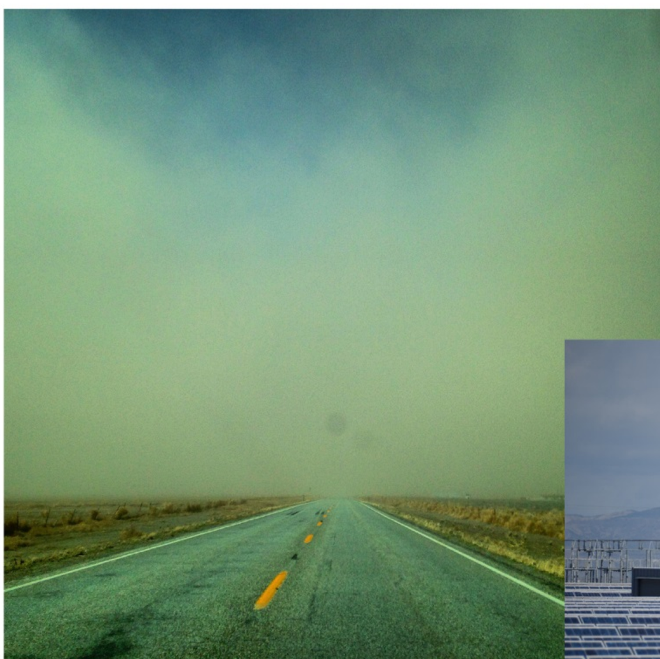
ANL/EVS-16/4

Modeling of Dust Levels Associated with Potential Utility-Scale Solar Development in the San Luis Valley-Taos Plateau Study Area

Final Report

Environmental Science Division



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Modeling of Dust Levels Associated with Potential Utility-Scale Solar Development in the San Luis Valley-Taos Plateau Study Area

Final Report

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prepared for
U.S. Department of the Interior, Bureau of Land Management

July 2016

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NOTATION

The following is a list of acronyms and abbreviations, chemical names, and units of measure used in this document. Some acronyms used only in tables may be defined only in those tables.

ACRONYMS, INITIALISMS, AND ABBREVIATIONS

AERMOD	AMS/EPA Regulatory Model
AFWA	Air Force Weather Agency
AQCR	Air Quality Control Region
AQRVs	air quality-related values
ASU	Adams State University in Alamosa
BLM	Bureau of Land Management
CAA	Clean Air Act
CFR	Code of Federal Regulations
CO	carbon monoxide
EAF	erodible area fraction
EPA	U.S. Environmental Protection Agency
ESRL	Earth System Research Laboratory (NOAA)
EVT	existing vegetation type
GIS	geographic information system
GOCART	Global Ozone Chemistry Aerosol Radiation and Transport (model)
HQ	hazard quotient
I	wind erodibility index
IMPROVE	Interagency Monitoring of Protected Visual Environments
IQ	intelligence quotient
LANDFIRE	Landscape Fire and Resource Management Planning Tools
LT	local time
MB	Municipal Building in Alamosa
NAAQS	National Ambient Air Quality Standards
NAD	North American Datum
NCDC	National Climatic Data Center
NM	National Monument
NO_2	nitrogen dioxide

NOAA	National Oceanic and Atmospheric Administration
NO_x	nitrogen oxides
O_3	ozone
OAQPS	Office of Air Quality Planning and Standards (EPA)
Pb	lead
PEIS	Programmatic Environmental Impact Statement
PM	particulate matter
$PM_{2.5}$	PM with an aerodynamic diameter of a nominal 2.5 microns or less (also known as fine particles)
PM_{10}	PM with an aerodynamic diameter of a nominal 10 microns or less
$PM_{10-2.5}$	PM with an aerodynamic diameter that is larger than 2.5 μm but smaller than or equal to 10 μm (also known as coarse particles)
PSD	Prevention of Significant Deterioration
RME	reasonable maximum exposure
RRTMG	rapid radiative transfer model-global
S	source function
SAAQS	State Ambient Air Quality Standards
SEZ	solar energy zone
SIP	State Implementation Plan
SLAMS	State and Local Air Monitoring Stations
SLV	San Luis Valley
SO_2	sulfur dioxide
SO_x	sulfur oxides
SRMS	Solar Regional Mitigation Strategy
UOC	University of Cologne
USDA	U.S. Department of Agriculture
VOCs	volatile organic compounds
WA	Wilderness Area
WEG	wind erodibility group
WPS	WRF Preprocessing System
WRF	Weather Research and Forecasting (model)
WRF-Chem	WRF model coupled with Chemistry

UNITS OF MEASURE

°C	degree(s) Celsius
cm	centimeter(s)
°F	degree(s) Fahrenheit
ft	foot (feet)
in.	inch(es)
kg	kilogram(s)
km	kilometer(s)
km^2	square kilometers(s)
m	meter(s)
m^3	cubic meter(s)
mg	milligram(s)
mi	mile(s)
mm	millimeter(s)
mph	mile(s) per hour
MW	megawatt(s)
s	second(s)
µg	microgram(s)
µm	micrometer(s)

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EXECUTIVE SUMMARY

ES.1 PURPOSE OF THE STUDY

The San Luis Valley (SLV)–Taos Plateau study area in south-central Colorado and north-central New Mexico is a large alpine valley surrounded by mountains with an area of approximately 6,263,000 acres (25,345 km^2) (Figure ES.1-1). This area receives ample sunshine throughout the year, making it an ideal location for solar energy generation, and there are currently five photovoltaic facilities operating on private lands in the SLV, ranging in capacity from 1 to 30 megawatt (MW).

In 2012 the Bureau of Land Management (BLM) launched its Solar Energy Program, which included the identification of four solar energy zones (SEZs) in the SLV totaling 16,308 acres (66 km^2), as well as over 50,000 (202 km^2) acres of other BLM-administered lands potentially available for application for solar development. The SEZ areas, named Antonito Southeast, De Tilla Gulch, Fourmile East, and Los Mogotes East, were defined by the BLM as areas well-suited for utility-scale (i.e., larger than 20 MW) production of solar energy where solar energy development would be prioritized (BLM 2012). Nonetheless, it was recognized that solar development in the SEZs would result in some unavoidable adverse impacts, and so the BLM initiated a solar regional mitigation strategy (SRMS) study for three of the SEZs (BLM and Argonne 2016).[1] The SRMS is designed to identify residual impacts of solar development in the SEZs (that is, those that cannot be avoided or minimized onsite), identify those residual impacts that warrant compensatory mitigation when considering the regional status and trends of the resources, identify appropriate regional compensatory mitigation locations and actions to address those residual impacts, and recommend appropriate fees to implement those compensatory mitigation measures.

The *Draft and Final Programmatic Environmental Impact Statement for Solar Energy Development in Six Southwestern States* (Solar PEIS) (BLM and DOE 2010, 2012) assessed potential impacts from solar development across a broad array of ecological and human resources, including air quality. Of particular concern with respect to air quality was the potential to generate large quantities of dust (also called particulate matter or PM) through construction activities that could involve grading of large areas of land. For example, the SEZs in Colorado range in size from 1,064 acres (4.3 km^2) to 9,712 acres (39.3 km^2), and it is possible that about 80% of the SEZ areas would be used for solar fields. Therefore, the Solar PEIS included extensive analysis and modeling of the potential impacts of construction-generated dust on communities and specially-designated areas near the SEZs. Although the Solar PEIS also included a comprehensive set of design features for solar development requiring stabilization of cleared areas and other measures to limit dust generation, there are remaining concerns

1 The Fourmile East SEZ is not being studied at this time.

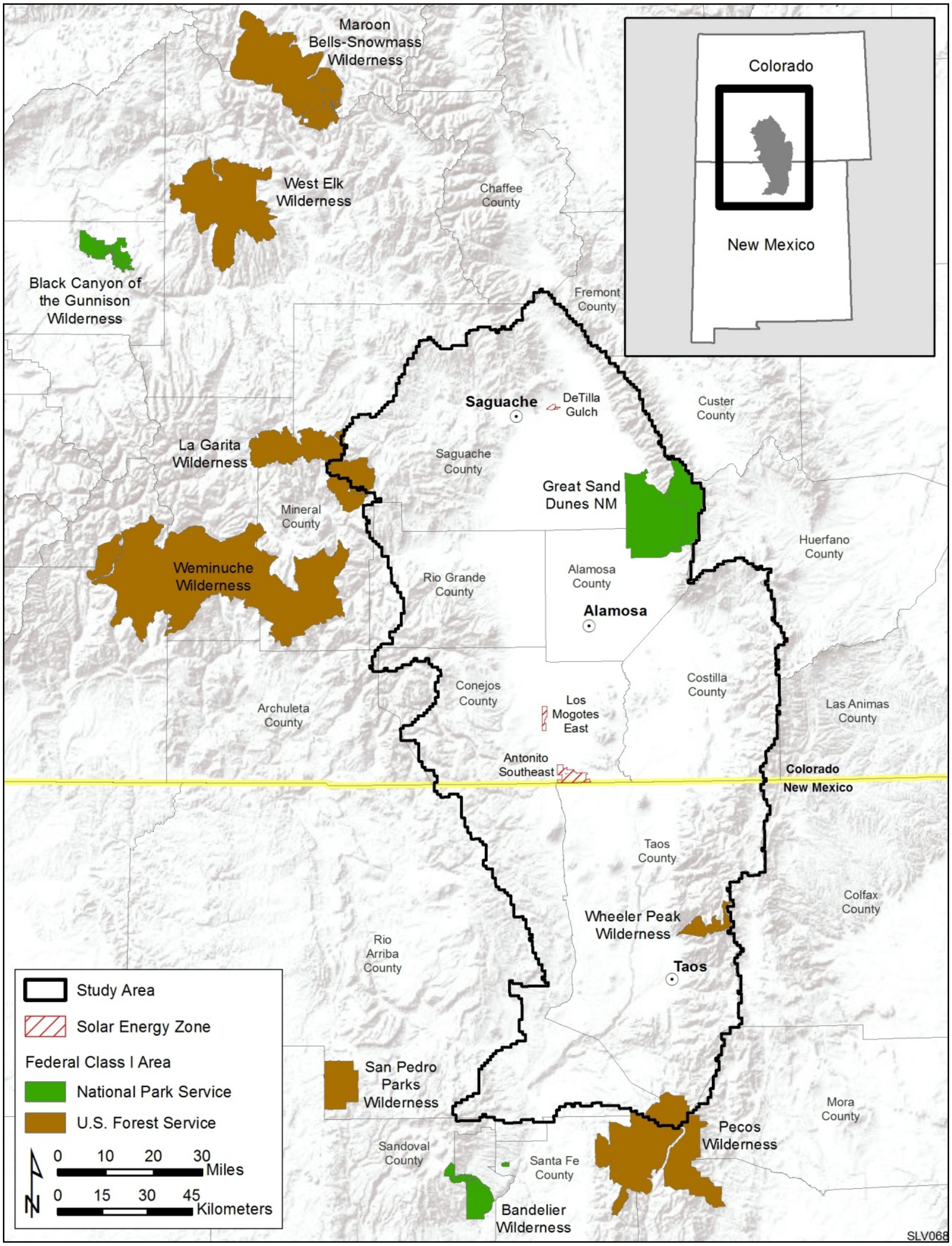

FIGURE ES.1-1 Locations of the San Luis Valley-Taos Plateau Study Area, Solar Energy Zones, and Nearby Federal Class I Areas

regarding the potential for wind-blown dust impacts during construction and operations. Questions include:

- Will dust levels be increased during the construction and operational phases of solar facilities, and if yes, what will be the area of impact?

- Would wind-blown dust generation be decreased if solar development avoided areas of highly-erodible soils? How would the use of dust suppressants impact the amount of dust generated?

- If there are increased dust levels during operations, what would be the cumulative impacts of operations in SEZs?

- If there are increased dust levels during construction and operations, would there be associated adverse health impacts for residents of nearby communities? Would arsenic-contaminated dust be a health concern?

The aim of this study is to support the SRMS by answering the questions posed above, both through a review of construction-phase modeling that was conducted for the Solar PEIS, and through innovative new modeling of the potential for operations-phase emissions. The modeling is innovative in that it adapts a well-known model used for estimating dust levels across very large areas (i.e., the Weather Research and Forecasting [WRF] model with Chemistry [WRF-Chem] model) to estimate dust levels for a smaller area on the basis of soil erodibility and land cover.

ES.2 BACKGROUND ON CLIMATE AND AIR QUALITY

ES.2.1 General Information

The SLV–Taos Plateau Level IV Ecoregion (identified as the study area for this report) includes portions of south-central Colorado and north-central New Mexico. About two-thirds of the study area (65%) occurs in Colorado. The study area includes all or portions of 12 counties in Colorado and six counties in New Mexico. Among these, five counties in Colorado (Alamosa, Conejos, Costilla, Rio Grande, and Saguache) and two counties in New Mexico (Rio Arriba and Taos) account for about 99% of the study area (these are called the primary counties in this study). The study area is approximately 172 mi (277 km) from north to south and 95 mi (153 km) from east to west. The extent of the study area is influenced by the two dominant mountain ranges in the region, which bound the study area, with the Sangre de Cristo Mountains to the east and the San Juan Mountains to the west. Elevations within the study area range from approximately 5,000 to 14,000 ft (1,524 to 4,267 m).

ES.2.2 Climate

Prevailing winds across the study area are from the southwest. The western side of the San Juan Mountains receives a substantial amount of precipitation, which is caused when air masses rise and subsequently cool, dumping their precipitation on the windward (western) side of higher elevations. This results in reduced rainfall on the leeward (eastern) side of the San Juan Mountains (i.e., in the study area) giving it an arid climate marked by cold winters and moderate summers, light precipitation, low relative humidity, and abundant sunshine due to the thin atmosphere caused by its high elevation. Because of daytime heating by the sun and nighttime cooling in the arid environment, along with cold air drainage from the surrounding mountains, daily temperature swings in the study area are large. Additionally, because of wide variations in elevation, topographic features, and latitude, meteorological conditions vary considerably from location to location within the study area.

ES.2.3 Particulate Matter

Dust (or PM) can deteriorate air quality and visibility and have adverse effects on health, particularly for people with asthma or other respiratory problems (see Section ES.5 for more detailed discussion of potential health impacts). It also has important effects on climate through its influence on the absorption and scattering of the sunlight and on the properties of clouds. PM is defined as a complex mixture of extremely small particles and liquid droplets that are not individually visible to the human eye, such as dust, fly ash, soot, smoke, aerosols, and mists. The composition and size of airborne particles and droplets varies.

When the levels of PM in the air are being monitored, particles are generally collected in two sizes, PM_{10} and $PM_{2.5}$. $PM_{2.5}$ (also called fine particles) is the mass of particles less than or equal to 2.5 micrometers (a micrometer, abbreviated μm, is equal to one millionth of a meter). PM_{10} is all of the particles with sizes less than or equal to 10 μm.[2] Coarse particles, or the subset of PM_{10} that is larger than 2.5 μm but smaller than or equal to 10 μm ($PM_{10\text{-}2.5}$), are not transported over long distances because they are too large to float in air streams and are readily removed from the atmosphere by depositing to the ground. On the other hand, fine particles can remain airborne for a long period and travel hundreds of miles with winds. Coarse particles can be inhaled into and accumulate in the upper respiratory system, while fine particles can penetrate deeper into the parts of the lungs that are more vulnerable to injury.

ES.2.4 PM Sources

PM can be put into the air directly from human (anthropogenic) activities or natural sources, or formed from chemicals already in the atmosphere. Anthropogenic sources of PM include agricultural operations, industrial processes, grazing, construction and demolition activities, unpaved roads and off-road vehicle use, woodstoves, street sanding during colder months, and fossil fuel combustion from stationary (e.g., power plants) or mobile (e.g., vehicles)

[2] 10 μm is 0.0004 inches, or one-seventh the width of a human hair.

emission sources. Natural sources of PM include wind-blown dust, such as from desert soils, or soot from wildfires. In general, coarse PM ($PM_{10-2.5}$) is largely made up of soil particles. Secondary particles are formed in the atmosphere from chemical reactions involving gaseous pollutants, such as sulfur oxides (SO_x), nitrogen oxides (NO_x), volatile organic compounds (VOCs), and ammonia. Emissions from power plants, industrial facilities, mobile sources, and other combustion sources are the main precursors of secondary particles. A significant portion of fine particles is made up of secondary particles.

The primary seven counties encompassing the study area generally are comprised of small towns, and their overall character is considered mostly rural to light industrial (in the few more urban areas like Alamosa). Because of its relatively low population density, low level of industrial activities, and relatively low traffic volume, the quantity of anthropogenic emissions (except agricultural emissions) in the study area is small; however, periodic dusty air and seasonal dust storms can occur. Wind-blown dust storms occur most frequently in the spring months, as a result of high winds and dry soil conditions.

ES.2.5 Air Quality Measures

Under the Clean Air Act (CAA), the U.S. Environmental Protection Agency (EPA) has established National Ambient Air Quality Standards (NAAQS)[3] for six criteria pollutants, including the pollutants that are the focus of this study, PM_{10} and $PM_{2.5}$. PM_{10} has 24-hour primary and secondary NAAQS of 150 $\mu g/m^3$, which is considered to be attained when the standard is not exceeded more than once per year on average over 3 years. $PM_{2.5}$ has 24-hour primary and secondary NAAQS of 35 $\mu g/m^3$, which is considered to be attained when the 3-year average of the annual 98^{th} percentile is less than or equal to the standard. In addition, $PM_{2.5}$ has primary and secondary annual-average NAAQS of 12 $\mu g/m^3$ and 15 $\mu g/m^3$, respectively, which are considered to be attained when the 3-year average of the annual mean is less than or equal to the standard.

Any geographic area that does not meet the NAAQS for a criteria pollutant is designated by the EPA as a nonattainment area, while any area that cannot be classified on the basis of available information as meeting or not meeting the NAAQS for the pollutant is called unclassifiable. Currently, portions of all the counties within the study area are designated as unclassifiable or in attainment of the NAAQS for all criteria pollutants, including PM. There are no nonattainment areas inside the study area.

The attainment of NAAQS requirements is determined based on the most recent three consecutive years of monitoring data, and thus these standards do not apply to construction or operation emissions from individual facilities. Therefore the NAAQS levels are used in this study as indicators of potentially significant dust levels with respect to adverse human health

3 The Clean Air Act establishes two types of NAAQS: primary standards to protect human health and secondary standards to protect public welfare, including protection against visibility impairment, damage to animals, crops, vegetation, and buildings.

impacts or other potential impacts, and should not be interpreted as requirements for individual solar facilities.

The Prevention of Significant Deterioration (PSD) regulations (40 CFR 52.21), which are designed to limit future air pollution in clean areas, apply to a major new source or modification of an existing major source within an attainment or unclassified area. While the NAAQS and State Ambient Air Quality Standards (SAAQS) place upper limits on the levels of air pollution, PSD regulations limit the total increase in pollution levels above established baseline levels in clean areas. The allowable increases are the smallest in areas identified as Mandatory Class I Federal Areas, such as national parks and wilderness areas (WAs), e.g., Great Sand Dunes National Monument in Colorado and Wheeler Peak WA in New Mexico (see Figure ES.1-1). For Class I areas, maximum allowable 24-hour and annual-average PSD increments are 8 and 4 $\mu g/m^3$ for PM_{10} and 2 and 1 $\mu g/m^3$ for $PM_{2.5}$, respectively.

ES.2.6 Existing Air Quality in the San Luis Valley-Taos Plateau

Air monitoring data shows infrequent wind-blown dust events[4] once or twice per year on average, mostly during springtime, in the Colorado portions of the SLV. There have been an increasing annual number of events in recent years. The main causes of wind-blown dust events are higher winds and dry, loose, exposed soils related to agricultural activities in spring months. Another potential factor is that increases in wind-blown dust events may be due to a northward migration of storm tracks associated with climate change. The upward trend in dust emissions in the region is expected to increase in the future because model predictions of future precipitation generally indicate that the study area will become drier. There is emerging evidence that this is already underway. Deserts in the United States are projected to expand to the north, east, and upward in elevation in response to projected warming and associated changes in climate. As an example, the 1955-2014 climatological data at Alamosa, Colorado show an upward trend in temperature and a downward trend in precipitation.

Currently, there are five air monitoring sites within the study area where PM concentrations are collected. Three of the stations are State and Local Air Monitoring Stations (SLAMS) sites, at: (1) Adams State University (ASU) in Alamosa, Colorado; (2) the Municipal Building (MB) also in Alamosa; and (3) Taos, in Taos, New Mexico.[5] At these sites, 24-hour PM_{10} has been monitored since 1989, 2002, and 2003, respectively. Twenty-four hour PM_{10} data are collected daily at the two sites in Alamosa and on every sixth day at the site in Taos. The Alamosa ASU and MB sites, which are located in the western and eastern parts of Alamosa,

[4] An event is defined as an occurrence of dust levels that exceeds the standard concentration, although a single exceedance does not mean an area is not in attainment.

[5] In the SLV, air monitoring networks are sparsely and irregularly spaced over a large area, with monitors concentrated in populous areas such as Alamosa and Taos. However, wind patterns and dust emission potential vary widely in the valley. Thus, air monitoring networks in the valley do not resolve actual spatial and temporal variability of PM levels. Broader and denser monitoring networks, particularly at smaller towns where the modeling predicts likely exceedances, would provide a better understanding of the spatial distributions of PM levels and would also detect local dust events across the study area.

respectively, are about 0.85 mi (1.4 km) apart. Two Interagency Monitoring of Protected Visual Environments (IMPROVE)[6] sites in the study area are also in operation. The IMPROVE monitoring sites include: (1) Great Sand Dunes National Monument and (2) Wheeler Peak WA. PM_{10} and $PM_{2.5}$ measurements have been taken at these sites at 3-day intervals since 1988 and 2000, respectively.

A total of 51 exceedances above the 24-hour PM_{10} NAAQS of 150 $\mu g/m^3$ have been reported at the monitoring sites in Alamosa. At the ASU site, 24-hour PM_{10} concentrations exceeded the NAAQS 29 times over the 25-year monitoring period, with the peak value of 473 $\mu g/m^3$. At the MB site, there were 22 NAAQS exceedances over the 12-year monitoring period, with the peak value of 635 $\mu g/m^3$. At these Alamosa sites, 24-hour PM_{10} concentrations less than 50 $\mu g/m^3$ occurred about 93-95% of the time and less than 100 $\mu g/m^3$ about 99% of the time. On average, 24-hour PM_{10} concentration exceeded the NAAQS level 1.2 and 1.8 days per year, respectively, at these locations; however, over the last ten years (2004-2013), these exceedances increased to 1.8-2.2 days per year.

At Taos, no exceedances over the 24-hour PM_{10} NAAQS have occurred since the start of monitoring in July 2003. At the two IMPROVE sites, 24-hour PM_{10} concentrations have been relatively low due to their elevated locations and distance from PM sources. One exception was the high PM episode in April 1994 when a 24-hour PM_{10} concentration of 352 $\mu g/m^3$ was reported at the Great Sand Dunes National Monument. A lower concentration of 21 $\mu g/m^3$ at a site in Alamosa only 26 mi (42 km) away on the same day suggests that this high concentration was a localized event. At the two IMPROVE sites, 24-hour and annual NAAQS for $PM_{2.5}$ have not been exceeded.

In general, some higher concentrations were associated with wind-blown dust events over the broad region but others were more localized. About six out of seven exceedances have been identified by the EPA as exceptional events, i.e., regional-scale natural wind storms, and thus were excluded from determining NAAQS compliance according to EPA-approved procedures. Monitoring data over the region indicates that elevated PM levels are generally associated with local conditions upwind of and near the monitoring locations that create wind-blown dust. As a result, there were many low readings in the region, even during regional dust storm events.

In Figure ES.2-1 (top panel), the number of days (by year) that 24-hour PM_{10} concentrations exceeded the NAAQS of 150 $\mu g/m^3$ are shown for all five monitoring sites within the study area. Most exceedances occurred at the two monitoring sites in Alamosa, and the number of exceedance days tended to increase more recently. As shown in Figure ES.2-1 (bottom panel), no exceedances over the NAAQS level have occurred during the months of January, July through September, or November. The highest PM exceedances tend to occur more frequently in late winter through early summer with a peak in April.

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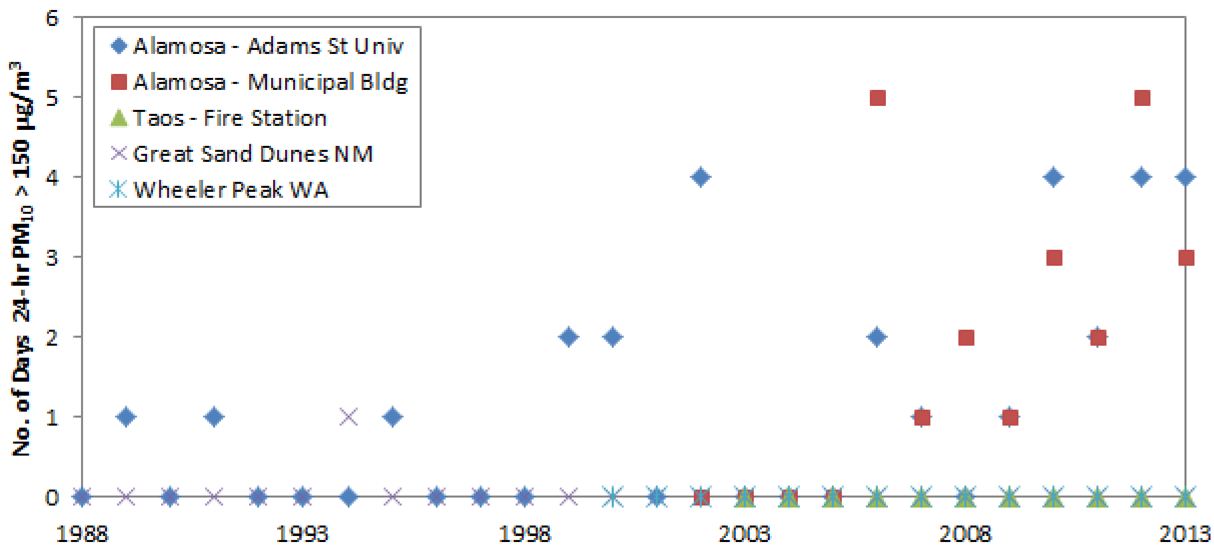
[6] The Interagency Monitoring of Protected Visual Environments (IMPROVE) monitoring program was established in 1985 to aid in the creation of federal and state implementation plans for the protection of visibility in Mandatory Prevention of Significant Deterioration (PSD) Class I Federal Areas.



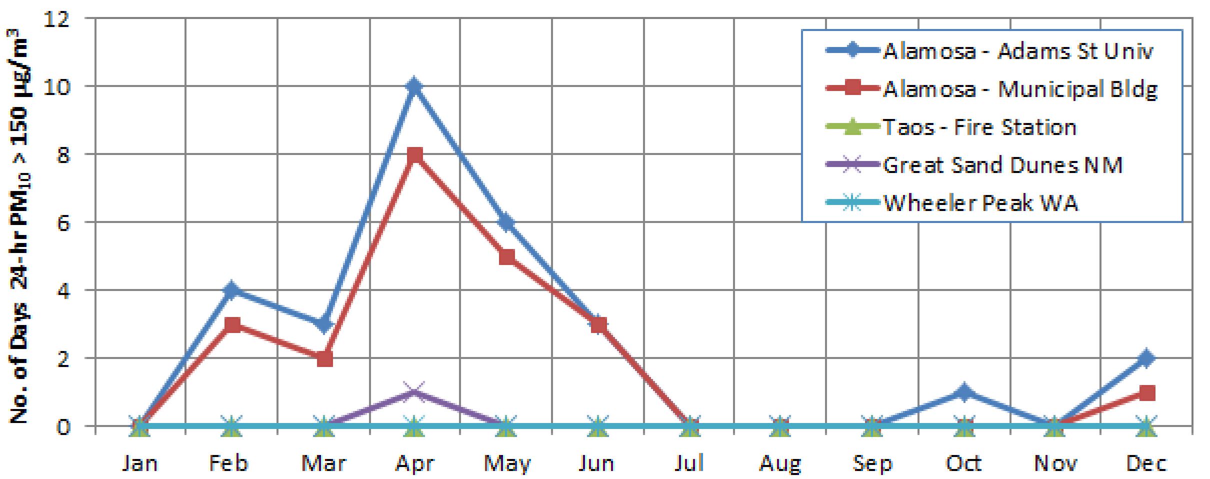


FIGURE ES.2-1 Number of Days by Year and by Month with Monitored 24-Hour PM_{10} Concentrations Exceeding NAAQS of 150 µg/m^3 at All Monitoring Sites Within the Study Area

ES.3 STUDY METHODS AND DATA

To estimate potential impacts on air quality associated with development of solar facilities in the SLV, air dispersion modeling was performed for construction and for wind-blown dust during operations. For the assessment of construction phase dust modeling the focus is on PM_{10} and $PM_{2.5}$ generated from soil disturbance caused by construction activities such as removal of vegetative cover, vehicle traffic, installation of power-conducting cable, and construction of site control buildings. For the assessment of operations phase dust modeling the focus is on wind-blown dust and the impact of land use/land cover changes on atmospheric concentrations of PM_{10} and $PM_{2.5}$ in the SLV-Taos Plateau region.

ES.3.1 Construction Activity Assumptions and Model

The Colorado SEZs have a flat terrain that would require only minimal site preparation work for solar facilities, perhaps with no large-scale earthmoving operations. However, depending on the amount of soil disturbed for a given solar project, dust emissions from soil disturbances during the construction phase could be a significant concern because of the large areas that would be disturbed in an area that already experiences some windblown dust problems. In work done for the Solar PEIS, potential impacts from PM_{10} and $PM_{2.5}$, which are widely used indicators of dust problems, were presented.

To conduct the dust impact assessment, an area-based emission factor of 0.11 tons of PM_{10} per acre per month was assumed.[7] The $PM_{2.5}$ emission factor assumed for construction activities was 10% of the PM_{10} emission. It was assumed that the conventional dust control measure of water spraying, with a control efficiency of 50%, would be applied over the disturbed area and on unpaved roads.

It was assumed that one construction project could occur annually within any of the Colorado SEZs. Based on actual solar facility construction projects, it was assumed that each project could disturb up to 3,000 acres (12.1 km^2) annually for Antonito Southeast SEZ. Because the other SEZs have areas of less than 3,000 acres, it was assumed that the entire developable area of each SEZ could be developed in a single year, equal to an assumed disturbed area of 851 acres (3.4 km^2) for the De Tilla Gulch SEZ and 2,120 acres (8.6 km^2) for the Los Mogotes East SEZ. To maximize estimated impacts, the construction for Antonito Southeast SEZ was also assumed to be located in the area closest to off-site residences and/or nearby towns. Also to maximize estimated impacts, it was assumed that all modeled PM would remain airborne (i.e., no dry or wet deposition was assumed), although in actuality the larger particles would settle to the ground within a short distance from the point at which they were generated. This assumption would result in some overestimation of PM concentrations.

Air quality modeling for PM_{10} and $PM_{2.5}$ emissions associated with construction activities was performed using the AMS/EPA Regulatory Model (AERMOD) recommended by the EPA. Modeling was done using five years[8] of representative meteorological data, which is recommended by EPA to incorporate the widest spectrum of possible meteorological conditions. These meteorological conditions were used to estimate the maximum PM concentrations over the 1-2 year construction period. Estimated air concentrations were compared with both NAAQS levels and PSD increments for Class I areas (Section ES.2.5).

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7 This area-based emission factor is an average of emission factors derived from construction activities at several sites in western states, activity levels of which range from low to heavy (e.g., heavy earthmoving, cut/fill, trucking of fill materials). Typical solar construction activities in the SLV would likely be low to moderate, so the assumed emission factor might somewhat overestimate actual emissions.

8 In air quality modeling for the De Tilla Gulch SEZ, only two years of meteorological data from the Saguache Airport were available at the time of analysis.

ES.3.2 Wind-Blown Dust Modeling for Operations

To assess potential impacts associated with wind-blown dust generated during the operation of solar facilities, the WRF-Chem was used; this is one of the state-of-the-art air quality models. The development of WRF-Chem is ongoing as a collaborative effort among the air quality modeling community. The model simulates the emission, transport, mixing, and chemical transformation of trace gases and aerosols simultaneously with atmospheric dynamics. It is widely used for investigation of regional- or global-scale air quality or climate change. The model is designed to operate on modern high-performance-computing equipment.

The modeling area was chosen to account for both local emissions in the study area and regional transport into the study area from upwind dust source areas, including the nearby Colorado Plateau and the more remote Sonoran, Mojave, Great Basin, and Chihuahuan Deserts. Therefore the modeling area included all of Arizona, Colorado, New Mexico, and Utah, and portions of surrounding states, such as California, Nevada, Oregon, Idaho, Wyoming, Nebraska, Kansas, Oklahoma, Texas, and northern Mexico.

To model dust generation potential across broad geographic regions, the WRF-Chem model typically uses input data related to soil properties (specifically clay fraction, and sand fraction) and an erosion factor. The erosion factor is based on topographic differences of a specific location compared to surrounding areas, which account for the loose sediment that accumulates in topographic depressions, including ancient lake beds that are the primary sources of dust on the global scale. However, these erosion factor fields do not characterize dust emission potentials in smaller areas like the SLV-Taos Plateau adequately, so a different method for modeling dust within the WRF-Chem model was used in this study, based on a combination of the soil characteristics of wind erodibility group (WEG) and land cover.

Wind Erodibility Group (WEG). The WEG is defined as a grouping of soils that have similar properties affecting their susceptibility to wind erosion in cultivated areas. In assigning WEG groups to soils, data on soil characteristics used include the following: soil texture class, organic matter content, carbonate effervescence class (an indicator of calcic soil), rock fragment content, and mineralogy. The WEG group provides an estimate of the level of wind erodibility of a given soil after disturbance, and was used to develop the erosion factor for wind-blown dust modeling. WEGs are classified into eight categories, ranging from 1 to 8. The soils assigned to group 1 are the most susceptible to wind erosion, and those assigned to group 8 are the least susceptible. In other words, the lower the WEG number (i.e., WEG 1 or 2), the greater the wind erodibility potential (or the more susceptible to wind erosion).

The WEG data for the study area are plotted in Figure ES.3-1. Higher elevations and slopes within the study area have higher WEG levels with low potential for wind-blown dust generation. Lower WEGs are prevalent on the valley floor in Colorado, which primarily is agricultural areas and sand dunes. In contrast, the valley floor in New Mexico has high WEGs (low potential for dust generation) except for a small portion in the southwestern corner. Antonito Southeast and Los Mogotes East SEZs have relatively high WEGs with no WEG 1 or 2 areas, and so are less susceptible to wind erosion. About 21% of the area (about 225 acres [0.91 km^2]) of the De Tilla Gulch SEZ has high erodibility potential, with WEG 1 or 2.

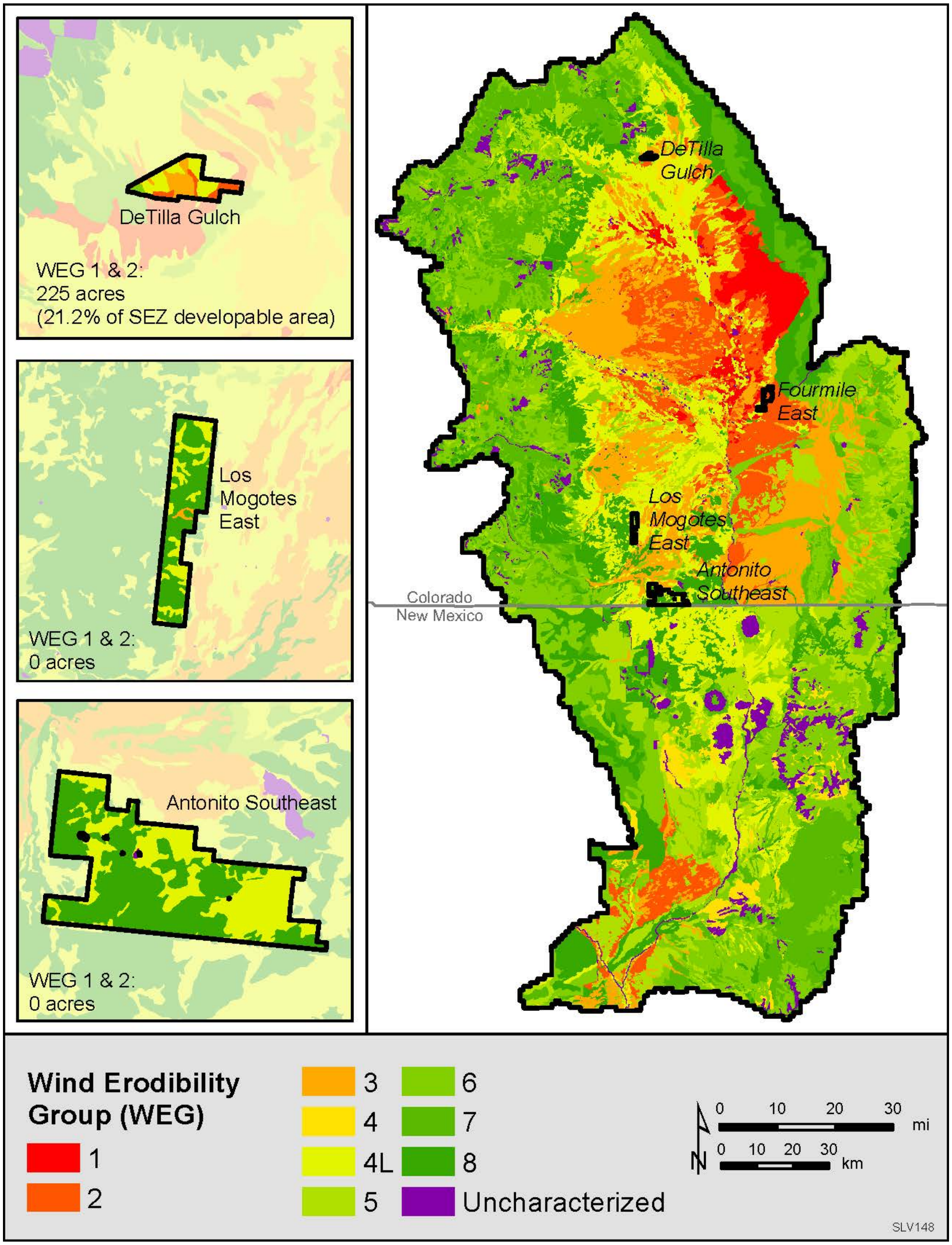

FIGURE ES.3-1 Distributions of Wind Erodibility Group (WEG) for the Study Area and Three Solar Energy Zones (SEZs)

Land Cover. All lands are not erodible; even if an area has a high erosion potential (i.e., low WEG value), no wind-blown dust will be generated if the area is not disturbed. Stable vegetation serves to hold soils in place and minimize dust generation. Thus, in addition to the WEG value, LANDFIRE existing vegetation type[9] data were used in the modeling, representing the vegetation types currently present in the study area. As shown in the left panel of Figure ES.3-2, existing vegetation type data are classified into 18 categories for the study area. Primary vegetation types in the study area include montane and subalpine conifer forest (about 35.2%) and pinyon-juniper woodland (about 10.2%), which are located along the high elevations and slopes of the study area, and basin grassland and shrubland (about 27.6%), which are widely scattered on the valley floor. Wetland vegetation accounts for about 10.2% of the eastern portion of the study area in Colorado. As shown in the right panel of Figure ES.3-2, erodible land was defined as those areas covered by three vegetation categories: barren (about 1.5%); herbaceous agricultural vegetation (6.9%); and recently disturbed or modified (2.8%). The erodible areas are mostly located in the Colorado portion of the study area. Most areas of SEZs currently have natural vegetation, which has no erosion potential. Development could involve removal of the natural vegetation, allowing potential for erodibility according to each areas WEG level.

Modeling. Using WEG and land cover data, modeled erosion factor distributions were generated as shown in Figure ES.3-3. As expected (see the right panel in Figure ES.3-2), erosion factors on the Colorado side of the study area, where most erodible vegetation types are located, are relatively high, whereas erosion factors on the New Mexico side are mostly near zero.

The study area is in complex terrain, which can lower the accuracy of modeling of dust generation. To address some of the modeling limitations, realistic assumptions for dust generation potential were incorporated through use of WEG and land cover data for the study area. The wind-blown dust modeling used for this study captures general patterns and predicted concentration levels that are in reasonable agreement with observations (see Figure ES.3-4). The methodology used is useful for the estimation of expected percent change in the dust levels due to solar development in the SEZs,

ES.4 RESULTS FOR THE SAN LUIS VALLEY-TAOS PLATEAU

ES.4.1 Construction Impacts Analysis

Fugitive dust emissions from soil disturbances during the entire construction phase were identified as a concern, because of the large areas that could be disturbed over relatively prolonged periods[10] in a region that experiences windblown dust problems. Therefore, the

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9 In the LANDFIRE model, exiting vegetation types are mapped using decision tree models, field data, Landsat imagery, elevation, and biophysical gradient data.

10 For the Antonito Southeast SEZ, which has a recommended developable area of approximately 9,000 acres (BLM and Argonne 2016), construction activities would likely occur over a period of 3 to 5 years, not necessarily consecutively. For the smaller De Tilla Gulch and Los Mogotes SEZs, construction activities would likely occur over a shorter period of 1 to 2 years.

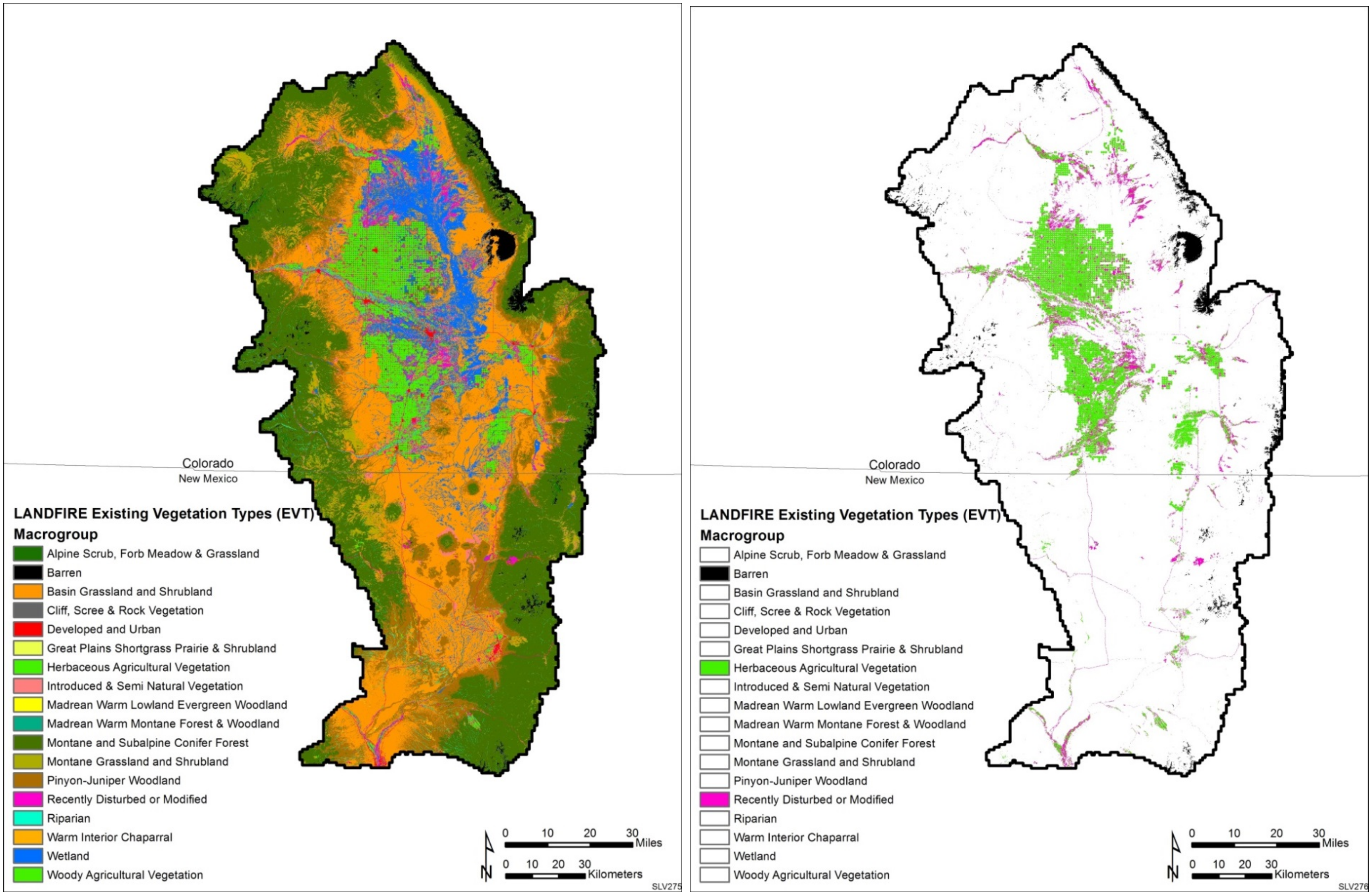

FIGURE ES.3-2 LANDFIRE Existing Vegetation Types (left panel) and Wind-Erodible Vegetation Types (right panel) in the Study Area

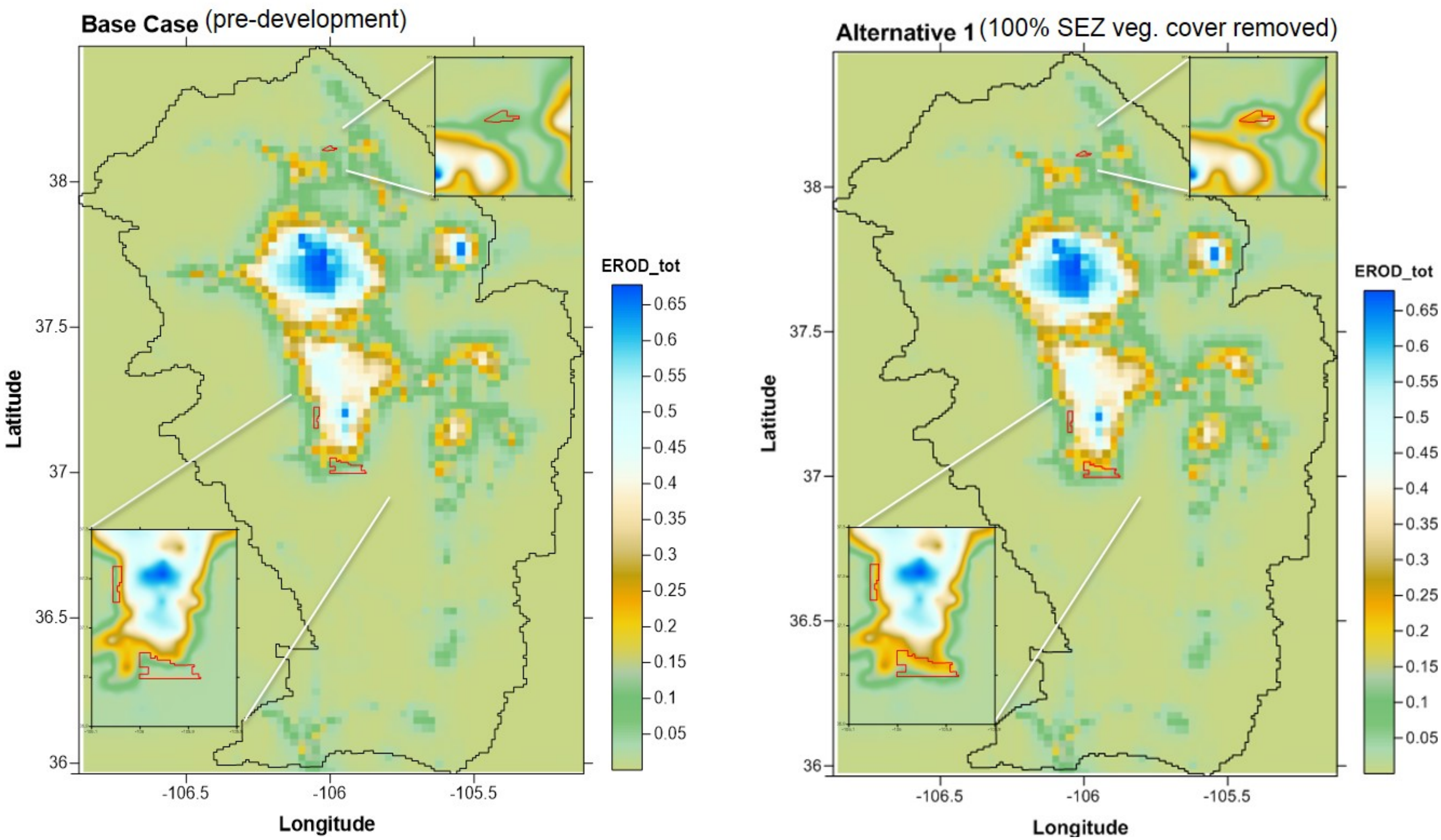

FIGURE ES.3-3 Erosion Factor Fields in the San Luis Valley-Taos Plateau Study Area along with Three Solar Energy Zones (inset): Base Case – Pre-Development (left panel); and Scenario 1 – 100% Solar Energy Zone Vegetative Cover Removed (right panel)

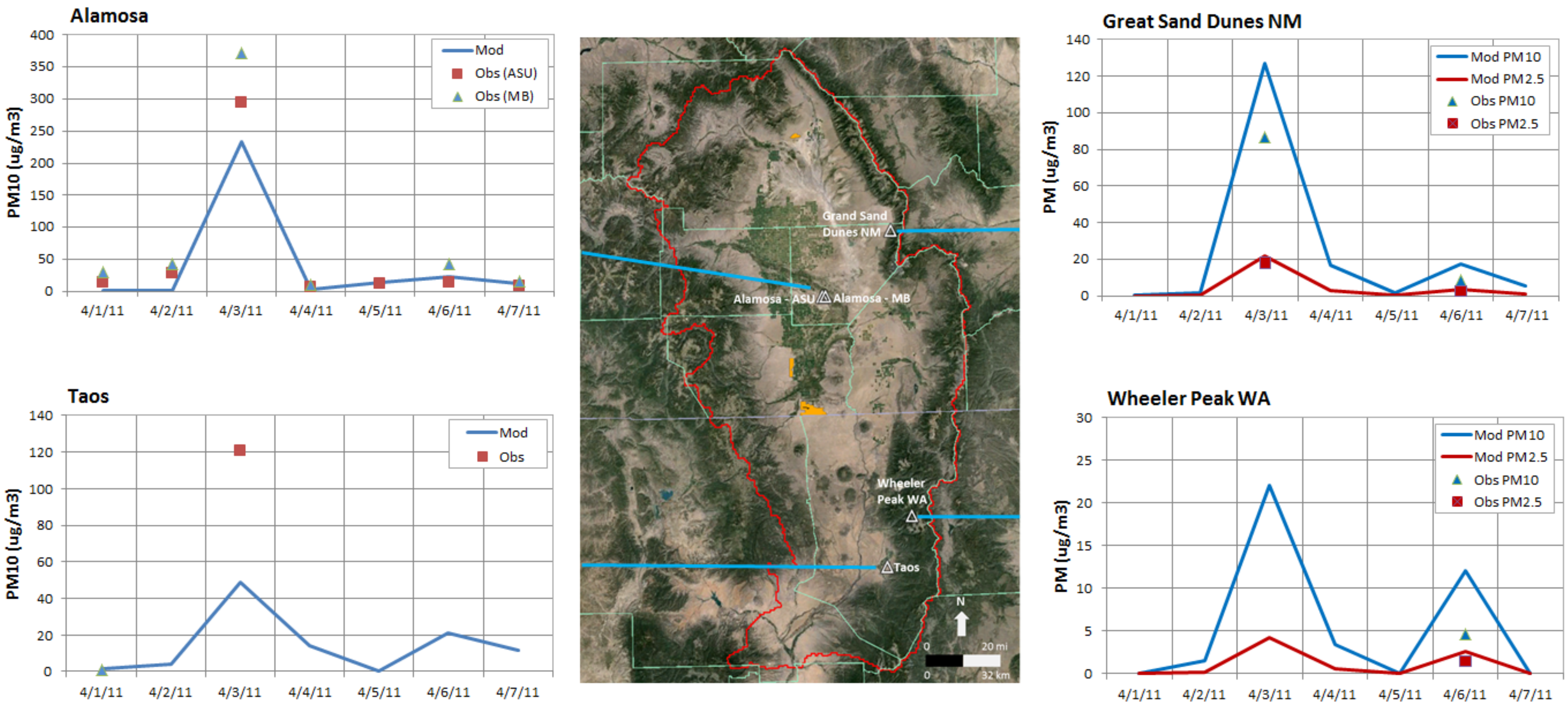

FIGURE ES.3-4 Comparison of Modeled and Observed 24-Hour PM_{10} at Alamosa and Taos and $PM_{10}/PM_{2.5}$ at Great Sand Dunes National Monument and Wheeler Peak Wilderness Area Within the San Luis Valley-Taos Plateau, for Meteorological Conditions Occurring April 1-7, 2011

potential dust levels associated with construction emissions were modeled and compared with NAAQS levels to evaluate the potential impacts to the environment and to human health (see Section ES.5). Many assumptions for the analyses were made with the intent of overestimating impacts, because detailed information on future construction activities (such as facility size, type of solar technology, heavy equipment fleet, activity level, and work schedule) was not available. For actual projects within SEZs, more detailed information on construction activities and the project locations within the SEZs would be available, and more realistic emission estimates based on activity-specific emission factors and actual detailed activity levels would be derived, which would likely be lower than those estimated in the current analysis. During actual construction, dust generation would be controlled by implementing control measures (such as increased watering frequency, using dust suppressing agents, installing wind fences, and/or paving road surfaces). Site operators would be required to maintain dust levels at the site boundaries at lower than the permit-required levels, through using these dust control measures, and altering construction practices and/or schedules.

The results of modeling of construction-related dust emissions are presented both as increments (dust levels over background) and total concentrations (modeled plus background concentrations) at site boundaries, nearest residences, and nearby towns. These results are summarized in Table ES.4-1. Both modeled maximum 24-hour PM_{10} concentration increments and total concentrations during construction activities are estimated to exceed the NAAQS level of 150 $\mu g/m^3$ at the boundaries of all three SEZs and at the nearest residence near the Antonito Southeast SEZ boundary. Under the conservative modeling assumptions, total concentrations could also be higher than the NAAQS at some nearby residences, within about 1 mi from the site boundaries for the Antonito Southeast SEZ and about 0.5 mi from the site boundaries for the Los Mogotes East SEZ. The estimated increments and total concentrations at nearby towns for all three SEZs are estimated to be below the 24-hour PM_{10} NAAQS, as shown in Table ES.4-1.

For $PM_{2.5}$, 24-hour total concentrations during construction were estimated to be higher than the NAAQS level of 35 $\mu g/m^3$ at site boundaries for all three SEZs. However, these concentrations would not be exceeded at the nearest residences or nearby towns. Total annual average $PM_{2.5}$ concentrations were estimated to exceed the primary standard of 12 $\mu g/m^3$ at the Antonito Southeast SEZ site boundaries and in the immediate vicinity of the boundaries. Total annual average $PM_{2.5}$ concentrations outside of the De Tilla Gulch and Los Mogotes East SEZs would not exceed the primary standard.

For solar development at the Antonito Southeast or De Tilla Gulch SEZs, predicted 24-hour increments at the nearest Class I areas – Great Sand Dunes National Monument and Wheeler Park WA – would be slightly higher than the PSD increment for Class I areas (8 $\mu g/m^3$). Due to distances and/or intervening high mountains, PSD increments would not be exceeded at other Class I areas which are located near to but outside of the study area.

Since the Los Mogotes East and Antonito Southeast SEZs are within about 12 mi (19 km) of each other, the likelihood of cumulative impacts from construction of solar facilities at the two SEZs was evaluated. Because the prevailing wind direction is from the southwest and the Los Mogotes SEZ is located to the north-northwest of the Antonito Southeast SEZ, dust impacts would only be minimally additive. Additionally, the duration of construction activities is limited

TABLE ES.4-1 Maximum Air Quality Impacts from Emissions Associated with Construction Activities for the Antonito Southeast, De Tilla Gulch, and Los Mogotes East SEZs

				Concentration (µg/m³)				Percentage of NAAQS[c]	
Pollutant[a]	Averaging Time	Rank[b]	Location	Maximum Increment[b]	Back-ground	Total	NAAQS	Increment	Total
San Antonito Southeast SEZ									
PM_{10}	24 hours	H6H	SEZ boundary	569	27	596	150	***380***	***398***
			Nearest residence	230		257		***153***	***171***
			Antonito	100		127		67	85
			San Antonio	60		87		40	58
$PM_{2.5}$	24 hours	H8H	SEZ boundary	40.0	16	56.0	35	***114***	***160***
			Nearest residence	15		31		43	89
			Antonito	3.5		19.5		10	56
			San Antonio	3.5		19.5		10	56
	Annual	-[d]	SEZ boundary	10.6	4	14.6	12/15[e]	88/70	***122***/97
			Nearest residence	1.8		5.8		15/12	48/39
			Antonito	0.4		4.4		3/3	37/29
			San Antonio	0.4		4.4		3/3	37/29
De Tilla Gulch SEZ									
PM_{10}	24 hours	H3H	SEZ boundary	430	27	457	150	***287***	***305***
			Nearest residence	81.3		108		54	72
			Saguache	13.4		40.4		9	27
			Moffat	10.7		37.7		7	25
$PM_{2.5}$	24 hours	H8H	SEZ boundary	26.3	16	42.3	35	75	***121***
			Nearest residence	3.8		19.8		46	57
			Saguache	0.1		16.1		0.3	46
			Moffat	0.3		16.3		0.9	47
	Annual	-	SEZ boundary	6.5	4	10.5	12/15[e]	54/43	88/70
			Saguache	0.02		4		0.1/0.1	33/27
			Moffat	0.02		4		0.1/0.1	33/27
Los Mogotes East SEZ									
PM_{10}	24 hours	H6H	SEZ boundary	374	27	401	150	***249***	***267***
			Nearest residence	141		168		94	***112***
			Conejos	33.3		60.3		22	40
			Romeo	31.1		58.1		21	39
$PM_{2.5}$	24 hours	H8H	SEZ boundary	26.0	16	42.0	35	74	***120***
			Nearest residence	6.8		22.8		46	65
			Conejos	0.7		16.7		2	48
			Romeo	1.9		17.9		5	51
	Annual	-	SEZ boundary	6.3	4	10.3	12/15[e]	53/42	86/68
			Conejos	0.1		4.1		1/1	34/27
			Romeo	0.2		4.2		2/1	35/28

Footnotes on next page.

TABLE ES.4-1 (Cont.)

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[a] $PM_{2.5}$ = particulate matter with an aerodynamic diameter of ≤2.5 µm; PM_{10} = particulate matter with an aerodynamic diameter of ≤10 µm.

[b] Concentrations for attainment demonstration are presented. H3H = highest of the third-highest concentrations at each receptor using two years of meteorological data available at that time. H6H = highest of the sixth-highest concentrations at each receptor using five years of meteorological data. H8H = highest of the multiyear average of the eighth-highest concentrations at each receptor using two or five years of meteorological data, as available. For the annual average, multiyear averages of annual means using two or five years of meteorological data, as available, are presented. Maximum concentrations are predicted to occur at the site boundaries.

[c] Values in reds indicate NAAQS exceedances.

[d] A dash indicates not applicable.

[e] A left-hand value denotes primary standard to protect public health, while a right-hand value denotes secondary standard to protect public welfare.

and it is likely that those activities would occur at different times in each SEZ. Therefore, adverse cumulative air quality impacts would not be expected. If two solar facilities were being constructed at approximately the same time at the two SEZs, specific schedules could be managed to reduce air quality impacts.

The impacts of construction activities on air quality as predicted by the conservative modeling described above can be characterized as moderate at the site boundaries and some of the nearby residences, but temporary in nature (likely occurring over a 1 to 5-year period). The modeling indicates that when combined, dust emissions from construction in the SEZs and natural dust generated from winds and windstorms could cause temporary adverse cumulative air quality impacts in the general vicinity of SEZ solar facilities if not controlled. However, construction practices that would limit actual emissions to below permit required levels would be required; the modeled estimates are useful for predicting likely maximum concentrations if required minimization measures were not implemented, in order to identify the need for implementation of additional dust control measures during construction.

For this screening analysis, modeled results were used to assess potential problems and as a consideration in the permitting process. In doing so, several conservative assumptions were used, e.g., use of area-based emission factors, no dry or wet deposition of PM was modeled, and for the Antonito Southeast SEZ, the solar facility was assumed to be next to the SEZ boundary closest to nearby residences. During the permitting process for an actual facility, refined modeling with more detailed and realistic information would be conducted, and predicted results would be lower than those presented here. In addition, site operators would be required to monitor PM concentrations at site boundaries and/or nearby residences to verify that dust control measures were keeping PM levels lower than levels identified in the site permits.

ES.4.2 Operations Impact Analysis

ES.4.2.1 Scenarios Analyzed

For modeling of wind-blown dust impacts during operations, a pre-development or base case and the six development scenarios were evaluated, as follows:

- Base Case (or Baseline) – pre-development (current);
- Scenario 1: Assumes 100% of SEZ vegetative cover is removed;
- Scenario 2: Assumes 80% (corresponds to PEIS full build out) of SEZ vegetative cover is removed;
- Scenario 3: Assumes 50% of SEZ vegetative cover is removed;
- Scenario 4: Assumes 20% of SEZ vegetative cover is removed;
- Scenario 5: Assumes 100% of SEZ vegetative cover is removed (as for Scenario 1), but dust suppressant is applied over 20% of SEZ area (assume suppressant decreases dust emissions by 50%); and
- Scenario 6: Assumes 100% of SEZ vegetative cover is removed (as for Scenario 1), but dust suppressant is applied over 80% of SEZ area (assume suppressant decreases dust emissions by 50%).

The base case (baseline or current pre-development conditions) serves as a benchmark to assess future impacts in the study area. For this scenario, erodible lands in the study area, such as agricultural lands or disturbed lands, are assumed to be subject to wind erosion. Because the soils of the three SEZs currently have natural vegetation, they are assumed to be non-erodible for the base case modeling.

For Scenario 1, it is assumed that 100% of vegetative cover is removed for all three SEZs. Note that, although the Solar PEIS assumed a maximum of 80% vegetative cover removal at full build out, for this study 100% was modeled as a worst-case. For Scenarios 2 through 4, 80%, 50%, and 20% of SEZ vegetative cover are assumed to be removed.

For Scenarios 5 and 6, it is assumed that 100% of SEZ vegetative cover is removed (as was assumed for Scenario 1), and dust suppressant is applied over 20% and 80% of SEZ area, respectively. It is conservatively assumed that dust suppressant would decrease dust emissions by 50%, although a control efficiency of 80% or higher is common. Dust suppressants can have variable effectiveness and also can result in some adverse environmental impacts (additional details provided in Section 4.2.4 of this report.

ES.4.2.2 Results for Operations Impacts

To assess air quality impacts for the base case conditions and future scenarios, first the model performance was evaluated for the base case and the erosion factor was calibrated. Then potential dust impacts for future development in the study area (as estimated by assuming varied levels of vegetative cover removal in the SEZs) were examined for the other scenarios by assuming meteorological conditions similar to previous dust storm episodes. The meteorological conditions from historic wind-blown dust episodes were selected to support the modeling, particularly a severe event that occurred on April 3, 2011.

The modeled 24-hour PM_{10} results around the SEZs are shown in Figure ES.4-1, along with concentration changes between the base case scenario and Scenario 1.[11] For the base case, it was assumed that the SEZs have natural vegetation, which was assigned as non-erodible and thus the SEZs would not be a source of wind-blown dust generation. The base case 24-hour PM_{10} concentrations were highest on agricultural lands and their immediate downwind areas (left panels of Figure ES.4-1). Under the 100% development scenario (Scenario 1), higher concentrations are predicted to occur immediately downwind of the SEZs (center panels). The difference between 24-hour PM_{10} concentrations for the base case and Scenario 1 (worst case) are displayed in the right panels of Figure ES.4-1.

At the boundaries of Antonito Southeast and Los Mogotes SEZs, PM_{10} concentrations are predicted to increase by about 260 and 50 $\mu g/m^3$, respectively, but concentrations would decrease rapidly with distance. The Antonito Southeast SEZ contains soils less erodible soils (see Figure ES.3-1) and most of the towns near the SEZ (shown as green dots) are located upwind and thus would be minimally affected by large-scale soil disturbance at the SEZ. Conversely, several towns are located downwind of the Los Mogotes East SEZ. However, in general increases in PM_{10} concentrations due to wind-blown dust from development of the Los Mogotes SEZ would be low because the SEZ also contains less erodible soils, and only a narrow region of the SEZ is exposed to the prevailing wind direction. Nonetheless, PM_{10} concentrations at Romeo, which is located about 3 mi (5 km) east of the Los Mogotes East SEZ, would increase by about 20%. Increases at other towns near SEZs would be much lower.

At the boundary of the De Tilla Gulch SEZ, modeled PM_{10} concentrations are predicted to increase by about 40 $\mu g/m^3$ with 100% development. A portion of the De Tilla Gulch SEZ (about 225 acres or 21% of the SEZ) has soils with WEG group of 1 or 2 (indicating a higher erosion or dust generation potential). However, most towns are not downwind of and/or are far from the SEZ, and thus potential dust impacts related to development of the SEZ would be minor.

[11] The study was based on modeling a hypothetical future event assuming weather conditions identical to those that occurred on April 3, 2011. To assess the impact of land use/land cover changes, the same meteorological conditions were used with the added SEZ land disturbance.

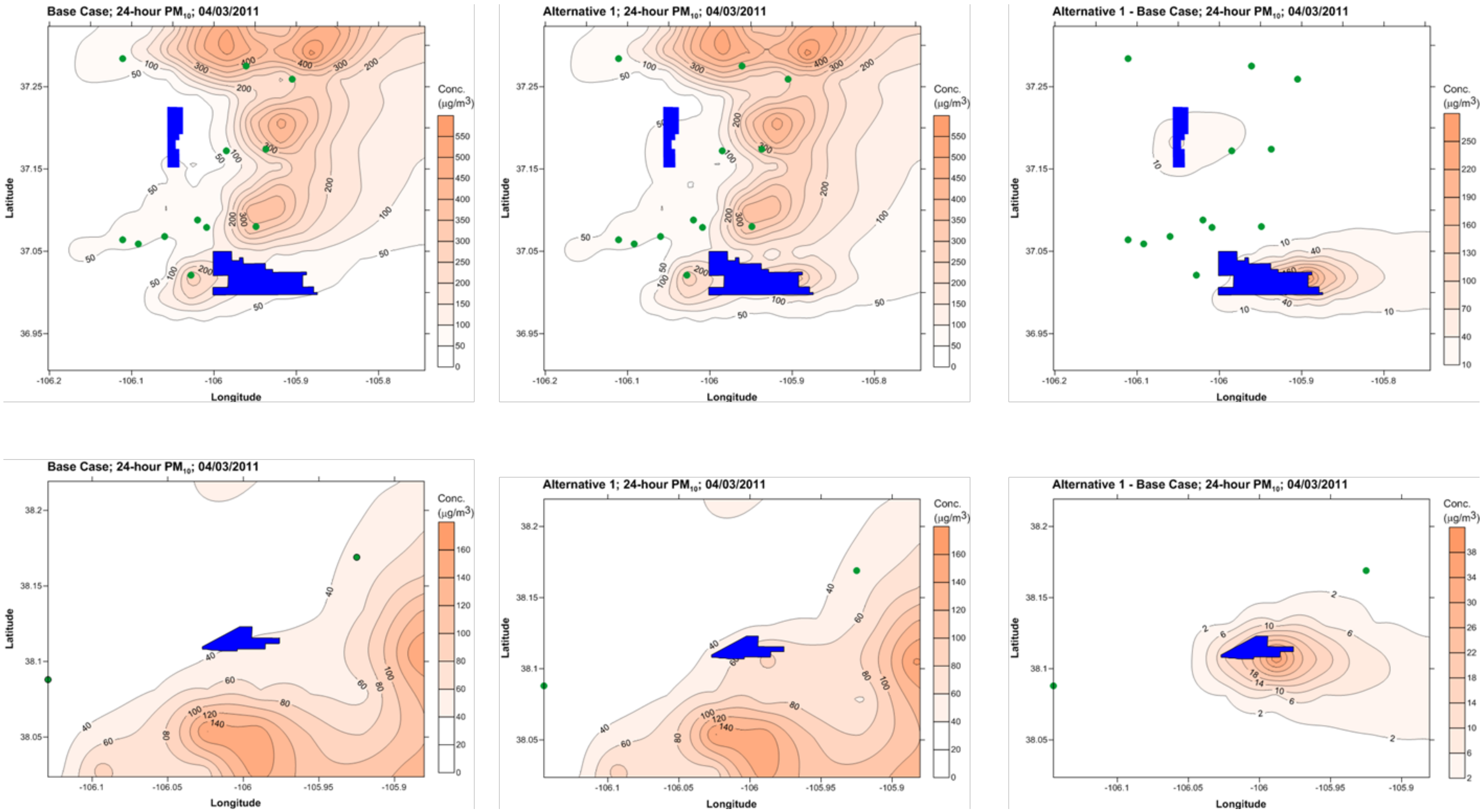

FIGURE ES.4-1 Modeled 24-Hour PM_{10} Concentrations for the Base Case and Scenario 1, and Difference of Scenario 1 from Base Case around the Antonito Southeast and Lost Mogotes East SEZs (upper panels), and De Tilla Gulch SEZ (lower panels). Note – Uses meteorological conditions of April 3, 2011 as representative for a dust generation episode

Table ES.4-2 along with Figure ES.4-2 presents the estimated PM_{10} concentrations at towns around the SEZs and at the five air monitoring stations for the base case and the six development scenarios. In general for the base case (no development), 24-hour PM_{10} concentrations at towns that are located downwind of agricultural lands are predicted to exceed the NAAQS of 150 $\mu g/m^3$ during dust episodes in the SLV. These towns are Alamosa, La Jara, Lobatos, Manassa, San Antonito, and Sanford. In contrast, lower PM_{10} concentrations are generally predicted for towns upwind of agricultural activities. Scenario 1 has the largest impact on air quality because the scenario assumes that all of the SEZ vegetative cover is removed for solar development of the three SEZs.

Under Scenario 1, projected 24-hour PM_{10} concentrations at the nearest towns remain almost the same as under the non-development base case or have a relatively small increase (a few percent at most). This is because most towns are located far from and/or upwind of the SEZs. For example, most towns around the Antonito Southeast SEZ (shown as green dots in Figure ES.4-1) are located upwind of prevailing winds. An exception is the town of Romeo, which is located immediately downwind of the Los Mogotes East SEZ; there the 24-hour PM_{10} concentration under Scenario 1 is predicted to increase by about 20% (from 81 to 97 $\mu g/m^3$) compared with the base case. At Joyful Journey Hot Spring Spa about 5 mi (8 km) northeast of the De Tilla Gulch SEZ, the 24-hour PM_{10} concentration is predicted to increase by about 4% (from 54 to 56 $\mu g/m^3$) compared with the base case. At the five air monitoring sites within the study area (which are quite distant from the SEZs), the model results indicate that the development of SEZs would increase 24-hour PM concentrations resulting from wind-blown dust by 0.3% at most. Modeling indicates that 24-hour PM_{10} concentrations would increase by about 0.2% at Great Sand Dunes National Monument directly downwind of the De Tilla Gulch SEZ. Therefore, dust impacts associated with development of the three SEZs on other Class I PSD areas around the SLV (shown in Figure ES.1-1) would be much lower.

Overall, the modeling indicates that potential dust impacts on air quality associated with development of the three SEZs would be relatively small because: (1) the Antonito Southeast and Los Mogotes East SEZs have a large combined area but contain soils with less dust emission potential; and (2) the De Tilla Gulch SEZ contains soils with a higher dust emission potential but these soils extend over a small area (225 acres, about 21% of the SEZ). An additional factor that leads to low predicted impacts is that most towns are upwind of and/or relatively far from the SEZs.

The estimated impacts discussed above and presented in Table ES.4-2 are cumulative impacts, that is, the modeling assumed that development of all three SEZs could occur at the same time. The De Tilla Gulch SEZ is located more than 60 mi (96 km) north of the Antonito Southeast and Los Mogotes East SEZs and thus cumulative impacts associated with the De Tilla Gulch SEZ would be minimal. For the representative meteorological conditions shown in the right panels of Figure ES.4-1, dust plumes showing the differences between the base case (non-development) and Scenario 1 stretch out eastward around the Antonito Southeast and Los Mogotes East SEZs and east-southeastward around the De Tilla Gulch SEZ with relatively short contours. As shown, the dust plume originating from each SEZ may merge with that of another SEZ at a long distance from either, but at those locations the PM_{10} concentrations would

TABLE ES.4-2 Modeled 24-Hour PM_{10} Concentrations for Base Case and Scenarios 1-6 and Their Changes from Base Case at Towns/Locations around the Solar Energy Zones and at Air Monitoring Sites. Note – Uses meteorological conditions of April 3, 2011 as representative for a dust generation episode.

	Base Case (current)	Scenario 1 (100% vegetative cover removed)		Scenario 2 (80% vegetative cover removed)		Scenario 3 (50% vegetative cover removed)		Scenario 4 (20% vegetative cover removed)		Scenario 5 (dust suppressant applied 20% SEZ)		Scenario 6 (dust suppressant applied 80% SEZ)	
Town/Location Name	(µg/m^3)	(µg/m^3)	Change[a]	(µg/m^3)	Change[a]	(µg/m^3)	Change[a]	(µg/m^3)	Change[a]	(µg/m^3)	Change[a]	(µg/m^3)	Change[a]
Around Antonito Southeast and Los Mogotes East Solar Energy Zones													
Antonito	57.8	58.0	0.3%	58.0	0.2%	57.9	0.2%	57.9	0.1%	58.0	0.3%	57.9	0.2%
Capulin	78.9	78.8	0.0%	78.8	0.0%	78.9	0.0%	78.9	0.0%	78.8	0.0%	78.9	0.0%
Conejos	57.8	58.0	0.3%	58.0	0.2%	57.9	0.2%	57.9	0.1%	58.0	0.3%	57.9	0.2%
La Jara	246.6	250.6	1.7%	249.7	1.3%	248.3	0.7%	247.2	0.3%	250.2	1.5%	248.7	0.9%
Las Mesitas	87.7	87.7	0.1%	87.7	0.1%	87.7	0.0%	87.7	0.0%	87.7	0.1%	87.7	0.0%
Lobatos	317.4	316.8	-0.2%	316.9	-0.2%	317.1	-0.1%	317.3	0.0%	316.9	-0.2%	317.1	-0.1%
Manassa	251.2	257.5	2.5%	256.0	1.9%	253.9	1.1%	252.2	0.4%	256.7	2.2%	254.5	1.3%
Mogote	43.4	43.5	0.3%	43.5	0.2%	43.5	0.1%	43.4	0.1%	43.5	0.3%	43.5	0.2%
Paisaje	59.2	59.1	-0.2%	59.2	-0.2%	59.2	-0.1%	59.2	0.0%	59.1	-0.2%	59.2	-0.1%
Romeo	80.8	96.7	19.8%	93.2	15.4%	87.9	8.9%	83.4	3.3%	94.9	17.6%	89.6	11.0%
San Antonito	292.0	294.9	1.0%	294.3	0.8%	293.5	0.5%	292.6	0.2%	294.6	0.9%	293.8	0.6%
Sanford	191.4	195.6	2.2%	194.7	1.7%	193.4	1.1%	192.2	0.4%	195.1	2.0%	193.8	1.3%
Around De Tilla Gulch Solar Energy Zone													
Crestone	102.0	103.3	1.2%	103.0	1.0%	102.6	0.6%	102.2	0.2%	103.1	1.1%	102.7	0.7%
Joyful Journey Hot Springs Spa	53.6	55.5	3.7%	55.1	2.9%	54.6	1.8%	54.0	0.7%	55.3	3.3%	54.7	2.2%
Moffat	92.3	92.6	0.3%	92.5	0.2%	92.4	0.1%	92.4	0.0%	92.5	0.2%	92.5	0.2%
Saguache	21.7	21.7	-0.3%	21.7	-0.2%	21.7	-0.2%	21.7	0.0%	21.7	-0.3%	21.7	-0.2%
Air Monitoring Sites													
Alamosa (Adams St Univ)[b]	233.6	234.3	0.3%	234.2	0.2%	233.9	0.1%	233.7	0.1%	234.3	0.3%	234.0	0.2%
Alamosa (Municipal Bldg)[b]	233.6	234.3	0.3%	234.2	0.2%	233.9	0.1%	233.7	0.1%	234.3	0.3%	234.0	0.2%
Taos (Fire Station)	48.5	48.5	0.0%	48.5	0.0%	48.5	0.0%	48.5	0.0%	48.5	0.0%	48.5	0.0%
Great Sand Dunes National Monument	127.1	127.4	0.2%	127.3	0.1%	127.5	0.3%	127.4	0.2%	127.4	0.2%	127.4	0.2%
Wheeler Peak WA	22.0	22.0	0.0%	22.0	0.0%	22.0	0.0%	22.0	0.0%	22.0	0.0%	22.0	0.0%

[a] Percent change from modeled concentrations for the base case (or baseline).

[b] Two air monitoring sites at Alamosa are about 0.85 mi (1.4 km) apart but two sites fall onto the same 1.9 mi by 1.9 mi (3 km by 3 km) modeling grid cell.

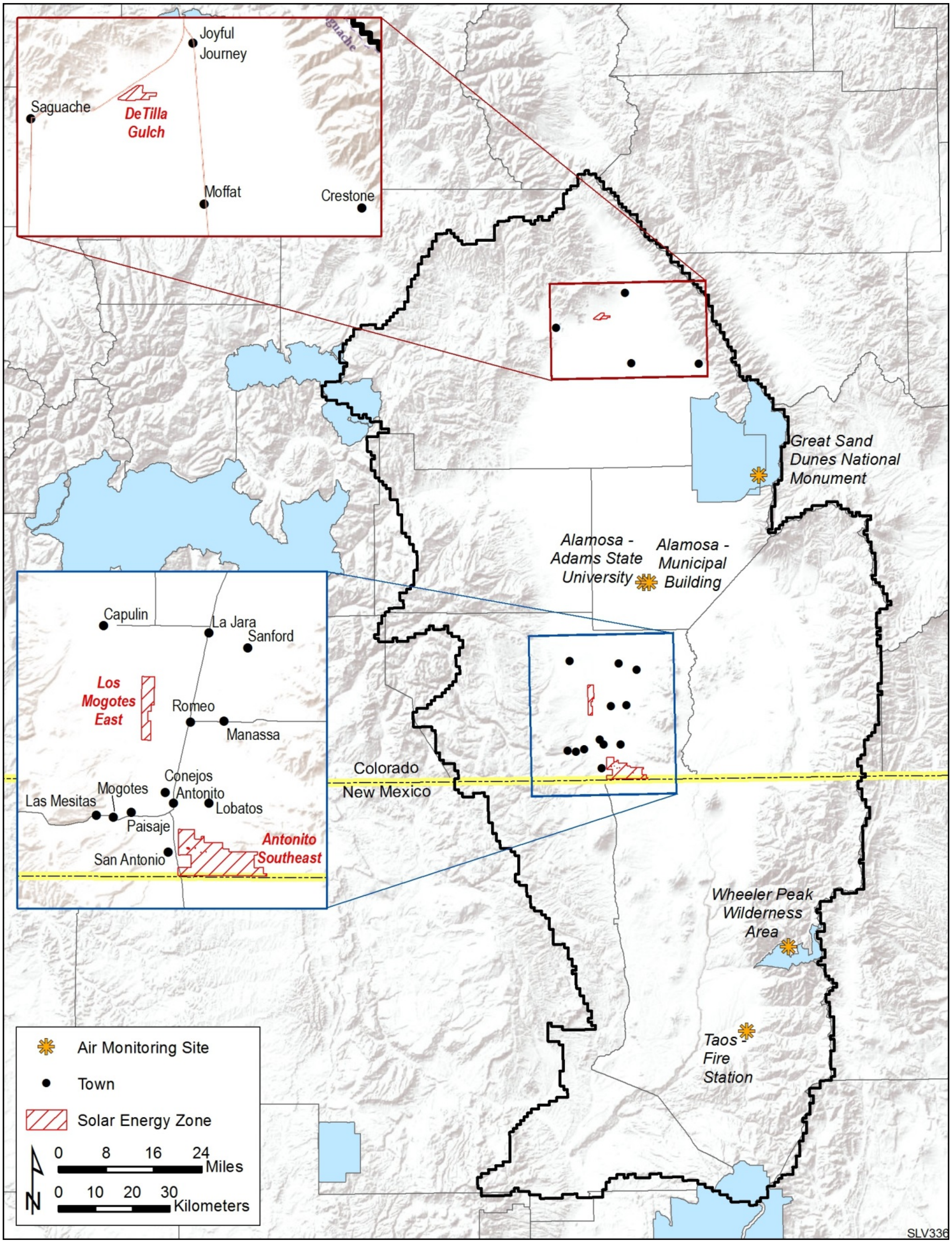

FIGURE ES.4-2 Locations of Air Monitoring Sites and Towns around the Solar Energy Zones within the San Luis Valley

be low, and thus cumulative contributions from all three SEZs combined would be low during dust storm episodes.

ES.4.2.3 Effectiveness of Dust Suppressants to Control Dust

The potential reduction in dust impacts from using dust suppressants was also estimated in Scenarios 5 and 6. Scenarios 5 and 6 assumed that 100% of the SEZ vegetative cover of each SEZ would be removed (same as Scenario 1) but Scenario 5 assumed dust suppressant would be applied over 20% of the SEZ area, whereas Scenario 6 assumed that dust suppressant would be applied over 80% of the SEZ area. The control efficiency of the dust suppressant was assumed to be 50%. These assumptions resulted in modeling dust emissions for Scenarios 5 and 6 of about 90% and 60% of Scenario 1 dust emissions, respectively. To state another way, dust suppressant use across 20% of the SEZs would reduce dust generation by 10%, and use across 80% of the SEZs would reduce dust generation by 40%, because the suppressants are not completely effective. Given that the dust impacts from solar development at most towns near the SEZs would generally be low even without the use of dust suppressants, the widespread application of dust suppressants across the SEZs may not be warranted. However, developers may apply such suppressants to reduce dust generation at selected locations within the SEZs (for example, locations nearest to residences).

ES.5 POTENTIAL HEALTH IMPACTS

Stakeholders living near the SEZs in the study area have expressed concern regarding the potential health hazards from high dust (or PM) levels that could occur if the SEZs are developed and there is large-scale disturbance of the soils. Potential PM-related health impacts may be associated with effects of the particles themselves or with substances contained within the particles (for example, arsenic that occurs naturally in soil in the study area could have toxic effects if exposure levels are high enough). PM exposures can cause or contribute to cardiovascular damage such as heart attack and thickening of the artery walls, adverse respiratory effects such as asthma, coughing, and difficulty breathing (often observed through increases in hospitalizations), and increased deaths due to these effects. It is important to have information on what levels of PM exposure can contribute to these health impacts. The EPA uses the following standards to limit health impacts from short-term exposures to particulate matter. These standards include limited allowance for exceedances (as explained in Section ES.2.5), so they are not directly applicable for individual measurements at monitoring stations. However, the dust standards are levels below which adverse health impacts would be expected to be minimal, and therefore are useful guidelines for evaluating the potential for health impacts to occur. The current standards for PM are:

- 24-hour average PM_{10} concentration of 150 $\mu g/m^3$ or less; or
- 24-hour average $PM_{2.5}$ concentration of 35 $\mu g/m^3$ or less.

Under background conditions (that is, what is happening in the study area currently), monitoring in Alamosa has shown that the 24-hour average PM_{10} health-based limit of 150 μg/m^3 was exceeded about 4 times per year over the period 2009-2013, and that the number of annual exceedances is increasing (see Figure ES.2-1). Because measurements have shown that PM_{10} usually contains about 38% $PM_{2.5}$, each exceedance of the PM_{10} standard means that the $PM_{2.5}$ standard was also probably exceeded, although only PM_{10} is measured at most of the SLV-Taos Plateau long-term monitoring locations. These high level exposures, although only occurring a few times per year, represent an existing public health concern in the SLV-Taos Plateau area, particularly for sensitive populations including the elderly and individuals with existing respiratory health issues.

During construction, modeling estimates indicate that PM concentrations at towns near to the SEZs would be unlikely to exceed the health based levels (specifically, 150 μg/m^3 24-hour average PM_{10} or 35 μg/m^3 24-hour average $PM_{2.5}$). However, the estimates showed that concentrations higher than these levels could occur at the SEZ boundaries and also possibly at a few nearby residences. As stated in Section ES.3.1, these estimates were made based on several conservative assumptions (e.g., use of area-based emission factors, no dry or wet deposition was assumed to occur), so predicted values are likely to be overestimates. Since human exposures to these high concentrations during construction could result in respiratory health effects, dust levels will have to be controlled to levels below the permitted levels at offsite locations where extended exposures can occur (specifically, at residences). Such control measures or practices to limit dust generation during construction include more frequent water spraying, application of dust suppressants, installation of wind fences, paving of frequently used roads, and/or limitation of disturbing areas and activities, especially on windy days.

For operations, the modeling data do not suggest that dust from the SEZs would cause PM exceedances in nearby towns, although several nearby towns (La Jara, Lobatos, Manassa, San Antonito, and Sanford) are predicted to have dust levels exceeding 150 μg/m^3 a few times a year during dust events not related to solar development. These high levels of dust are likely attributable to agricultural activities.

Some stakeholders living near the SEZs in the San Luis Valley have expressed concern regarding the potential health hazards from inhalation of arsenic that is naturally occurring in soil in the area. The concern is that large-scale disturbance of soil in the SEZs would result in high inhalation exposures because of increased concentrations of arsenic in wind-blown dust. Long-term exposure to elevated levels of arsenic can cause adverse health effects including anemia, liver damage, kidney damage, and increased risk of cancer, as well as some other health effects.

Concentrations of arsenic in soil in the SLV range from about 4.9 to 26 mg/kg, with an average level of 5.2 mg/kg, as compared with an average of 5.5 mg/kg overall in soils in the Western U.S. The average concentration can be used to calculate a risk of cancer and non-cancer health effects from both long-term inhalation and incidental ingestion.

Assuming high-end exposure levels for both workers at the SEZs and residents at nearby locations, calculations were conducted to estimate the risk of adverse cancer and non-cancer health effects from additional exposure to arsenic from windblown dust that could be associated with solar facilities at the SEZs. These estimated exposures are below levels that have been observed to cause adverse non-cancer health effects, and are also lower than exposures that would cause significantly increased cancer risks.

ES.6 SUMMARY AND CONCLUSIONS

This study was designed to answer several questions regarding possible air quality impacts from dust generated during construction and operation of solar facilities in the San Luis Valley SEZs. The questions and brief answers based on the modeling and calculations conducted are given below.

- *Will dust levels be increased during the construction and operational phases of solar facilities, and if yes, what will be the area of impact?*

  Dust levels will be increased during both construction and operational phases of solar facilities. PM would be most increased during construction, which would last from about one to five years. During construction, the highest increases in dust levels would be near the SEZ boundaries and at nearby residences.

- *Would wind-blown dust generation be decreased if solar development avoided areas of highly-erodible soils? How would the use of dust suppressants impact the amount of dust generated?*

  Yes, dust generation would be decreased either through avoiding areas of highly-erodible soils or through the use of dust suppressants over portions of the SEZs. The use of these methods to limit dust generation may be included in plans for solar projects within the SEZs.

- *If there are increased dust levels during operations, what would be the cumulative impacts of operations in SEZs?*

  Estimates of cumulative impacts assumed that development of all three SEZs could occur at the same time. The De Tilla Gulch SEZ is located more than 60 mi (96 km) north of the Antonito Southeast and Los Mogotes East SEZs and thus cumulative impacts associated with the De Tilla Gulch SEZ would be minimal. Because the Los Mogotes East and Antonito Southeast SEZs are located closer together, there is some potential for dust-related cumulative impacts. However, the two SEZs are not aligned with the prevailing southwesterly wind direction and thus their impacts are only minimally additive. Nevertheless, for construction impacts, work schedules could be coordinated to ensure that dust impacts in the vicinity of the two SEZs would remain low, even if construction activities were ongoing at the same time at both SEZs. For impacts during operations, modeling for this report showed that during periodic high dust episodes the estimated dust contours around these SEZs would only overlap far away from the SEZs at areas of lower PM concentrations. With appropriate management cumulative adverse air quality impacts are not expected.

- *If there are increased dust levels during construction and operations, would there be associated adverse health impacts for residents of nearby communities? Would arsenic-contaminated dust be a health concern?*

  The modeling in this report indicated that construction of solar facilities could contribute significantly to episodes of high dust levels that could occur several times per year during the construction period at locations near the SEZ boundaries and at some nearby residences. These elevated exposures could contribute to respiratory health effects in exposed people (for example, solar facility workers or residents of the nearby homes). However, during actual construction solar facility operators would be required to maintain dust levels at the site boundaries lower than permit-required levels, through altering construction practices and/or schedules and using dust control measures. For example, these include limiting surface disturbing activities on windy days and installing wind fences to control dust transport upwind of sensitive receptors (residences) and to induce particle deposition before PM arrives at the areas where the model predicted maximum impacts.

The analyses in this report did not indicate that the operation of solar facilities would result in adverse health effects from exposure to wind-blown dust from the developed areas of the SEZs. Additionally, exposure levels for arsenic contained in wind-blown dust were estimated to be lower than levels associated with cancer and non-cancer health effects from arsenic. Future monitoring of dust levels during construction and operations should be employed to verify that dust levels are maintained at levels lower than the health-based guidelines. Monitoring locations should be at sensitive receptor locations (residences) and/or site boundaries where highest impacts were predicted.

1 INTRODUCTION

1.1 PURPOSE OF THE STUDY

The San Luis Valley (SLV)-Taos Plateau in south-central Colorado and north-central New Mexico is a large alpine valley surrounded by mountains, with an area of approximately 6,263,000 acres (25,345 km^2) and an average altitude of about 7,600 ft (2,316 m) (Figure 1-1). This area receives ample sunshine throughout the year, making it an ideal location for solar energy generation. There are currently five photovoltaic facilities operating on private lands in the SLV, ranging in capacity from 1 to 30 megawatt (MW), with a total of 89 MW. The SLV also includes substantial areas administered by the Bureau of Land Management (BLM), including over 50,000 acres (202 km^2) considered to be eligible for application for solar development (BLM 2012).

In 2012 the BLM launched its Solar Energy Program, which included the identification of four solar energy zones (SEZs) in the SLV, totaling 16,308 acres (66 km^2). These areas, named Antonito Southeast, De Tilla Gulch, Fourmile East, and Los Mogotes East, were defined by the BLM as areas well-suited for utility-scale (i.e., larger than 20 MW) production of solar energy where solar energy development would be prioritized (BLM 2012). Nonetheless, it was recognized that solar development would result in some unavoidable adverse impacts, and so in response to stakeholder concerns, the BLM initiated a solar regional mitigation strategy (SRMS) study for three of the SEZs (BLM and Argonne 2016).[12] The SRMS is designed to identify unavoidable residual impacts of solar development in those SEZs (that is, impacts that cannot be avoided or minimized onsite), identify those residual impacts that warrant compensatory mitigation when considering regional status and trends of the resources, identify appropriate regional compensatory mitigation locations and actions to address those residual impacts, and recommend appropriate fees to implement those compensatory mitigation measures.

The *Draft and Final Programmatic Environmental Impact Statement for Solar Energy Development in Six Southwestern States* (Solar PEIS; BLM and DOE 2010, 2012) assessed potential impacts from solar development across a broad array of resources related to the human and ecological environment, including air quality. Of particular concern with respect to air quality was the potential to generate large quantities of dust (also called particulate matter or PM) through construction activities that could involve grading of large areas of land. For example, the SEZs in Colorado range in size from 1,064 acres (4.3 km^2) to 9,712 acres (39.3 km^2), and it is possible that about 80% of the SEZ areas would be used for solar fields. Therefore, the Solar PEIS included extensive analysis and modeling of the potential impacts of construction-generated dust on communities and specially-designated areas near the SEZs. Although the Solar PEIS also included a comprehensive set of design features for solar development requiring stabilization of cleared areas and other measures to limit dust generation, there are remaining concerns regarding the potential for wind-blown dust impacts during construction and operations. Questions include:

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[12] The Fourmile East SEZ is not being studied at this time.

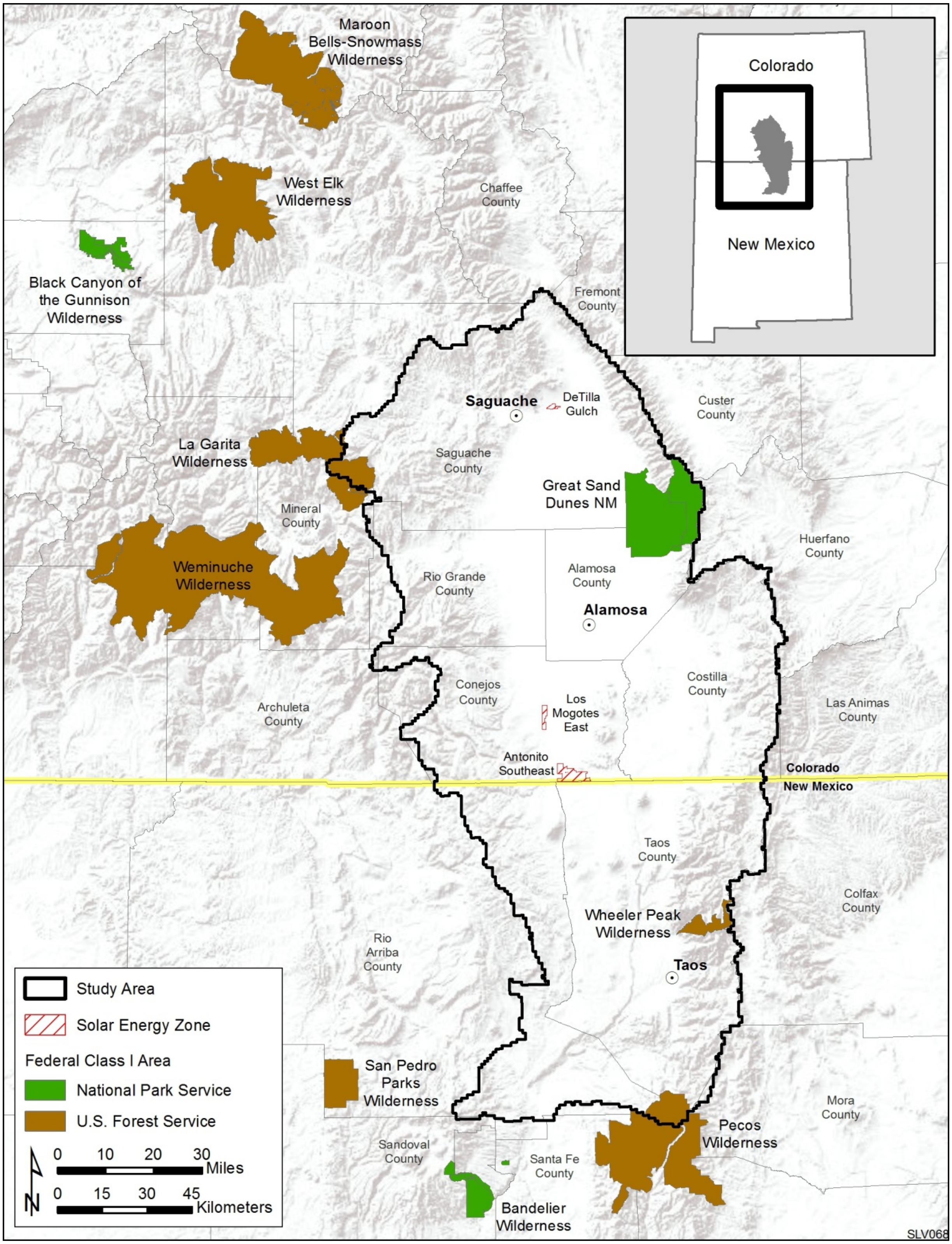

FIGURE 1-1 Locations of the San Luis Valley-Taos Plateau Study Area, Solar Energy Zones, and Nearby Federal Class I Areas

- Will dust levels be increased during the construction and operational phases of solar facilities, and if yes, what will be the area of impact?

- Would wind-blown dust generation be decreased if solar development avoided areas of highly-erodible soils? How would the use of dust suppressants impact the amount of dust generated?

- If there are increased dust levels during operations, what would be the cumulative impacts of operations in SEZs?

- If there are increased dust levels during construction and operations, would there be associated adverse health impacts for residents of nearby communities? Would arsenic-contaminated dust be a health concern? (This question has been asked by stakeholders in Conejos County near the Antonito Southeast SEZ.)

The aim of this study is to support the SRMS by answering the questions posed above, both through a review of construction-phase modeling that was conducted for the Solar PEIS, and through innovative new modeling of the potential for operations-phase emissions. The modeling is innovative in that it adapts a well-known model used for estimating dust levels across very large areas (i.e., the Weather Research and Forecasting [WRF] model with Chemistry [WRF-Chem] model; NCAR 2014a, b) to estimate dust levels for a smaller area on the basis of soil erodibility and land cover.

1.2 ORGANIZATION OF THE REPORT

This report consists of 7 chapters, as listed below.

- Chapter 1 discusses the purpose of the study and the organization of the report.

- Chapter 2 provides detailed background on the climate and the existing air quality conditions of the SLV-Taos Plateau study area.

- Chapter 3 summarizes study methods and data, including construction activity assumptions for dust emission estimation and modeling, and wind-blown dust modeling for operations.

- Chapter 4 presents the results associated with construction-phase dust modeling and operation-phase wind-blown dust generation and dispersion modeling that were conducted for the Antonito Southeast, De Tilla Gulch, and Los Mogotes East SEZs. This includes analysis of several development scenarios that assume varying levels of SEZ disturbance.

- Chapter 5 presents an assessment of potential health impacts associated with exposure to wind-blown dusts associated with solar energy development in the three SEZs.

- Chapter 6 provides a summary and conclusions of the results of this study, along with brief answers to questions raised in Chapter 1 based on the modeling and calculations conducted.

- Chapter 7 lists the references cited in the report.

2 BACKGROUND ON CLIMATE AND AIR QUALITY

2.1 GENERAL INFORMATION

The SLV-Taos Plateau Level IV Ecoregion (identified as the study area for this report) encompasses approximately 6,263,000 acres (25,345 km^2) and includes portions of south-central Colorado and north-central New Mexico (Figure 1-1). About two-thirds of the study area (65%) occurs in Colorado. The study area includes all or portions of 12 counties in Colorado (Alamosa, Archuleta, Chaffee, Conejos, Costilla, Custer, Fremont, Huerfano, Las Animas, Mineral, Rio Grande, and Saguache) and six counties in New Mexico (Colfax, Mora, Rio Arriba, Sandoval, Santa Fe, and Taos). Among these, five counties in Colorado (Alamosa, Conejos, Costilla, Rio Grande, and Saguache) and two counties in New Mexico (Rio Arriba and Taos) account for about 99% of the study area (these are called the primary counties in this study), and thus discussion on meteorology and air quality will in general be limited to these seven counties. The study area is situated in a north-south dimension, with the longest north-south axis of approximately 172 mi (277 km) and longest east-west axis of approximately 95 mi (153 km). The dimensions of the study area are influenced by the two dominant mountain ranges in the region, which bound the study area, with the Sangre de Cristo Mountains to the east and the San Juan Mountains to the west. Elevations within the study area range from approximately 5,000 to 14,000 ft (1,524 to 4,267 m).

2.2 CLIMATE

The local climate is strongly influenced by microclimatic features such as the orientation of mountain slope, aspect, and elevation. The local surface wind patterns and vertical temperature profiles are almost entirely dependent upon topography. Precipitation in the valley is strongly influenced by the surrounding mountains (SLVNWRC and USFWS 2012). In the prevailing westerlies regime, the windward side of the mountain ranges, particularly the San Juan Mountains, receives a substantial amount of orographic precipitation, which is caused when air masses rise and subsequently cool, dumping their precipitation on the windward (western) side of higher elevations. This results in reduced rainfall on the leeward (eastern) side of the San Juan Mountains, i.e., in the study area.

As a result of topographic features which act as barriers, the study area experiences an arid climate, which is marked by cold winters and moderate summers, light precipitation, low relative humidity, and abundant sunshine due to the thin atmosphere caused by its high elevation (NCDC 2014a). Because of daytime solar heating and nighttime radiative cooling in the arid environments along with cold air drainage from the surrounding mountains (to be discussed just below), daily temperature swings in the valley are significant. Meteorological conditions vary considerably from location to location within the study area due to wide variations in elevation, topographic features, and latitude.

2.2.1 Wind

As in most of the United States, the predominant wind aloft is from the west or the southwest, known as the prevailing westerlies. However, surface winds are greatly modified by local terrain and ground cover. The prevailing wind directions at the surface vary from site to site, and the distributions of wind speed and direction are also highly site-dependent. Thus, wind patterns are highly variable from location to location, depending on the elevation, the proximity to nearby mountains, and latitude. In Figure 2-1, wind roses (which graphically display the distribution of wind speed and direction classifications from which the winds originate) at a height of 33 ft (10 m) from three meteorological stations within the study area show the variations in surface winds (NCDC 2014b). The three airport meteorological stations are at Saguache, Alamosa, and Taos, located in the northern, central, and southern parts of the valley, respectively.

Because the study area is surrounded by mountains of high elevation, a local wind system of mountain and valley breezes develops along mountain slopes. During the day, sunlight warms the valley walls, which in turn warm the air in contact with them. Because the heated air is less dense than air at the same altitude above the valley, it rises as a gentle upslope wind. This upslope wind is called a *valley breeze* (Ahrens 2008). At night, as mountain slopes cool, chilling air reverses the flow. This cooled air is denser than the surrounding air and thus glides downslope into the valley, providing a *mountain breeze*. This downslope wind is referred to as a *gravity wind* or *nocturnal drainage wind* (Ahrens 2008). In particular, this nocturnal drainage flow of denser cold air at higher elevations into the valley floor creates a stable atmospheric condition (i.e., colder air at the surface and warmer air aloft), which results in poor dispersion and stagnation that trap air pollutants within the valley. This daily cycle of wind flow develops best in clear, summer weather when prevailing winds are light.

2.2.1.1 Saguache

A wind rose from the Saguache Municipal Airport in Saguache, Colorado for the periods 2005 to 2007 and 2011 to 2012 is presented in Figure 2-1 (NCDC 2014b). During this period, the annual average wind speed at the airport was about 9.6 mph (4.3 m/s) and the wind was predominantly from the northwest quadrant (more than half of the time). This was a common wind pattern along the valley that also developed to the northwest of Saguache. The northwesterly winds result from either prevailing westerlies which are steered by the valley running in the northwest-southeast direction or mountain breeze during the night. Wind speeds categorized as calm (less than 1.1 mph [0.5 m/s]), associated with conditions of poor atmospheric dispersion, occurred frequently—about 10% of the time. Seasonal average wind speeds were relatively uniform, with the highest at 10.7 mph (4.8 m/s) in spring and the lowest at 8.8 mph (3.9 m/s) in winter. Winds blow primarily from the northwest most of the time but winds from the southeast quadrant, so-called valley breeze (upslope wind from the valley due to temperature differences in air), are nearly comparable in frequency to those from the northwest quadrant during the day during all seasons.

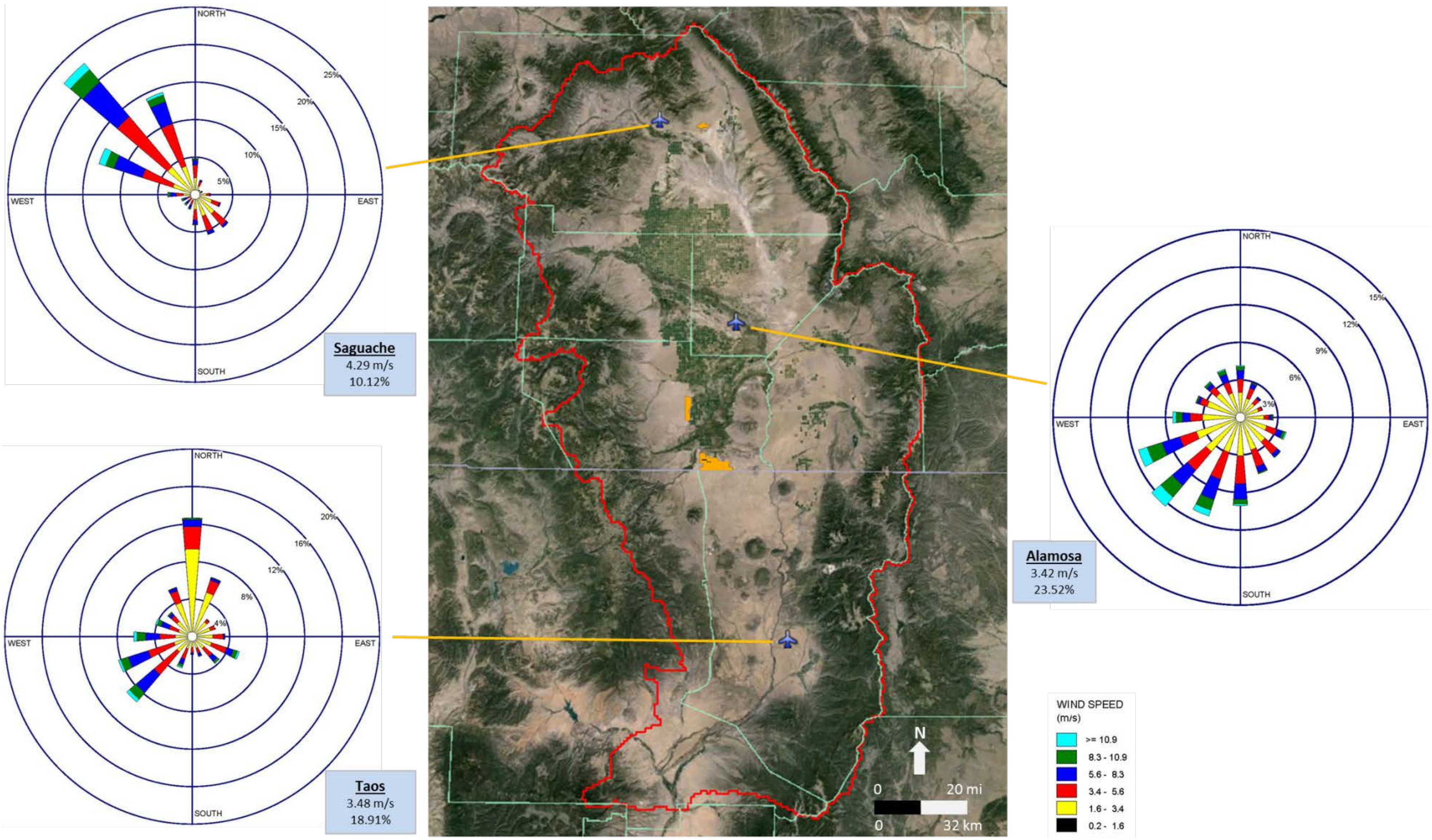

FIGURE 2-1 Wind Roses at 33-ft (10-m) Height at Airports (Alamosa [2009-2013] and Saguache [2005-2007 and 2011-2012] in Colorado and Taos [2009-2013] in New Mexico) within the Study Area (Source: NCDC 2014b)

2.2.1.2 Alamosa

A wind rose from the San Luis Valley Regional Airport in Alamosa, Colorado, for the period 2009 to 2013 is presented in Figure 2-1 (NCDC 2014b). During this period, the annual average wind speed at the airport was about 7.7 mph (3.4 m/s), with a relatively weak prevailing wind direction from the southwest (about 9.3% of the time). Winds that ranged from south to west–southwest occurred about one-third of the time, which is reflective of prevailing winds aloft due to Alamosa's central location in the valley, i.e., less affected by nearby mountains. These wind directions are frequent every month and day or night, except for north-northwest winds which occur during the day in January and east-southeast or southeast winds which occur during the night from July through September. Wind speeds categorized as calm occur more frequently (nearly one-fourth of the time) because of the stable conditions caused by strong radiative cooling that last from late night to sunrise. Seasonal average wind speeds were highest in spring at 10.4 mph (4.6 m/s) and lowest in winter at 5.9 mph (2.6 m/s).

2.2.1.3 Taos

A wind rose from the Taos Regional Airport in Taos, New Mexico for the period 2009 to 2013 is presented in Figure 2-1 (NCDC 2014b). During this period, the annual average wind speed at the airport was about 7.8 mph (3.5 m/s) and the prevailing wind direction was from the north (about 12.6% of the time) with secondary prevalent winds from the southwest (about 9.1% of the time). The former represents nocturnal drainage winds from nearby mountains, while the latter represents the prevailing westerlies. Wind speeds categorized as calm occurred frequently (about 18.9% of the time) because of the stable conditions caused by strong radiative cooling that lasted from late night to sunrise. Seasonal average wind speeds were highest at 9.6 mph (4.3 m/s) in spring and lowest at 6.6 mph (3.0 m/s) in winter. Northerly winds predominate throughout the year, except during March through June when southwesterly winds prevail. Southwesterly winds also dominate during the daytime, which is affected by prevailing westerlies aloft. Northerly winds are more frequent during the night throughout the year, except during the months of May through August when east-southeasterly winds dominate. Both trends are due to the mountain breeze originating from nearby mountains located north and east of the airport.

2.2.2 Temperature

Temperatures in the region vary widely with elevation, latitude, season, and time of day. Within the study area, topography plays a large role in determining the temperature of any specific location. The study area sits at a higher elevation; thus, temperatures there are lower than at lower elevations of comparable latitude. Historical annual average temperatures measured at stations within the study area ranged from 39.6°F (4.2°C) at Red River in New Mexico to 51.6°F (10.9°C) at Espanola, New Mexico, as presented in Table 2-1 (WRCC 2015). With the exception of Red River in New Mexico at an elevation of 8,680 ft (2,646 m), annual average temperatures at stations in Colorado are generally lower than those in New Mexico due to elevation and/or latitude. Typically, January is the coldest month, with nighttime lows ranging

TABLE 2-1 Temperature and Precipitation Summaries at Selected Meteorological Stations within the Study Area

		Temperature (°F)					Precipitation (in.)			
State	Station[a]	Lowest Minimum[b]	Highest Maximum[b]	Mean	Highest	Lowest	Water Equivalent	Snowfall	Elevation (ft)	Period of Record
Colorado	Saguache	4.1	81.1	42.8	99	-34	8.27	23.5	7,690	1894 - 2009
Colorado	Crestone 1 SE	9.5	83.7	44.7	98	-22	12.90	61.5	8,120	1982 - 2012
Colorado	Great Sand Dunes NM	9.8	80.8	43.9	96	-25	11.12	41.0	8,120	1950 - 2012
Colorado	Center 4 SSW	-0.9	80.5	41.4	95	-41	7.00	25.0	7,670	1941 - 2012
Colorado	Del Norte	5.7	78.7	42.8	91	-34	9.39	39.7	7,880	1893 - 2012
Colorado	Monte Vista	0.5	80.6	41.5	94	-38	7.71	24.5	7,650	1893 - 2012
Colorado	Alamosa WSO AP	-1.8	82.4	41.5	96	-42	7.05	31.2	7,540	1948 - 2012
Colorado	Blanca	2.0	81.7	42.2	97	-38	8.56	24.3	7,750	1909 - 2010
Colorado	San Luis 1 E	3.7	80.8	42.4	94	-28	9.58	20.0	8,060	1980 - 2006
Colorado	Manassa	2.1	80.5	42.6	95	-37	7.27	24.8	7,690	1893 - 2012
New Mexico	Cerro	7.5	81.9	44.4	100	-34	12.73	55.0	7,650	1910 - 2012
New Mexico	Red River	4.6	76.3	39.6	94	-40	20.95	146.4	8,680	1906 - 2012
New Mexico	Tres Piedras	5.7	79.8	42.1	95	-37	13.89	34.8	8,140	1905 - 2011
New Mexico	Taos	10.1	85.7	47.3	101	-27	12.35	29.5	6,970	1892 - 2010
New Mexico	Alcalde	15.2	89.2	51.0	102	-34	10.01	10.8	5,680	1953 - 2012
New Mexico	Espanola	14.9	89.7	51.6	107	-38	9.88	11.7	5,640	1895 - 2012

[a] All stations are listed in descending order from the highest to the lowest in latitude (i.e., from north to south).

[b] "Lowest Minimum" denotes the lowest monthly average of the daily minimum, which normally occurs in January. "Highest Maximum" denotes the highest monthly average of the daily maximum, which normally occurs in July.

Source: WRCC (2015).

from -1.8 to 15.2°F (-18.8 to -9.3°C), and July is the warmest month, with daytime highs ranging from 76.3°F to 89.7°F (24.6 to 32.1°C). During the reporting period, the highest temperature of 107°F (42°C) was reached in July 2003 at Espanola, New Mexico, and the lowest temperature of -42°F (-41°C) was reached in December 1964 at Alamosa WSO AP, Colorado. Each year, there were only a few days at most stations in Colorado and New Mexico that had a maximum temperature exceeding 90°F (32°C). The exceptions were Alcalde and Espanola, at which daily maximum temperatures of 38 and 45 days exceeded 90°F (32°C), respectively, in New Mexico. Across all stations, there were as few as 170 days and as many as 249 days during which the minimum temperatures were at or below freezing, with subzero temperatures occurring on 3 to 47 days.

2.2.3 Precipitation

Within the study area, precipitation patterns are largely controlled by mountain ranges and elevation. The interior, continental location, ringed by mountains on all sides, has low precipitation year-round. Air masses crossing the region, which gather moisture over the Pacific Ocean or the Gulf of Mexico and traverse several hundred miles of mountainous terrain, have already precipitated a large percentage of their moisture by the time they reach the study area, and thus the study area receives little precipitation. For the reporting period, annual precipitation ranged from about 7.00 in. (17.78 cm) at Center 4 SSW, Colorado to 20.95 in. (53.21 cm) at Red River, New Mexico as shown in Table 2-1 (WRCC 2015). In general, precipitation is higher in summer months (about 36 to 45% of the annual total), and lower in winter months (about 10 to17% of the annual total) at stations within the study area. In southern and western Colorado, higher summer precipitation occurs when the Southwest Monsoon is most active (NCDC 2014c). In New Mexico, summer rains fall mostly during brief, but frequently intense thunderstorms due to southeasterly circulation from the Gulf of Mexico, while winter precipitation is caused mainly by frontal activity associated with general movement of Pacific Ocean storms across the country. On average, 45 to 99 days a year have measurable precipitation (0.01 in [0.025 cm] or higher). Snowfall varies by location, ranging on average from 10.8 in. (27.4 cm) at Alcalde, New Mexico to 146.4 in. (371.9 cm) at Red River, New Mexico (WRCC 2015). Within the study area, snow falls as early as September or October and continues as late as April or May, with the latest in July at Red River, New Mexico. However, most snow falls in the colder months from November to March. Within the study area, precipitation tends to decrease slightly with increasing latitude, while snowfall tends to increase with increasing elevation.

Average annual precipitation has slightly increased in the valley based on data from the inception of data collection at the sites of concern to recent years (WRCC 2015). However, considering the recent 30 years, it has trended downward at most monitoring sites in the valley, which renders the study area more susceptible to wind erosion.

2.2.4 Severe Weather Events

The study area occurs at higher elevations where there are no major water bodies affecting the local weather system. The surrounding mountain ranges block air masses, preventing them from penetrating the valley. The most frequent severe weather events include droughts, hail storms, heavy snow, high winds and thunderstorm winds, and winter storms (NCDC 2015). While tornadoes have occurred in the study area, they are rare. In general, severe weather events data have been compiled from 1950 to September 2014 (NCDC 2015); and selected events are discussed below. Note that: (1) severe weather events could be double-counted in total counts if they occurred in more than one county; and (2) discussion for severe weather events is limited to the seven primary counties within the study area.

Since 1998, 28 floods and 33 flash floods have been reported in counties within the study area (NCDC 2015). Flash flooding from localized intense thunderstorms, which peak in summer months, is more severe than flooding caused by snowmelt, which peaks in spring months. These floods/flash floods did cause substantial property and minor crop damage; one flash flood, which occurred in Rio Arriba County, New Mexico in 2006, caused one death.

Within the study area, a total of 121 hail storm events have been reported since 1955; some of these events have caused property and/or crop damage (NCDC 2015). Hail storms occurred mostly in warmer months, from May through September. In 2008, hail measuring 2.5 in. (6.4 cm) in diameter was reported in Alamosa County, Colorado.

Since 1962, 725 high wind and 35 thunderstorm wind events occurred in counties within the study area. Most of these events were reported in Colorado counties (NCDC 2015). These wind events occurred throughout the year but with no occurrences in July and August. Peak high wind events occurred in January and April, while thunderstorm wind events occurred more frequently in warmer months, with a peak in June. A high wind with a maximum speed of 105 mph (47 m/s) was reported in the northern part of the Sangre de Cristo Mountains in March 2004.

Complex terrain in Colorado and New Mexico typically disrupts the mesocyclones associated with tornado-producing thunderstorms; thus, tornadoes are less frequent and destructive within the study area than they are in the eastern plains in Colorado or New Mexico. From 1950 to September 2014, a total of 37 tornadoes (34 in Colorado and three in New Mexico) were reported in the seven counties within the study area, compared with 2,462 reported for Colorado and New Mexico combined (NCDC 2015). Nearly half of these tornadoes (17 tornadoes) were spotted in Alamosa County, Colorado. Most tornadoes occurring within the valley were relatively weak, mostly F0 or F1 on the Fujita tornado scale[13] (except for two F2s and one F3). The F3 tornado hit near Fort Garland in Costilla County on July 31, 1955. None of the tornadoes caused deaths or injuries but minor property damage was reported.

13 The original Fujita tornado scale classified U.S. tornadoes into six damage categories (from the weakest F0 to the most destructive F5) based on the type and severity of damage produced (from which wind speeds were then estimated). On February 1, 2007, the Enhanced Fujita scale replaced the original Fujita scale in all tornado damage surveys in the U.S. Similar to the original Fujita scale, the damage categories of the enhanced scale are from EF0 to EF5, but the estimated wind speed ranges associated with each category have been refined. Historical tornadoes before February 1, 2007 are still categorized with the original Fujita scale, as are those in the National Climatic Data Center's (NCDC's) *Storm Events* database.

According to the *Storm Events* database, no dust storms have been reported in counties within the study area (NCDC 2015),[14] but air monitoring data collected at Alamosa, Colorado indicates that wind-blown dust storms have occurred in the study area on occasion (see Section 2.6). High winds can trigger large amounts of blowing dust in the valley generated from dry, loose, exposed soils with sparse vegetation.

Since 2000, 69 wildfires have been reported in counties within the study area, starting as early as March and peaking in June, and causing some property damage (NCDC 2015). These fires were mostly triggered by lightning in the area. Associated with ongoing global warming, large-scale wildfire frequency, fire duration, and fire season length have increased substantially in the western United States in recent decades and are projected to increase, especially in the Southwest (USGCRP 2014). This is due primarily to earlier spring snowmelt and higher spring and summer temperatures that reduce the moisture availability and dry out the vegetation that provides the fuel for fires.

Because they are far inland, Colorado and New Mexico are not directly affected by hurricanes; however, remnants from decayed hurricanes from the Pacific or the Gulf of Mexico may dump heavy, widespread rains in these states on an infrequent basis (NCDC 2014c).

2.3 PARTICULATE MATTER (PM)

PM is a complex mixture of small particles and liquid droplets that are not individually visible to the human eye, such as dust, fly ash, soot, smoke, sea salt, fumes, mists, biogenic aerosols, and anthropogenic aerosols such as sulfate and nitrate. The composition and size of these airborne particles and droplets vary. The concentration of PM is often reported as the weight in a unit volume of air and represents the sum of mass collected on a filter paper when air at a certain flow rate is pumped through the particle collector.

Dust, which is one major component of PM, can deteriorate air quality and visibility and have adverse effects on health, particularly for people with asthma or other respiratory problems (see Chapter 5 for more detailed discussion of potential health impacts). In addition, dust has important effects on climate through its influence on solar and terrestrial radiation and the radiative and physical properties of clouds.

Particles collected in two size cuts, PM_{10} and $PM_{2.5}$, are widely monitored. The $PM_{2.5}$ particle size cut represents the mass of aerosols less than or equal to 2.5 μm in aerodynamic diameter and PM_{10} represents all of the particles with sizes less than or equal to 10 μm in aerodynamic diameter. [15] Fine particles ($PM_{2.5}$) are linked to their potential for damaging human health and the environment such as visibility impairment. Coarse particles, or the subset of PM_{10} that is larger than 2.5 μm but smaller than or equal to 10 μm ($PM_{10\text{-}2.5}$), are not transported over

[14] Dust storm events occurring since 1996 are recorded. Although no dust storms have been reported in the SLV, high winds have been reported on the days of dust storm events in surrounding counties.

[15] 10 μm is 0.0004 inches, or one-seventh the width of a human hair.

long distances because they are too large to be sustained in air streams and are readily removed from the atmosphere as a result of their larger settling velocities and inertial properties. On the other hand, fine particles ($PM_{2.5}$) can remain airborne for a long period and travel hundreds of miles along with winds. Coarser particles can be inhaled into and accumulate in the respiratory system, while fine particles can penetrate deeper into the parts of the lungs that are more vulnerable to injury.

The typical half life and travel distance of fine particles range from days to weeks and from 100s to 1000s of km, respectively, while those of coarse particles range from minutes to hours and <1 to 10s of km (Wilson and Suh 1997). Thus, the longer residence time and travel distance of fine particles tend to homogenize spatial variations in mass concentrations, different from larger spatial variations of coarse particles (NARSTO 2004). In many cities, average $PM_{2.5}$ concentrations are more uniform than PM_{10} concentrations.

2.4 PARTICULATE MATTER SOURCES

PM can be emitted directly or formed in the atmosphere. Primary particles are those released directly to the atmosphere by either human (anthropogenic) or natural activities. Anthropogenic sources include agricultural operations, industrial processes, fossil-fuel combustion, construction and demolition activities, paved/unpaved road dust, etc. Natural sources include wind-blown dust, such as the undisturbed desert, and wildfires. In general, coarse PM ($PM_{10-2.5}$) is composed largely of particles from mineral dust (i.e., soils). Secondary particles are formed in the atmosphere from chemical reactions involving primary gaseous emissions, such as sulfur oxides (SO_x), nitrogen oxides (NO_x), volatile organic compounds (VOCs), and ammonia, from power plants, industrial facilities, mobile sources, and other combustion sources. A significant portion of fine PM ($PM_{2.5}$) contains secondary particles.

The primary seven counties comprising the study area generally are comprised of small towns, and their overall character is considered mostly rural to light industrial (in urban areas). Because of its relatively low population density, low level of industrial activities, and relatively low traffic volume, the quantity of anthropogenic emissions (except agricultural emissions) in the study area is small; however, dusty air and seasonal dust/sand storms can occur. The main sources of particulate emissions in the valley are primarily related to wind-blown dust from agricultural fields, wildfires (controlled and uncontrolled burns), grazing, construction/ demolition, paved/unpaved roads, off-road vehicle use, woodstoves and street sanding during colder months, as well as fossil fuel combustion from stationary and mobile emission sources. Wind-blown dust storms occur most frequently in the spring months, as a result of seasonal high winds and dry soil conditions in the valley.

2.5 AIR QUALITY MEASURES

2.5.1 National Ambient Air Quality Standards (NAAQS)

Under the Clean Air Act (CAA), the U.S. Environmental Protection Agency (EPA) has established National Ambient Air Quality Standards (NAAQS)[16] for six criteria pollutants: carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO_2), ozone (O_3), PM with an aerodynamic diameter of 2.5 micrometers (µm) or less and 10 µm or less (for $PM_{2.5}$ and PM_{10}, respectively), and sulfur dioxide (SO_2) (EPA 2014a). PM, including $PM_{2.5}$ and PM_{10}, is the focus of this study. The $PM_{2.5}$ and PM_{10} NAAQS are provided in Table 2-2. PM_{10} has a concentration of 150 $\mu g/m^3$ as both the 24-hour primary and secondary NAAQS (the standard is considered to be attained when the 150 $\mu g/m^3$ concentration is not exceeded more than once per year on average over 3 years). $PM_{2.5}$ has a concentration of 35 $\mu g/m^3$ as both the 24-hour primary and secondary NAAQS (the standard is considered to be attained when the 3-year average of the annual 98th percentile is less than or equal to the 35 $\mu g/m^3$ concentration). In addition, $PM_{2.5}$ has primary and secondary annual-average NAAQS values of 12 and 15 $\mu g/m^3$, respectively, which are considered to be attained when the 3-year average of the annual mean is less than or equal to the standard.

Any geographic area that meets the NAAQS for a criteria pollutant is designated by the EPA as an attainment area. Any area that does not meet the NAAQS for a criteria pollutant is designated as a nonattainment area. Any area that cannot be classified on the basis of available information as meeting or not meeting the NAAQS for the pollutant is called unclassifiable. Previous nonattainment areas where air quality has improved to meet the NAAQS are redesignated as maintenance areas and are subject to an air quality maintenance plan. States must have State Implementation Plans (SIPs) that demonstrate how nonattainment areas will meet the NAAQS and how the NAAQS will be maintained in maintenance areas.

The attainment of NAAQS requirements is determined based on the most recent three consecutive years of monitoring data, and thus these standards do not apply to construction or operation emissions from individual facilities. Therefore the NAAQS levels are used in this study as indicators of potentially significant dust levels with respect to adverse human health impacts or other potential impacts, and should not be interpreted as requirements for individual solar facilities.

Six counties (Alamosa, Conejos, Costilla, Mineral, Rio Grande, and Saguache) in Colorado, which encompass the study area, are located administratively within San Luis Intrastate Air Quality Control Region (AQCR) (Title 40, Part 81, Section 176 of the *Code of Federal Regulations* [40 CFR 81.176]). Three counties (portions of Rio Arriba County lying east

[16] The CAA establishes two types of NAAQS: primary standards to protect human health and secondary standards to protect public welfare. Any individual state can have its own standards, referred to as State Ambient Air Quality Standards (SAAQS), but they must be at least as stringent as the NAAQS. If no state standards exist, or if the SAAQS are not as stringent as the NAAQS, then the NAAQS apply. Neither Colorado nor New Mexico has an SAAQS for PM; therefore, the NAAQS for $PM_{2.5}$ and PM_{10} apply for these states.

TABLE 2-2 National Ambient Air Quality Standards (NAAQS) for Particulate Matter (PM)[a,b] and Maximum Allowable Prevention of Significant Deterioration (PSD) Increments for Class I and II Areas

		NAAQS		PSD Increments ($\mu g/m^3$)	
Pollutant[c]	Averaging Time	Value ($\mu g/m^3$)	Type[d]	Class I	Class II
$PM_{2.5}$	24-hour	35	P, S	2	9
	Annual	12	P	1	4
	Annual	15	S		
PM_{10}	24-hour	150	P, S	8	30
	Annual	-[e]	-	4	17

[a] Detailed information on attainment determination criteria for NAAQS and reference methods for monitoring are available in 40CFR 50 and EPA (2014a). Attainment determination criteria for each state are similar to those for the NAAQS criteria.

[b] Neither Colorado nor New Mexico has State Ambient Air Quality Standards for PM (Code of Colorado Regulations [CCR], 5 CCR 1001-14; New Mexico Administrative Code [NMAC], 20.2.3 NMAC).

[c] Notation: $PM_{2.5}$ = particulate matter ≤ 2.5 μm in aerodynamic diameter; and PM_{10} = particulate matter ≤ 10 μm in aerodynamic diameter.

[d] P = Primary standard whose limits were set to protect public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly; S = Secondary standard whose limits were set to protect public welfare, including protection against decreased visibility, and damage to animals, crops, vegetation, and buildings.

[e] A dash indicates that no standard exists.

Source: 40 CFR 52.21; EPA (2014a).

of the Continental Divide, Santa Fe, and Taos) in New Mexico, which encompass the study area, are located administratively within the Upper Rio Grande Valley Intrastate AQCR (40 CFR 81.239), along with one other county (Los Alamos) located outside the study area.

Currently, portions of all the counties within the study area are designated as unclassifiable or in attainment of the NAAQS for all criteria pollutants, including PM (40 CFR 81.306 for Colorado and 40 CFR 81.332 for New Mexico). There are no nonattainment areas inside the study area; however, two small areas within two of the included Colorado counties but outside the study area are designated as maintenance areas for PM_{10} (EPA 2015): (1) Canon City, in Fremont County, and (2) Pagosa Springs, in Archuleta County.

2.5.2 Prevention of Significant Deterioration (PSD)

The Prevention of Significant Deterioration (PSD) regulations (40 CFR 52.21), which are designed to limit future air pollution in clean areas, apply to a major new source or modification of an existing major source within an attainment or unclassified area. While the NAAQS and State Ambient Air Quality Standards (SAAQS) place upper limits on the levels of air pollution, PSD regulations limit the total increase in ambient pollution levels above established baseline levels for SO_2, NO_2, PM_{10}, and $PM_{2.5}$ to prevent "polluting up to the standard" in clean areas. The allowable increases are the smallest in Mandatory Class I Federal Areas, such as national parks and wilderness areas (WAs). The rest of the country is subject to larger Class II increments. The maximum allowable PSD increments of PM for Class I and II areas are given in Table 2-2. As a matter of policy, the EPA recommends that the permitting authority notify Federal Land Managers when a proposed PSD source would locate within 100 km (62 mi) of a Class I area.

Two Class I areas (Great Sand Dunes National Monument [NM] in Colorado and Wheeler Peak WA in New Mexico) are located within the study area, and portions of two Class I areas (La Garita WA in Colorado and Pecos WA in New Mexico) straddle the study area as shown in Figure 1-1. In addition, several Class I areas in Colorado and New Mexico are located within 100 km (62 mi) of the study area. Those in Colorado include: (1) Maroon Bells-Snowmass WA; (2) West Elk WA; (3) Black Canyon of the Gunnison WA; and (4) Weminuche WA. Those in New Mexico include: (1) San Pedro Parks WA; and (2) Bandelier WA.[17]

With the exception of the Great Sand Dunes NM and Wheeler Peak WA, the Class I areas within and surrounding the study area are far away from and/or not located downwind of prevailing winds at the proposed SEZs (see Figure 1-1). Considering the distances to nearby Class I areas, topography, and the prevailing wind direction, there is little likelihood that activities at the proposed SEZs could adversely affect air quality and air quality-related values (AQRVs) (e.g., visibility or acid deposition) in any of the Class I areas, except the Great Sand Dunes NM and Wheeler Peak WA.

2.6 EXISTING AIR QUALITY IN THE SAN LUIS VALLEY-TAOS PLATEAU

Air monitoring data shows infrequent wind-blown dust events[18] occurring once or twice per year on average, mostly during springtime, in the Colorado portions of the SLV. These events show an increasing trend in the number of events in recent years. Primary causes of wind-blown dust in the valley are seasonal high winds and dry, loose, exposed soils with sparse vegetation related to agricultural activities in spring months. Another potential factor is that increases in wind-blown dust events may be due to northward migration of storm tracks associated with climate change (USGCRP 2014). The upward trend in dust emissions in the region is expected to

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[17] Federal Class I PSD areas can be found at http://www.nature.nps.gov/air/maps/classiloc.cfm.

[18] An event is defined as an occurrence of dust levels that exceeds the standard concentration, although a single exceedance does not mean an area is not in attainment.

increase in the future as model predictions of future precipitation generally indicate that northern areas will become wetter, and southern areas, particularly in the West, will become drier. The arid Southwest is projected to become even drier in this century. There is emerging evidence that this is already underway. Deserts in the United States are also projected to expand to the north, east, and upward in elevation in response to projected warming and associated changes in climate. As an example, the 1955-2014 climatological data at Alamosa, Colorado show an upward trend in temperature and a downward trend in precipitation (NCDC 1986, 2014a). Most other stations in the SLV also show increasing temperature and decreasing precipitation throughout this period (WRCC 2015).

Currently, there are five air monitoring sites within the study area where PM concentrations are collected (Figure 2-2). Table 2-3 presents the detailed information on these monitoring sites, such as location, reporting agency, and operating schedule, etc. Three of the stations are State and Local Air Monitoring Stations (SLAMS)[19] sites in the valley (EPA 2014b), at: (1) Adams State University (ASU) in Alamosa, Colorado and (2) Municipal Building (MB) also in Alamosa; and (3) Taos, in Taos, New Mexico.[20] At these sites, 24-hour PM_{10} has been monitored since 1989, 2002, and 2003, respectively. Twenty-four hour PM_{10} data are collected daily at the two sites in Alamosa and on every sixth day at the site in Taos. The Alamosa ASU and MB sites, which are located in the western and eastern parts of Alamosa, respectively, are about 0.85 mi (1.4 km) apart.

Two Interagency Monitoring of Protected Visual Environments (IMPROVE)[21] sites in the study area are also in operation (Figure 2-2) (CIRA 2014). The IMPROVE monitoring sites include: (1) Great Sand Dunes NM in Colorado; and (2) Wheeler Peak WA in New Mexico, which are designated as Class I Areas. PM_{10} and $PM_{2.5}$ measurements have been taken at these sites at 3-day intervals since 1988 and 2000, respectively.

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19 The CAA requires every state to establish a network of air monitoring stations for criteria pollutants, using criteria set by the EPA’s Office of Air Quality Planning and Standards (OAQPS) for their location and operation. The monitoring stations in this network are called the State and Local Air Monitoring Stations (SLAMS). The states must provide OAQPS with an annual summary of monitoring results at each SLAMS monitor, and detailed results must be available to OAQPS upon request.

20 In the SLV, air monitoring networks are sparsely and irregularly spaced over a large area, with monitors concentrated in populous areas such as Alamosa and Taos. However, wind patterns and dust emission potential vary widely in the valley. Thus, air monitoring networks in the valley do not resolve actual spatial and temporal variability of PM levels. Broader and denser monitoring networks, particularly at smaller towns where the modeling predicts likely exceedances, would provide a better understanding of the spatial distributions of PM levels and would also detect local dust events across the study area.

21 The CAA gives Federal Land Managers an affirmative responsibility through the New Source Review permitting process to protect the AQRVs, such as visibility and acid deposition, from the adverse impacts of air pollution. The Interagency Monitoring of Protected Visual Environments (IMPROVE) monitoring program was established in 1985 to aid in the creation of federal and state implementation plans for the protection of visibility in mandatory federal Prevention of Significant Deterioration (PSD) Class I areas (CIRA 2014).

FIGURE 2-2 Locations of Air Monitoring Sites within the Study Area

TABLE 2-3 General Information on Air Monitoring Sites within the Study Area

Site	State	Monitor Type[a]	Reporting Agency[b]	Site ID/Code	Elevation	Sample Collection Frequency	Date Started
Alamosa - Adams State University	Colorado	SLAMS	CDPHE	08-003-0001	7,552 ft (2,302 m)	Daily	6/15/1989
Alamosa - Municipal Building	Colorado	SLAMS	CDPHE	08-003-0003	7,549 ft (2,301 m)	Daily	4/1/2002
Taos - Fire Station	New Mexico	SLAMS	NMED	35-055-0005	6,959 ft (2,121 m)	Every 6th Day	7/1/2003
Great Sand Dunes National Monument	Colorado	IMPROVE	WRAP	GRSA1	8,196 ft (2,498 m)	Every 3rd Day	5/4/1988
Wheeler Peak Wilderness Area	New Mexico	IMPROVE	WRAP	WHPE1	11,043 ft (3,366 m)	Every 3rd Day	8/19/2000

[a] SLAMS = State and Local Air Monitoring Stations; and IMPROVE = Interagency Monitoring of Protected Visual Environments.

[b] CDPHE = Colorado Department of Public Health and Environment; NMED = New Mexico Environment Department; and WRAP = Western Regional Air Partnership.

Source: CIRA (2014); EPA (2014b).

2.6.1 Data from SLAMS Sites

Maximum 24-hour and annual-average PM_{10} concentrations by year and monthly-average PM_{10} concentrations at the three SLAMS sites are presented in Figure 2-3. Note that concentrations related to exceptional events[22] are included because this study is more focused on potential air quality impacts than demonstrating compliance with NAAQS.

At the Alamosa ASU site, maximum 24-hour PM_{10} concentrations were over 400 $\mu g/m^3$ in 1991 and then remained at lower levels over the next 14 years (e.g., the highest measurement over the 14-year period was 263 $\mu g/m^3$ in 1999). During the 1992-2005 period, there were nine exceedances of the 24-hour PM_{10} NAAQS of 150 $\mu g/m^3$, all of which occurred at ASU and four of which occurred in 2002 as seen in Table 2-4. During the same period, 24-hour PM_{10} concentrations reached close to the NAAQS (over 120 $\mu g/m^3$, i.e., 80% of 150 $\mu g/m^3$) eight times at ASU and five times at MB (observations started from 2002). However, since 2006,

[22] Exceptional events are unusual or naturally occurring events that can affect air quality but are not reasonably controllable using techniques that tribal, state or local air agencies may implement in order to attain and maintain the NAAQS. For more information, see http://www.epa.gov/ttn/analysis/exevents.htm.

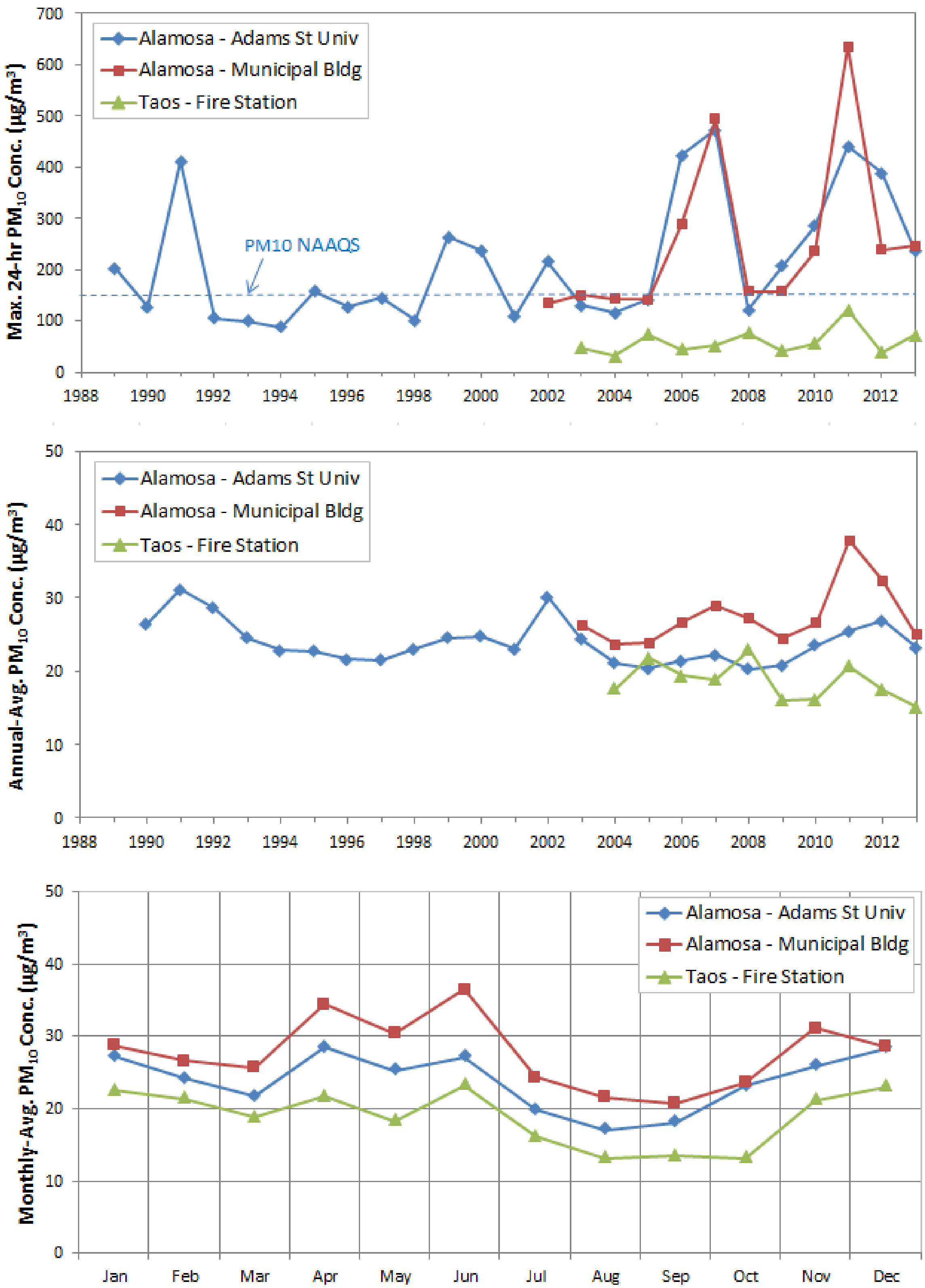

FIGURE 2-3 Monitored PM_{10} Concentrations at Three State and Local Air Monitoring Stations (SLAMS) Sites within the Study Area (Source: EPA 2014b)

TABLE 2-4 Monitored 24-Hour PM_{10} Concentration Data Exceeding National Ambient Air Quality Standard of 150 $\mu g/m^3$ at Any Air Monitoring Sites within the Study Area

Date	Alamosa (Adams State University)	Alamosa (Municipal Building)	Taos (Fire Station)	Great Sand Dunes National Monument	Wheeler Peak Wilderness Area
6/21/1989	203	-[a]	-	-	-
4/10/1991	412	-	-	(71)[b]	-
4/23/1994	(21)	-	-	352	-
4/14/1995	158[c]	-	-	-	-
3/31/1999	263	-	-	(43)	-
4/9/1999	190	-	-	-	-
4/18/2000	238	-	-	-	-
12/17/2000	217	-	-	(13)	(10)
2/8/2002	215	-	-	-	-
2/25/2002	182	-	-	(9)	(9)
3/23/2002	164	-	-	-	-
5/21/2002	160	(134)	-	-	-
2/10/2006	424	289	(37)	(5)	(17)
2/15/2006	158	206	-	-	-
4/14/2006	(15)	213	-	(6)	(4)
4/28/2006	(145)	181	-	-	-
6/26/2006	(13)	160	-	-	-
6/6/2007	473	494	-	-	-
4/15/2008	(121)	155	-	-	(7)
4/30/2008	(99)	157	(42)	(58)	(12)
4/8/2009	(135)	157	-	-	-
10/5/2009	207	-	-	-	-
4/5/2010	185	-	-	(24)	-
4/28/2010	285	236	-	-	-
5/11/2010	160	161	-	(49)	(34)
5/22/2010	260	194	-	-	-
4/3/2011	295	372	(121)	(87)	-
12/1/2011	440	635	-	-	-
2/23/2012	(117)	239	-	-	-
3/18/2012	324	237	-	-	-
3/26/2012	(116)	169	-	-	-
4/2/2012	389	(31)	-	-	-
5/26/2012	253	182	-	-	-
6/20/2012	204	207	(29)	(26)	(14)
4/8/2013	(111)	162	-	-	-
4/16/2013	237	-	(21)	(73)	(11)
4/23/2013	184	(141)	-	-	-
5/1/2013	229	246	-	(29)	(20)
5/31/2013	204	193	-	(31)	-

[a] No measurements were made.

[b] Concentrations at other monitoring sites on the same day when exceedances occurred at one or more sites.

[c] Flagged as an exceptional event by EPA (highlighted in gray) and thus excluded in determining NAAQS compliances.

Source: CIRA (2014); EPA (2014b).

higher monitored values have been observed more frequently, e.g., 424 $\mu g/m^3$ in 2006, 473 and 494 $\mu g/m^3$ in 2007, 440 and 635 $\mu g/m^3$ in 2011, as in Table 2-4. These higher values may be explained by increasing activities such as agriculture, grazing, and off-road vehicle use that can destabilize soils, making them more susceptible to wind erosion. Looking forward, as the effects of global climate change continue, it is likely that desertification will intensify in the Southwestern States (due to the northern migration of storm tracks [USGCRP 2014]); thus, it is also likely that more dust will be produced as vegetative cover decreases and soils dry (Mormon 2010). No exceedances over the 24-hour PM_{10} NAAQS of 150 $\mu g/m^3$ have occurred at Taos since the inception of monitoring in July, 2003.

Annual-average PM_{10} concentrations were well below the NAAQS of 50 $\mu g/m^3$, which was revoked in 2006 because there was no evidence to link long-term exposure to coarse particles to health problems. Annual-average PM_{10} levels were highest at the Alamosa-MB site and lowest at the Taos site. Annual-average PM_{10} levels have tended to increase over time at the Alamosa-MB site but have decreased in Taos. Monitoring data at the Alamosa-ASU site, measured over a longer period than the other two SLAMS sites, showed a slight downward trend.

Monthly-average PM_{10} concentrations are also presented in Figure 2-3. In general, PM_{10} levels were higher in the months of April through June and November through January. Higher monthly averages are primarily due to higher winds and dry soils associated with agricultural activities for the former and anthropogenic sources, such as woodstove burning and street sanding, for the latter.

At SLAMS sites, PM levels are relatively low because dust-generation activities around the sites are relatively minor and wind-erodible lands are limited in the valley. Immediately upwind areas of SLAMS sites have a wind erodibility group (WEG) with medium dust potential (to be discussed in Section 3.2.1.3) but have undisturbed natural vegetation, and wind-blown dust generation is thus relatively low. Although agricultural activities occur at some distance upwind of the SLAMS monitors, coarse particulates (PM_{10}), consisting mostly of fugitive dust, deposit close to their source unless higher winds sustain them over long distances. Average 24-hour PM_{10} concentrations were estimated to be approximately 24.1, 27.6, and 18.6 $\mu g/m^3$ at Alamosa-ASU, Alamosa-MB, and Taos, respectively, over the entire monitoring period at each site. At sites in Alamosa, 24-hour PM_{10} concentrations less than 50 $\mu g/m^3$ occurred about 93-95% of the time and less than 100 $\mu g/m^3$ about 99% of the time. On average, 24-hour PM_{10} concentration exceeded the NAAQS level once or twice (or 1.2 and 1.8 days per year, respectively) at these locations based on the entire monitoring period. However, considering the last ten years (2004-2013), these exceedances increased to 1.8-2.2 days per year.

2.6.2 Data from IMPROVE Sites

At the Great Sand Dunes NM site, monitored 24-hour PM (both PM_{10} and $PM_{2.5}$) concentrations were well below the NAAQS since 1988, as shown in Figure 2-4. One exception was the high PM episode on April 23rd, 1994 when a 24-hour PM_{10} concentration of 352 $\mu g/m^3$ was reported. In this event, coarse mass (PM_{10} minus $PM_{2.5}$), which results from fugitive dust,

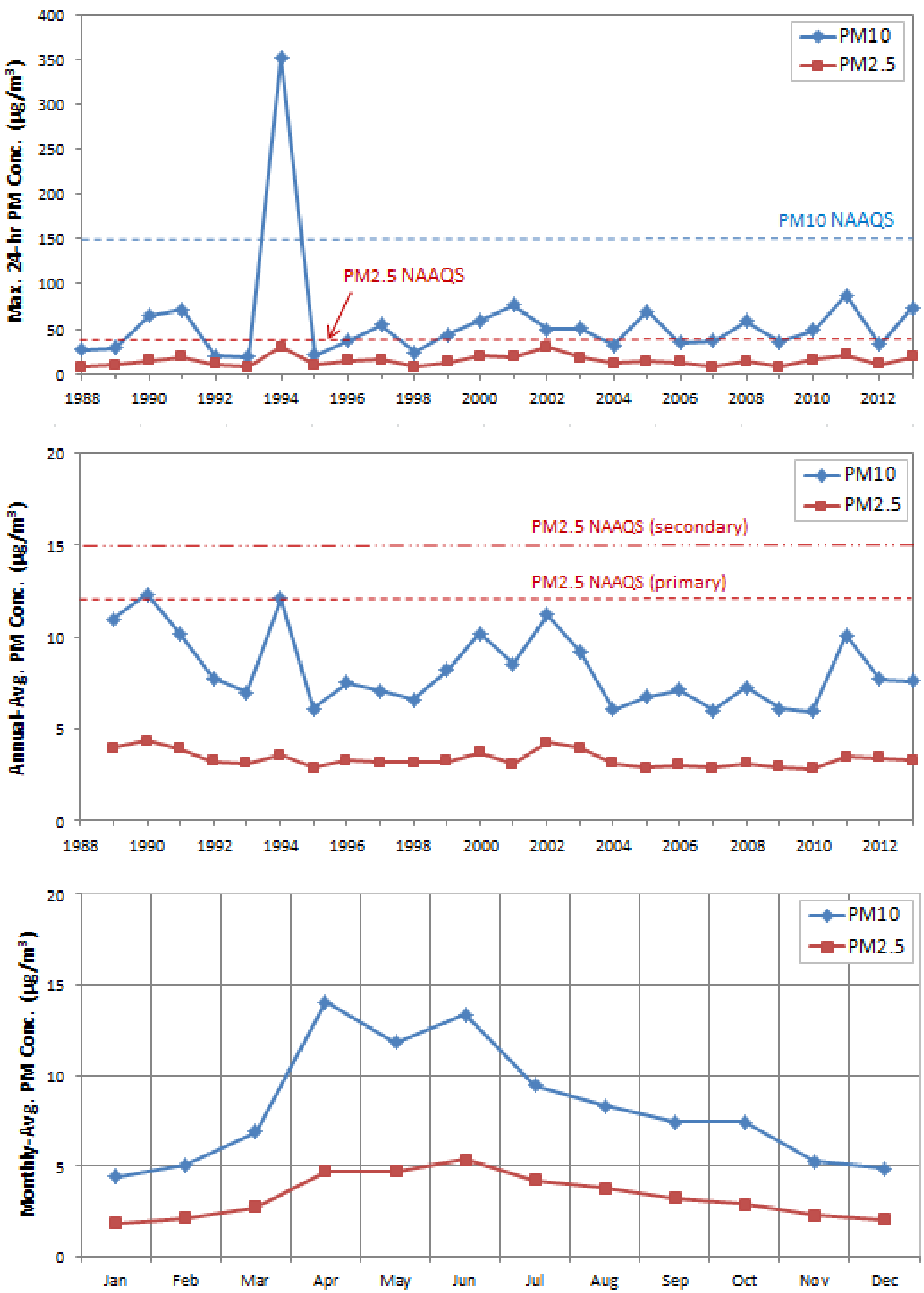

FIGURE 2-4 Monitored PM_{10} and $PM_{2.5}$ Concentrations at an Interagency Monitoring of Protected Visual Environments (IMPROVE) Site, Great Sand Dunes National Monument, within the Study Area (Source: CIRA 2014)

such as that generated by agriculture, construction and mining operations, road dust, and natural wind-blown dust, was the largest contributor to this level. A lower concentration of 21 $\mu g/m^3$ at a site in Alamosa on the same day suggests that this extreme concentration was a localized event. Additionally, annual-average PM levels are well below the old and current NAAQS and show slight downward trends. Monthly-average PM concentrations were higher in May and June and peaked in April, but no secondary peaks in colder months were measured, in contrast to those at the SLAMS sites. This site is located far from urban areas and thus removed from anthropogenic emissions, such as woodstove and street sanding, which contribute to PM concentrations in colder months.

At the Wheeler Peak WA site, PM levels show patterns and trends similar to those at the Great Sand Dunes NM site except for slight upward trends in annual-average PM and a monthly peak in June, as shown in Figure 2-5. The Wheeler Peak WA site had lower PM concentrations than those at the Great Sand Dunes NM site due in part to its higher elevation (11,043 ft [3,366 m] versus 8,196 ft [2,498 m]).

2.6.3 Summary

As shown in Table 2-4, a total of 52 exceedances over 24-hour PM_{10} NAAQS were reported at monitoring sites within the study area, among which 39 exceedances were unique (i.e., counted as one exceedance if exceedances occurred at more than one site on the same day - in some cases, exceedances were reported at both Alamosa sites). In general, some higher concentrations were associated with wind-blown dust events over the broad region but others were more localized, e.g., the April 14, 2006 and April 2, 2012 exceedances. About six out of seven exceedances are flagged as exceptional events, i.e., regional-scale natural wind storms, and thus were excluded from determining NAAQS compliances. Monitoring data over the region indicates that elevated PM levels were associated with upwind and local conditions for the site of interest, even when meteorological and soil conditions were favorable for wind-blown dust. As a result, there were many low readings in the region, even during regional dust storm events.

In Figure 2-6, the number of days (by year and by month) for 24-hour PM_{10} concentrations exceeding the NAAQS of 150 $\mu g/m^3$ are shown for all five monitoring sites within the study area. As mentioned previously, no exceedances occurred at the Taos and Wheeler Peak WA sites but one exceedance was reported in 1994 at the Great Sand Dunes NM. Most exceedances occurred at the two SLAMS sites in Alamosa and the number of exceedance days tended to increase with time. Historically, no exceedances over the NAAQS level occurred during the months of January, July through September, or November. The highest PM exceedances tend to occur more frequently in late winter through early summer with a peak in April.

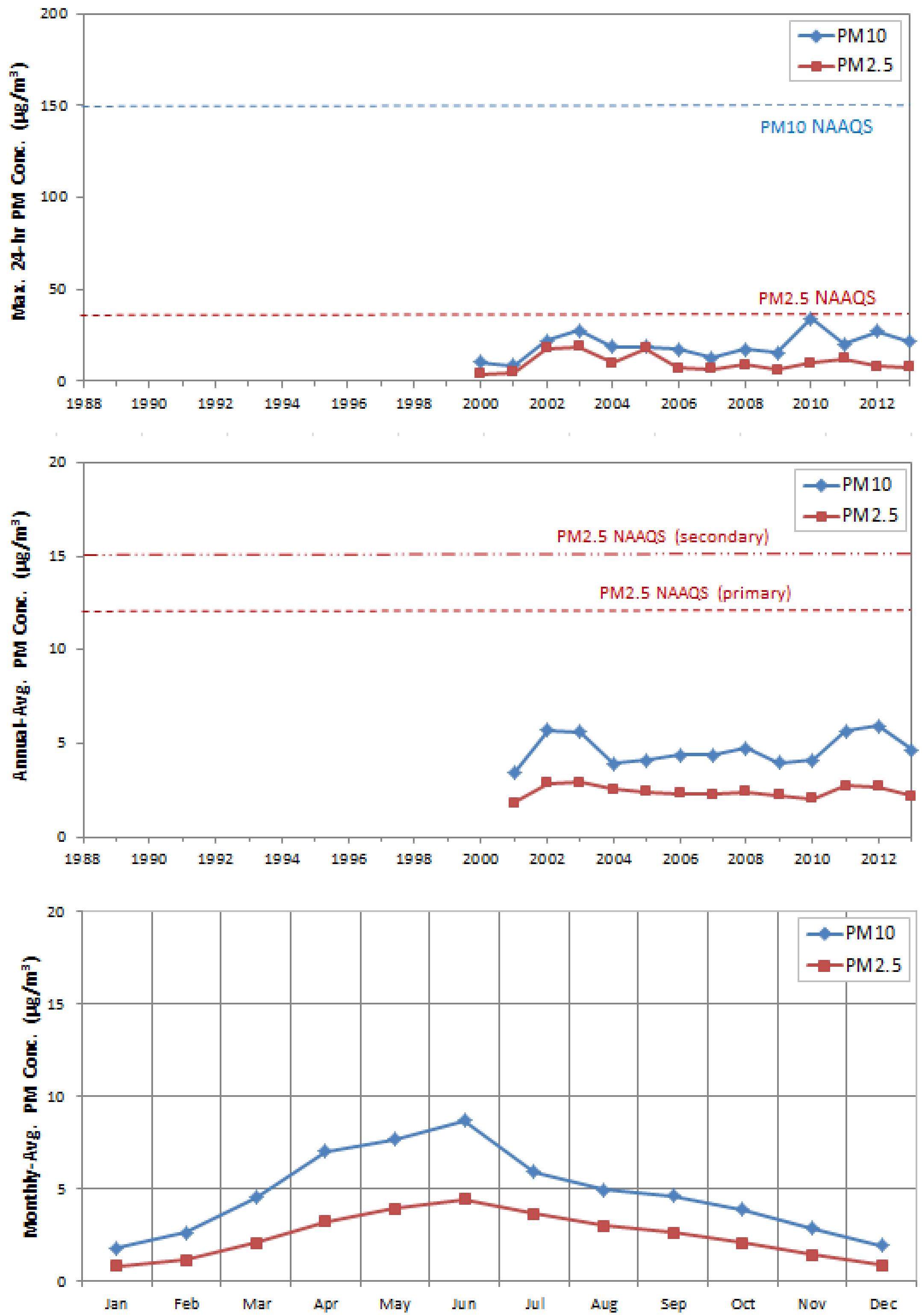

FIGURE 2-5 Monitored PM_{10} and $PM_{2.5}$ Concentrations at an Interagency Monitoring of Protected Visual Environments (IMPROVE) Site, Wheeler Peak Wilderness Area, within the Study Area (Source: CIRA 2014)

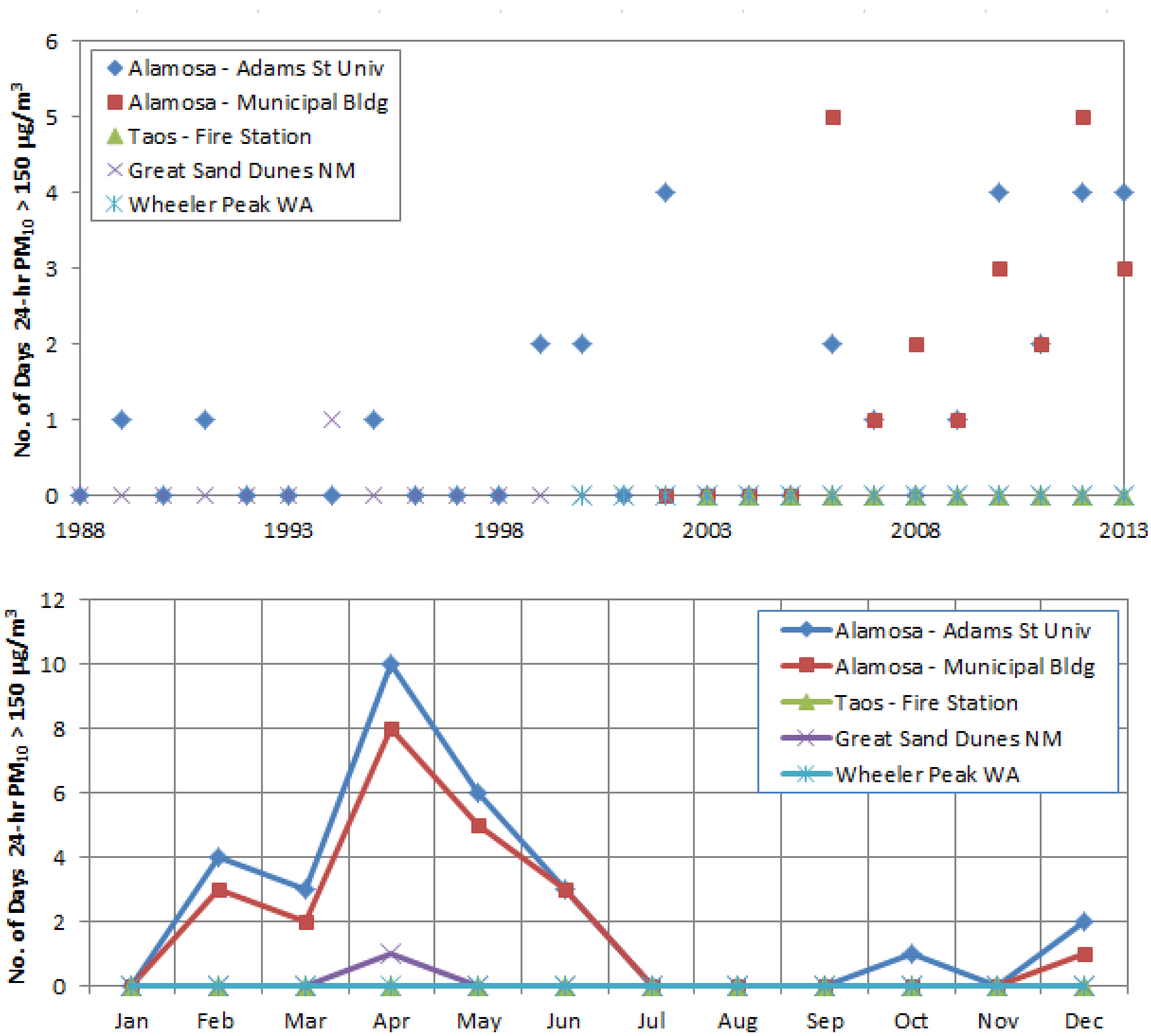

FIGURE 2-6 Number of Days by Year and by Month with Monitored 24-Hour PM_{10} Concentrations Exceeding NAAQS of 150 µg/m^3 at All Monitoring Sites within the Study Area (Source: CIRA 2014; EPA 2014b)

3 STUDY METHODS AND DATA

The potential dust impacts from construction of solar facilities in the Colorado SEZs were studied extensively in the Draft Solar PEIS. Because of the reductions in size of some of the SEZs between the Draft and Final Solar PEIS, estimated dust levels from construction were revised for the Final Solar PEIS. Section 3.1 summarizes the assessment methods of dust impact modeling for the construction phase that were presented in the Draft and Final Solar PEIS (BLM and DOE 2010, 2012). Construction phase dust modeling in this report focuses on $PM_{2.5}$ and PM_{10} generated from soil disturbance caused by construction activities such as removal of vegetative cover, vehicle traffic, installation of power-conducting cable, and construction of site control buildings (see Section 4.1 for results).

Section 3.2 discusses the assessment methods for modeling impacts from wind-blown dusts associated with solar energy facility operations in the three SEZs. For the assessment of operations phase dust modeling the focus is on wind-blown dust and the impact of land use/land cover changes on atmospheric concentrations of $PM_{2.5}$ and PM_{10} in the study area (see Section 4.2 for results).

3.1 CONSTRUCTION ACTIVITY ASSUMPTIONS AND MODEL

The Colorado SEZs have a flat terrain that would require only minimal site preparation work, perhaps with no large-scale earthmoving operations. However, depending on the amount of soil disturbed for a given solar project, dust emissions from soil disturbances during the construction phase could be a significant concern because of the large areas that would be disturbed in an area that already experiences some wind-blown dust problems. In work done for the Solar PEIS, potential impacts from PM_{10} and $PM_{2.5}$ were presented. PM_{10} and $PM_{2.5}$ are criteria pollutants for which standards are available (see Section 2.5) and are widely used indicators of dust problems,

To conduct the dust impact assessment, assumptions were needed regarding the pace of future construction and the type of heavy equipment to be used. Typical emission factors for various levels of construction activity are available as input modeling assumptions (MRI 1996). An area-based emission factor of 0.11 tons of PM_{10} per acre per month was assumed for the Solar PEIS modeling; this value is an average for typical construction activities in western states.[23] The $PM_{2.5}$ emission factor assumed for construction activities was 10% of the PM_{10} emission factor (MRI 2006). It was assumed that the conventional dust control measure of water spraying, with a control efficiency of 50%, would be applied over the disturbed area and on unpaved roads. For modeling it was assumed that construction emissions would be uniform regardless of solar technology.

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[23] This area-based emission factor is an average of emission factors derived from construction activities at several sites in western states, activity levels of which range from low to heavy (e.g., heavy earthmoving, cut/fill, trucking of fill materials). Typical solar construction activities in the SLV would likely be low to moderate, so the assumed emission factor might somewhat overestimate actual emissions.

For the Colorado SEZs with areas of less than 10,000 acres (40 km^2), it was assumed that one construction project could occur annually. Based on actual solar facility construction projects, it was assumed that each project could disturb up to 3,000 acres (12.1 km^2) annually for Antonito Southeast SEZ. It was also conservatively assumed that the project being constructed would be located in the area of each SEZ that is closest to off-site residences. Because the other SEZs have areas of less than 3,000 acres, it was assumed that the entire developable area of each SEZ could be disturbed in one year for the De Tilla Gulch SEZ and Los Mogotes East SEZ.

The level of construction emissions derived in the Solar PEIS was a best estimate based on the above assumptions regarding rate and type of construction. For actual proposed projects within SEZs, more detailed information on construction activities would be available, and more realistic emission estimates based on actual activity levels would be derived. During actual construction, site operators would be required to maintain dust levels at the site boundaries at lower than the permit-required levels, through altering construction practices and/or schedules and using dust control measures.

Air quality modeling for PM_{10} and $PM_{2.5}$ emissions associated with construction activities was performed for the Solar PEIS using the AMS/EPA Regulatory Model (AERMOD) preferred or recommended by the EPA (EPA 2009a) for a wide range of regulatory applications. AERMOD is a refined, steady-state plume model that incorporates air dispersion based on state-of-the-art planetary boundary layer turbulence structure and scaling concepts, and building wake effects and plume downwash for point sources. It includes treatment of both surface and elevated sources (including multiple point, area, and volume sources), and both simple and complex terrain, and can be applied to rural and urban areas. The model uses hourly sequential preprocessed meteorological data to estimate not only airborne concentrations, but also dry and wet deposition fluxes for both particulate and gaseous emissions of nonreactive pollutants for averaging times, ranging from 1 hour to multiple years. Surface characteristics influence boundary layer parameter estimates. Obstacles to the wind flow, the amount of moisture at the surface, and reflectivity of the surface, which are quantified through the surface roughness length, Bowen ratio, and surface albedo, all affect the estimates. In the AERMOD model, these parameters are used, varying by land use and season. Details on emissions estimation, the description of AERMOD, input data processing procedures, and modeling assumptions are described in the technical appendix (Appendix M) of the Solar PEIS (BLM and DOE 2010, 2012).

Estimated air concentrations were compared with NAAQS levels for PM_{10} (e.g., 150 $\mu g/m^3$ 24-hour) and $PM_{2.5}$ (e.g., 35 $\mu g/m^3$ 24-hour) at the SEZ boundaries and at nearby communities, and compared with PSD increment levels for PM_{10} (e.g., 8 $\mu g/m^3$ 24-hour) and $PM_{2.5}$ (e.g., 2 $\mu g/m^3$ 24-hour) at nearby Class I areas.[24]

24 To provide a quantitative assessment, the modeled air impacts of construction were compared to the NAAQS levels and the PSD Class I increment levels. Although NAAQS and PSD increments are not applicable to individual construction projects, a comparison with these values was used to quantify potential impacts. However, only monitoring data can be used to determine attainment status. The modeled data in this assessment are used to assess potential problems and as a consideration for future permitting requirements.

Assumptions in common for modeling for all three SEZs are presented below, and other modeling assumptions specific to each SEZ are presented in Sections 3.1.1 through 3.1.3.

- Construction activities would occur for 10 hours per day, from 7 a.m. to 5 p.m.

- As stated in the Solar PEIS, during construction the maximum disturbed area for each SEZ was assumed to be 3,000 acres (12.1 km^2). If an SEZ area was less than 3,000 acres, it was assumed that 80% of the developable area (corresponding to full-buildout) would be developed in one year.

- It was conservatively assumed that emissions would be area sources released at the ground level without a vertical dimension. In reality most construction-related emissions would be more accurately represented as volume sources centered on a certain height. Concentrations modeled as a volume source would be somewhat lower than but close to those modeled as an area source at ground level in the near and far field, respectively. Therefore, the simplified method of modeling an area source was considered sufficient for the purposes of this study.

- A regularly spaced receptor grid over a modeling domain of 62 mi × 62 mi (100 km × 100 km) centered on each SEZ was established, along with discrete receptors at the SEZ boundaries

- Dry and wet deposition mechanisms are uncertain and are not included in EPA's regulatory option, and thus, it is not recommended to use them for typical applications except in special cases (e.g., deposition impacts on vegetation). Accordingly, to err on the side of conservatism, no dry and wet deposition for construction-related PM modeling were assumed, i.e., all PMs were assumed to be airborne.

- Wind erosion from disturbed areas and material stockpiles are fugitive dust sources, especially under relatively high-wind conditions. Under such conditions, potential impacts from wind-blown dust might be significant. However, construction emissions and wind-blown dust are not additive because best management practices would dictate that construction activities would cease temporarily under high-wind conditions. Accordingly, potential impacts from wind-blown dust are presented separately in Sections 3.2 (modeling assumptions) and 4.2 (modeling results).

3.1.1 Antonito Southeast SEZ

For the Antonito Southeast SEZ, AERMOD modeling was conducted based on the following assumptions and data:

- Annual total emissions of 1,980 and 198 tons for PM_{10} and $PM_{2.5}$, respectively, were uniformly distributed over 3,000 acres (12.1 km^2) – about 31% of the developable area of 9,712 acres (39.3 km^2) – in the northwest corner of the SEZ, close to Antonito (the nearest town);

- Surface hourly meteorological data from the San Luis Valley Regional Airport in Alamosa and upper air sounding data from Denver for the 2004 to 2008 period;

- Additional discrete receptors at the nearest Class I area – Wheeler Peak WA – about 35 mi (57 km) southeast of the SEZ; and

- Concentrations for attainment demonstrations: For 24-hour PM_{10}, the 6^{th} highest concentration at each receptor over the 5-year period of 2004–2008 was presented. For 24-hour $PM_{2.5}$, the multi-year average of the 8^{th} highest concentration at each receptor was presented. For annual-average $PM_{2.5}$, the multi-year average of annual means at each receptor was presented. These values correspond to the guideline for modeling demonstrations of compliance with the NAAQS.

3.1.2 De Tilla Gulch SEZ

For the De Tilla Gulch SEZ, AERMOD modeling was conducted based on the following assumptions and data:

- A total area of 851 acres (3.4 km^2), 80% of the developable area of 1,064 acres (4.3 km^2), would be disturbed at any one time within the SEZ, with annual total emissions of 562 and 56 tons for PM_{10} and $PM_{2.5}$, respectively, uniformly distributed over the SEZ area;

- Surface hourly meteorological data from the Saguache Municipal Airport and upper air sounding data from Denver for the 2005 to 2006 period;[25]

- Additional discrete receptors at the nearest Class I area – Great Sand Dunes NM – about 19 mi (31 km) southeast of the SEZ; and

- Concentrations for attainment demonstrations: For 24-hour PM_{10}, the 3^{th} highest concentration at each receptor over the 2-year period of 2005–2006 was presented. For 24-hour $PM_{2.5}$, the two-year average of the 8^{th} highest concentration at each receptor was presented. For annual-average $PM_{2.5}$, the two-year average of annual means at each receptor was presented.

[25] In air quality modeling for the De Tilla Gulch SEZ, only two years of meteorological data from the Saguache Airport were available at the time of analysis.

3.1.3 Los Mogotes East SEZ

For the Los Mogotes East SEZ, AERMOD modeling was conducted based on the following assumptions and data:

- A total area of 2,120 acres (8.6 km^2), 80% of the developable area of 2,650 acres (10.7 km^2), would be disturbed at any one time within the SEZ, with annual total emissions of 1,399 and 140 tons for PM_{10} and $PM_{2.5}$, respectively, uniformly distributed over the SEZ area;

- Surface hourly meteorological data from the San Luis Valley Regional Airport in Alamosa and upper air sounding data from Denver for the 2004 to 2008 period;

- Additional discrete receptors at the nearest Class I area – Great Sand Dunes NM – about 45 mi (72 km) northeast of the SEZ; and

- Concentrations for attainment demonstrations: For 24-hour PM_{10}, the 6^{th} highest concentration at each receptor over the 5-year period of 2004–2008 was presented. For 24-hour $PM_{2.5}$, the multi-year average of the 8^{th} highest concentration at each receptor was presented. For annual-average $PM_{2.5}$, the multi-year average of annual means at each receptor was presented.

3.2 WIND-BLOWN DUST MODELING FOR OPERATIONS

The three SEZs located within the study area have given rise to concern among local residents regarding potential air quality impacts associated with solar energy facility operations in the three SEZs. Dust emissions during normal operations were not modeled as part of the Solar PEIS, because they are generally thought to be much lower than construction phase dust emissions, and lower than air quality guideline concentrations. However, because of concerns associated with dust events already occurring in the SLV (see Section 2.6), for this study the air quality impacts associated with operations were estimated.

Wind-blown dust during the operation phase was assessed for a base case (pre-development) condition and for six future development scenarios for the SEZs. Section 3.2.1 presents assumptions and the model used in dust impact modeling, including identification of the modeling domain, addressing the basis for the selection of the air quality model used in assessing potential air quality impacts along with its brief description, and presenting how the erosion factor fields are generated for use in estimating wind-blown dust emissions. In Section 3.2.2, observed wind speeds are compared with model predictions, and modeling calibrations are discussed.

3.2.1 Assumptions and Model Used

3.2.1.1 Modeling Domain

The modeling domain was chosen so as to account for local emissions in the SLV and regional transport into the SLV from upwind dust source areas, including the Colorado Plateau in the near field and the Sonoran, Mojave, Great Basin, and Chihuahuan Deserts in the far field, as shown in Figure 3-1. The modeling domain includes all of Arizona, Colorado, New Mexico, and Utah, and portions of surrounding states, such as California, Nevada, Oregon, Idaho, Wyoming, Nebraska, Kansas, Oklahoma, Texas, and northern Mexico.

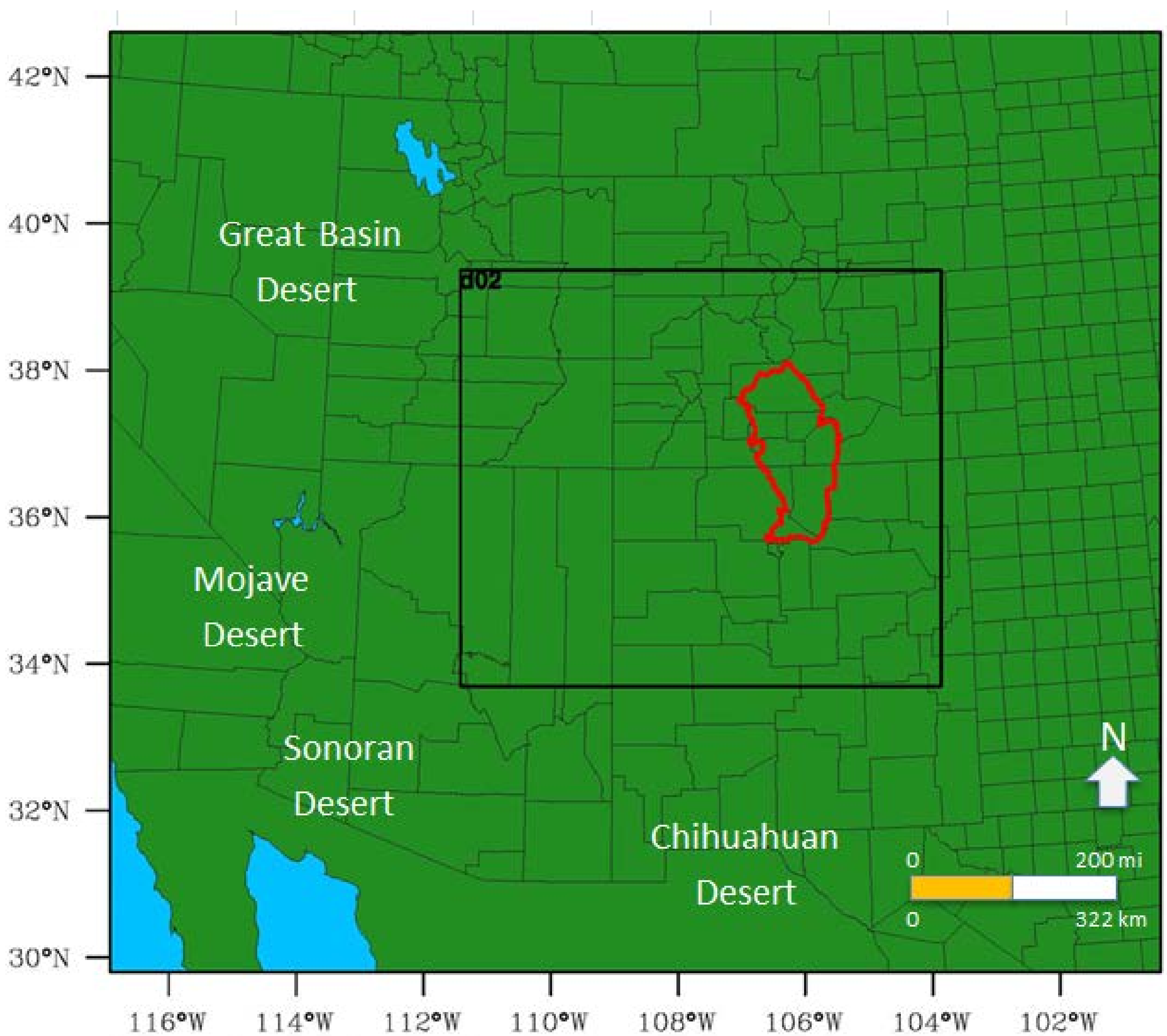


FIGURE 3-1 Nested Modeling Domain and Locations of Deserts

Grids were produced at two levels of resolution, a coarser outer domain at a spatial resolution of 5.6 mi (9 km) on each side, and a higher resolution inner grid at a spatial resolution of 1.9 mi (3 km) on each side that covered the region of SEZ development. The grids were based on a Lambert conformal projection, which is well-suited for mid-latitude domains (NCAR 2014a), with standard parallels at 30.5° N and 44.5° N and centered on a meridian of 108.7° W and a latitude of 36.5º N. The grids are measured in meters and use the North American Datum of 1983 (NAD 83).[26] This projection is centered on the Four Corners area in the northwestern New Mexico.

Figure 3-1 shows the locations and extents of the two modeling grids, the SLV, and state and county boundaries. The large outer or regional-scale grid covers the greater region around the study area with 9-km cells. This grid has 177 columns and 158 rows, covering an extent of 990 mi × 884 mi (1,593 km × 1,422 km). The inner grid has a 3-km cell size and covers the full extent of the SLV and the upwind Colorado Plateau. This grid has 243 columns and 210 rows, covering an extent of 453 mi × 391 mi (729 km × 630 km).

3.2.1.2 Air Quality Model – WRF-Chem

For this study, the Weather Research and Forecasting (WRF) model with chemistry (WRF-Chem), version 3.6 (NCAR 2014a, b) was used, which is one of the state-of-the-art air quality models. The development of WRF-Chem is ongoing, and is a collaborative effort among the air quality modeling community, in which the National Oceanic and Atmospheric Administration/Earth System Research Laboratory (NOAA/ESRL) scientists are the leaders and caretakers of the code. The model simulates the emission, transport, mixing, and chemical transformation of trace gases and aerosols simultaneously with atmospheric dynamics. The model is widely used for investigation of regional-scale air quality, field program analysis, and cloud-scale interactions between clouds and chemistry. The model is designed to operate on modern high-performance-computing architecture and is best suited for high spatial resolution simulations.

Technical details of the WRF and WRF-Chem models are presented in Skamarock et al. (2008) and Grell et al. (2005), respectively. The physics schemes used in this study include Grell-Devenyi convective parameterization (Grell and Devenyi 2002), Yonsei University planetary boundary layer scheme (Noh et al. 2003), Noah land surface model (Chen and Dudhia 2001), rapid radiative transfer model-global (RRTMG) longwave and shortwave radiative schemes (http://rtweb.aer.com; Iacono et al. 2008), and Morrison microphysics scheme (Morrison et al. 2009). The model simulates dust aerosols in five different size bins with effective radius sizes ranging from 0.1 to 10 μm (0.5, 1.4, 2.4, 4.5, 8.0 μm). Dry deposition includes gravitational settling as a function of particle size and air viscosity, and surface deposition as a function of surface type and meteorological conditions (Wesely 1989). Wet deposition accounts for the scavenging of aerosols in convective updrafts and rainout/washout in

[26] NAD 83 is the geographic coordinate system of the NOAA, National Geodetic Survey. It is the official legal coordinate reference system in the United States.

large-scale precipitation (Giorgi and Chameides 1986; Balkanski et al. 1993). During wind-blown dust events, dust accounts for most of the total PM concentrations with secondary particles that form in the atmosphere from combustion-related gaseous emissions (e.g., NO_x and SO_x) being small contributors to total PM. Thus, in the modeling study, secondary particles are not included and "running with only dust aerosols" option was employed.

3.2.1.3 Generation of Erosion Factor Fields

The WRF-Chem model is an online-coupled dynamics and chemistry model. It estimates dust emissions each time step using wind speeds generated in the model and then calculates dust transport. To run with only dust aerosols, several input data files are needed, which are the dust-related fields (erosion factor, clay fraction, sand fraction). These fields are fractions of erodible surface, clay, and sand, respectively, in each grid cell, which range from 0 to 1. Prescribed clay fraction and sand fraction are used for each grid cell and the erosion factor is calculated as a function of the fraction occupied by sand, silt, and clay, respectively. The values of these factors are prescribed based on soil type characteristics dataset defined at a spatial resolution of about 16 mi (25 km). The WRF Preprocessing System (WPS) is used to prepare the required input fields that generate the dust emissions and the simulated meteorological fields (NCAR 2014a, b).

Two separate dust aerosol options were available in the model at the time analyses for this study were ongoing.[27] The first option uses a dust emission module developed for the Global Ozone Chemistry Aerosol Radiation and Transport (GOCART) model (Chin et al. 2000, 2002); the second option improves the GOCART dust emission parameterizations using the Air Force Weather Agency (AFWA) modifications.

The GOCART dust flux equation is the following (Ginoux et al. 2001, 2004):

$$F_p = \begin{cases} C\, S\, s_p\, U^2\, (U - U_t) & \text{if } U > U_t \\ 0 & \text{otherwise} \end{cases}$$

where:

F_p = vertical dust flux for particle bin
C = dimensional tuning constant
S = erodibility fraction
s_p = particle bin mass fraction
U = 10-m wind speed
U_t = threshold 10-m wind speed

[27] Beyond GOCART, WRF-Chem version 3.7 (NCAR 2015) includes another dust emission scheme (Shao 2001, 2004; Shao et al. 2011), as an option for the GOCART dust emissions modeling, with University of Cologne (UOC) modifications. This option explicitly represents dynamic land surface effects on dust emissions and thus could better represent finer-scale physical processes controlling dust emissions. However, this option was not available in WRF-Chem version 3.6 at the time analyses for this study were ongoing.

Source function or erodibility fraction (S) is calculated based on elevation relative to surrounding area within certain area:

$$S_i = \frac{z_{max} - z_i}{z_{max} - z_{min}}$$

where:

S_i = probability of having accumulated sediments at grid cell *i*
z_{max} = maximum elevation in the surrounding topography
z_{min} = minimum elevation in the surrounding topography
z_i = elevation at grid cell *i*

The factor S is introduced to account for the loose sediment that accumulates in topographic depressions, i.e., Holocene lake beds that are the primary sources of dust on the global scale. The erodibility fraction is distributed into three classes associated with sand, silt, and clay with the ratio of 0.5, 0.25, and 0.25. However, the assumption that all erodible lands have a 50% sand, 25% silt, and 25% clay soil composition that was added to the GOCART code later is not realistic (Jones and Creighton 2011). The AFWA scheme (Jones and Creighton 2011) applies a correction to this scheme for bulk vertical dust flux. This correction is based on the methods proposed by Marticorena and Bergametti (1995) and applied to all particle size distribution (Kok 2011), and this algorithm (GOCART with AFWA modifications) was incorporated into this modeling exercise for the SLV-Taos Plateau study area.

The WRF-Chem model uses the erosion factor to estimate the dust emission rate based on land use and simulated wind speed. The topographic map and erosion factor map for the inner domain extracted from WRF-Chem built-in data are presented in Figure 3-2. However, erosion factors within the SLV are nearly zero, which would correspond to negligible dust emissions. Thus, the erosion factor map in the WRF-Chem model does not represent the wind erodibility conditions of the SLV, which has experienced high-level wind-blown dust events. Thus, a method other than use of topographic differences (as is done in the WRF-Chem model) was employed to characterize erosion factors representative for the SLV-Taos Plateau study area The method chosen relies on WEG and land cover type to predict dust emission rates, as described below.

Wind Erodibility Group (WEG) Evaluation. One of the important parameters that are associated with the development of the erosion factor is WEG, prepared by U.S. Department of Agriculture (USDA), based on the properties of the soil surface layer. Table 3-1 lists the description of each of the WEG groups (USDA-NRCS undated). A WEG is a grouping of soils that have similar properties affecting their resistance to soil erosion in cultivated areas.

The groups indicate the susceptibility of the soil to wind erosion and the amount of soil lost. Soils are grouped according to their content of stable 0.84-mm aggregates. These are represented idealistically by USDA textural classes. The wind erodibility index (I), used in the wind erosion equation, is assigned using the WEGs. Subpart B, Exhibits, Section 618.95

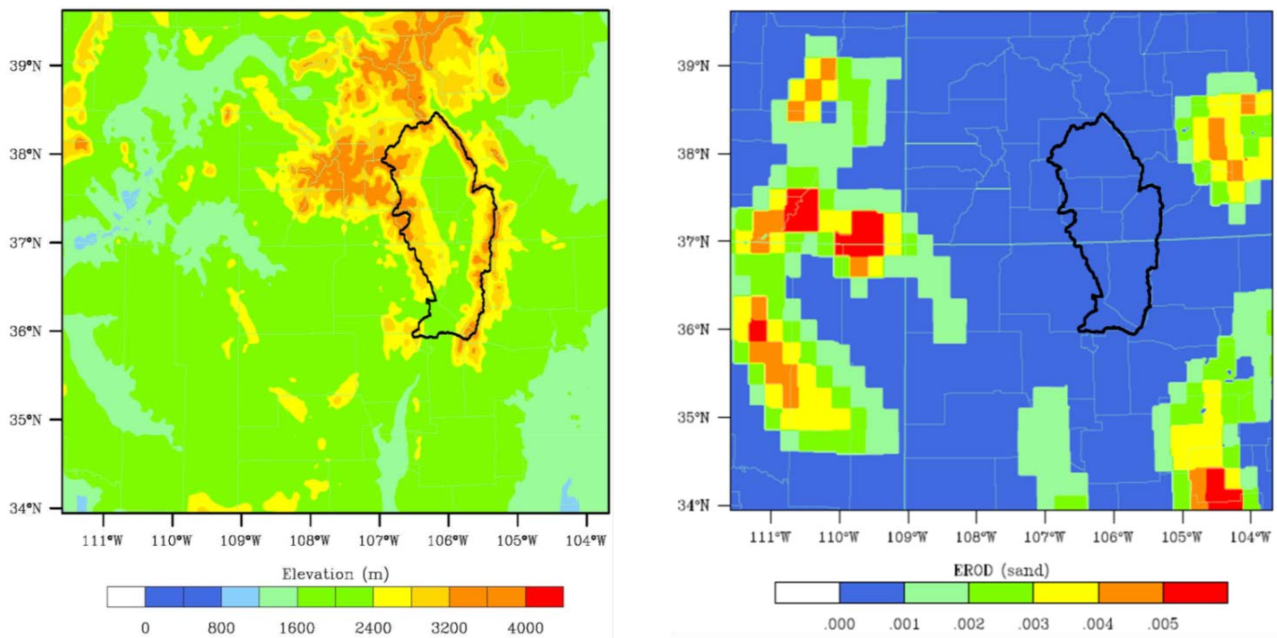


FIGURE 3-2 Topography (left panel) and Erosion Factor Map for Sand (right panel) from WRF-Chem Built-in Data for the Inner Domain

(USDA-NRCS undated) lists the I values assigned to the WEGs. The I values are assigned because the dry soil aggregates are very use-dependent on crop management factors. WEGs are classified into eight categories, ranging from 1 to 8. WEG 4 has two designations (4 and 4L), which have the same weight percent of dry soil aggregates and same I values. The only thing that distinguishes these two designations is whether the loams are calcareous (4L) or noncalcareous (4). The soils assigned to group 1 are the most susceptible to wind erosion, and those assigned to group 8 are the least susceptible. In other words, the lower the WEG number (i.e., WEG 1 or 2), the greater the wind erodibility potential (or the more susceptible to wind erosion).

These WEG data are available for the SLV and are plotted in Figure 3-3 (NRCS 2015). Higher elevations and slopes within the SLV have higher WEGs with low potential for wind-blown dust generation. Lower WEGs are prevalent on the valley floor in Colorado, which are primarily associated with agricultural activities and sand dunes. In contrast, the valley floor in New Mexico has high WEGs except for a small portion with lower WEGs in the southwestern corner. Antonito Southeast and Los Mogotes East SEZs have relatively high WEGs with no WEG 1 or 2, and so are less susceptible to wind erosion. About 21% of the area (about 225 acres [0.91 km^2]) of the De Tilla Gulch SEZ has WEG 1 or 2.

Land Cover Evaluation. All lands are not erodible. Even though an area has high erosion potential (i.e., low WEG value), no wind-blown dust will be generated if the area is not disturbed. Thus, in addition to the WEG number, some soil conditions (stability, disturbance) and sheltering ability are important to characterize when estimating a soil's susceptibility to wind

TABLE 3-1 Wind Erodibility Groups (WEG) and Index

WEG[1,3,4,5,7]	Properties of Soil Surface Layer	Dry Soil Aggregates > 0.84 mm (weight %)	Wind Erodibility Index (I) (tons/acre/ year)
1	Very fine sand, fine sand, sand or coarse sand[2]	1 2 3 5 7	310 250 220 180 160
2	Loamy very fine sand, loamy fine sand, loamy sand, and loamy coarse sand; very fine sandy loam and silt loam with 5 or less percent clay and 25 or less percent very fine sand; and sapric soil materials; except Folists.	10	134
3	Very fine sandy loam (but does not meet WEG criterion 2), fine sandy loam, sandy loam, and coarse sandy loam; noncalcareous silt loam that has greater than or equal to 20 to less than 50 percent very fine sand and greater than or equal to 5 to less than 12 percent clay.	25	86
4	Clay, silty clay, noncalcareous clay loam that has more than 35 percent clay and noncalcareous silty clay loam that has more than 35 percent clay; all of these do not have sesquic, parasesquic, ferritic, ferruginous, or kaolinitic mineralogy (high iron oxide content).	25	86
4L	Calcareous[6] loam, calcareous silt loam, calcareous silt, calcareous sandy clay, calcareous sandy clay loam, calcareous clay loam, and calcareous silty clay loam.	25	86
5	Noncalcareous loam that has less than 20 percent clay; noncalcareous silt loam with greater than or equal to 5 to less than 20 percent clay (but does not meet WEG criterion 3); noncalcareous sandy clay loam; noncalcareous sandy clay; and hemic soil materials	40	56
6	Noncalcareous loam and silt loam that have greater than or equal to 20 percent clay; noncalcareous clay loam and noncalcareous silty clay loam that have less than or equal to 35 percent clay; silt loam that has parasesquic, ferritic, or kaolinitic mineralogy (high iron oxide content).	45	48
7	Noncalcareous silt; noncalcareous silty clay, noncalcareous silty clay loam, and noncalcareous clay that have sesquic, parasesquic, ferritic, ferruginous, or kaolinitic mineralogy (high content of iron oxide) and are Oxisols or Ultisols; and fibric soil materials	50	38
8	Soils not susceptible to wind erosion due to rock and pararock fragments at the surface and/or wetness; and Folists.	--	0

The following footnotes are applied in the order listed:

[1] For all WEGs except 1 and 2 (sands and loamy sand textures), if percent rock and pararock fragments (>2mm) by volume is 15-35, reduce "I" value by one group with more favorable rating. If percent rock and pararock fragments by volume is 35-60, reduce "I" value by two favorable groups except for sands and loamy sand textures which are reduced by one group with more favorable rating. If percent rock and pararock fragments is greater than 60, use "I" value of 0 for all textures except sands and loamy sand textures which are reduced by three groups with more favorable ratings. An example of more favorable "I" rating is next lower number: "I" factor of 160 to "I" factor of 134 or "I" factor of 86 to "I" factor of 56. The index values should correspond exactly to their wind erodibility group (e.g., "I" factor of 56 = WEG 5).

Footnotes continued on next page.

TABLE 3-1 (Cont.)

[2] The "I" values for WEG 1 vary from 160 for coarse sands to 310 for very fine sands. Use an "I" of 220 as an average figure.

[3] All material that meets criterion 3 in the required characteristics for andic soil properties as defined in the *Keys to Soil Taxonomy*, 11th edition. Such material is placed in WEG 2 regardless of the texture class of the fine-earth fraction.

[4] All material that meets criterion 2, but not criterion 3, in the required characteristics for andic soil properties as defined in the *Keys to Soil Taxonomy*, 11th edition. Such material is placed in WEG 6, regardless of the texture class of the fine-earth fraction. The only exception to this is for Cryic Spodosols which have a medial substitute class and a MAAT < 4 degrees C.; these soils are placed in WEG 2.

[5] For surface layers or horizons that do not meet the required characteristics for andic soil properties but do meet Vitrandic, Vitritorrandic, Vitrixerandic, and Ustivitrandic subgroup criteria (thickness criterion excluded) move one wind erodibility group (WEG) with a less favorable rating.

[6] Calcareous is a strongly or violently effervescent reaction (class) of the fine-earth fraction to cold dilute (1N) HCl; a paper "Computing the Wind Erodible Fraction of Soils" by D. W. Fryear et al. (1994) in the Journal of Soil and Water Conservation 49 (2) 183-188 raises a yet unresolved question regarding the effect of carbonates on wind erosion.

[7] For mineral soils with thin "'O" horizons, the WEG is based on the first mineral horizon.

Source: USDA-NRCS (undated).

erosion and quantifying the PM wind-blown dust emissions in the SLV. Currently, no detailed information on these soil conditions is available. To determine which areas are erodible or not, LANDFIRE Existing Vegetation Type (EVT)[28] data are used (LandFire 2015), which represent the vegetation species composition currently present at a given site. As shown in the left panel of Figure 3-4, EVT data are classified into 18 categories for the SLV. Primary vegetation types in the valley include montane and subalpine conifer forest (about 35.2%) and pinyon-juniper woodland (about 10.2%), which are located along the high elevations and slopes of the valley, and basin grassland and shrubland (about 27.6%), which are widely scattered in the valley floor. Wetland and herbaceous agricultural vegetation account for about 10.2% and 6.9% of the area mostly in the eastern and western portions of the valley in Colorado, respectively. As shown in the right panel of Figure 3-4, erodible land, which is determined in consultation with a soil scientist at Argonne National Laboratory, is defined as those areas covered by three vegetation types: barren (about 1.5%); herbaceous agricultural vegetation (6.9%); and recently disturbed or modified (2.8%). The erodible areas are mostly located in the Colorado portion of the study area and most areas of three SEZs currently have natural vegetation, which has no erosion potential.

In summary, the WEG group and the land use data were introduced as a surrogate for estimating dust emission potential. The underlying rationale is that the lower WEG soils (e.g., WEG 1 or 2) with more fine sands and less clay content are more prone to wind erosion, in which sand can be airborne over certain distances and its energy can readily disintegrate clay clods at the ground. This leads to higher dust emissions.

[28] EVTs are mapped using decision tree models, field data, Landsat imagery, elevation, and biophysical gradient data. Decision tree models are developed separately for each of the three lifeforms (tree, shrub, and herbaceous) and are then used to generate lifeform specific EVT layers.

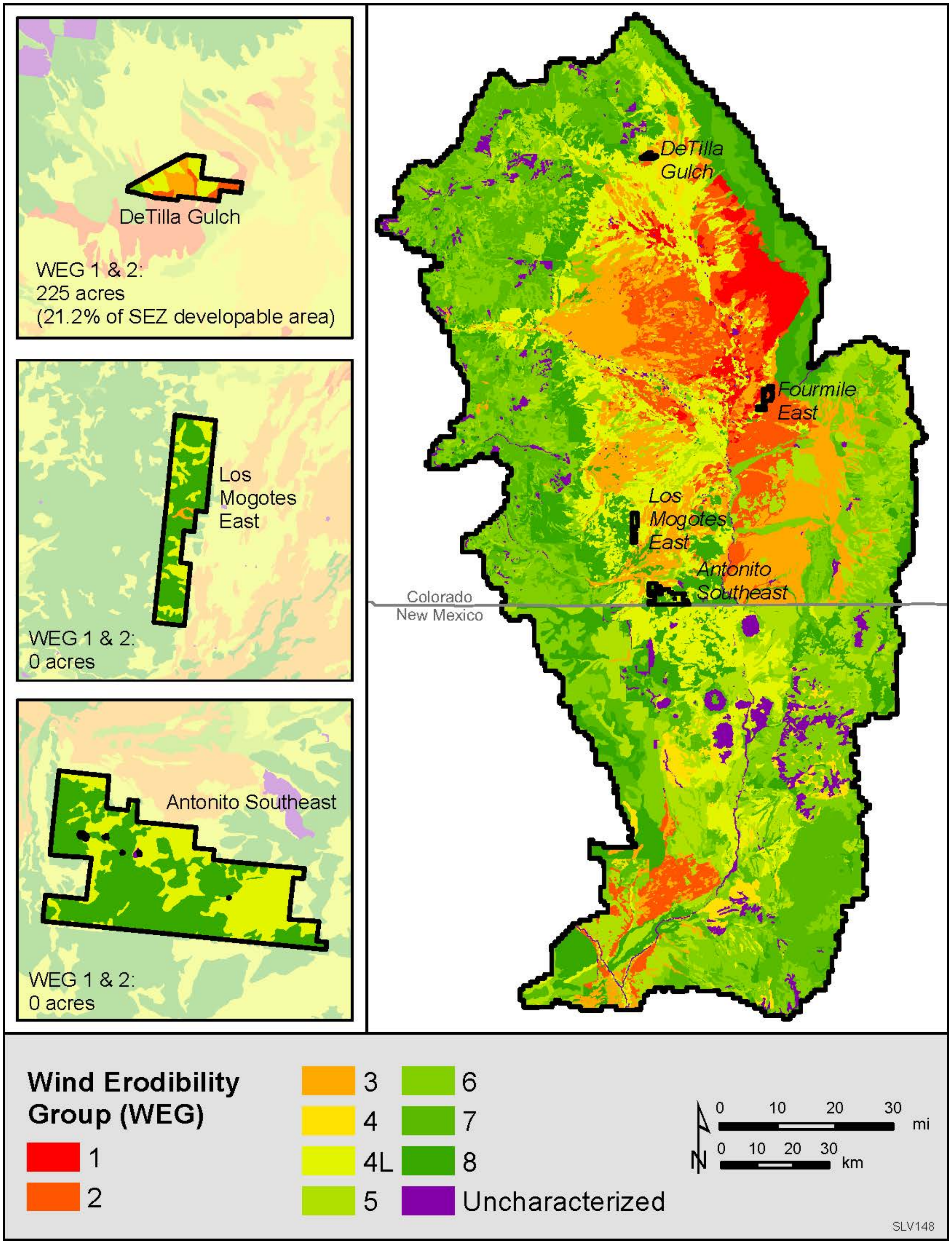


FIGURE 3-3 Distributions of Wind Erodibility Group (WEG) for the Study Area and Three Solar Energy Zones (SEZs) (Source: NRCS 2015)

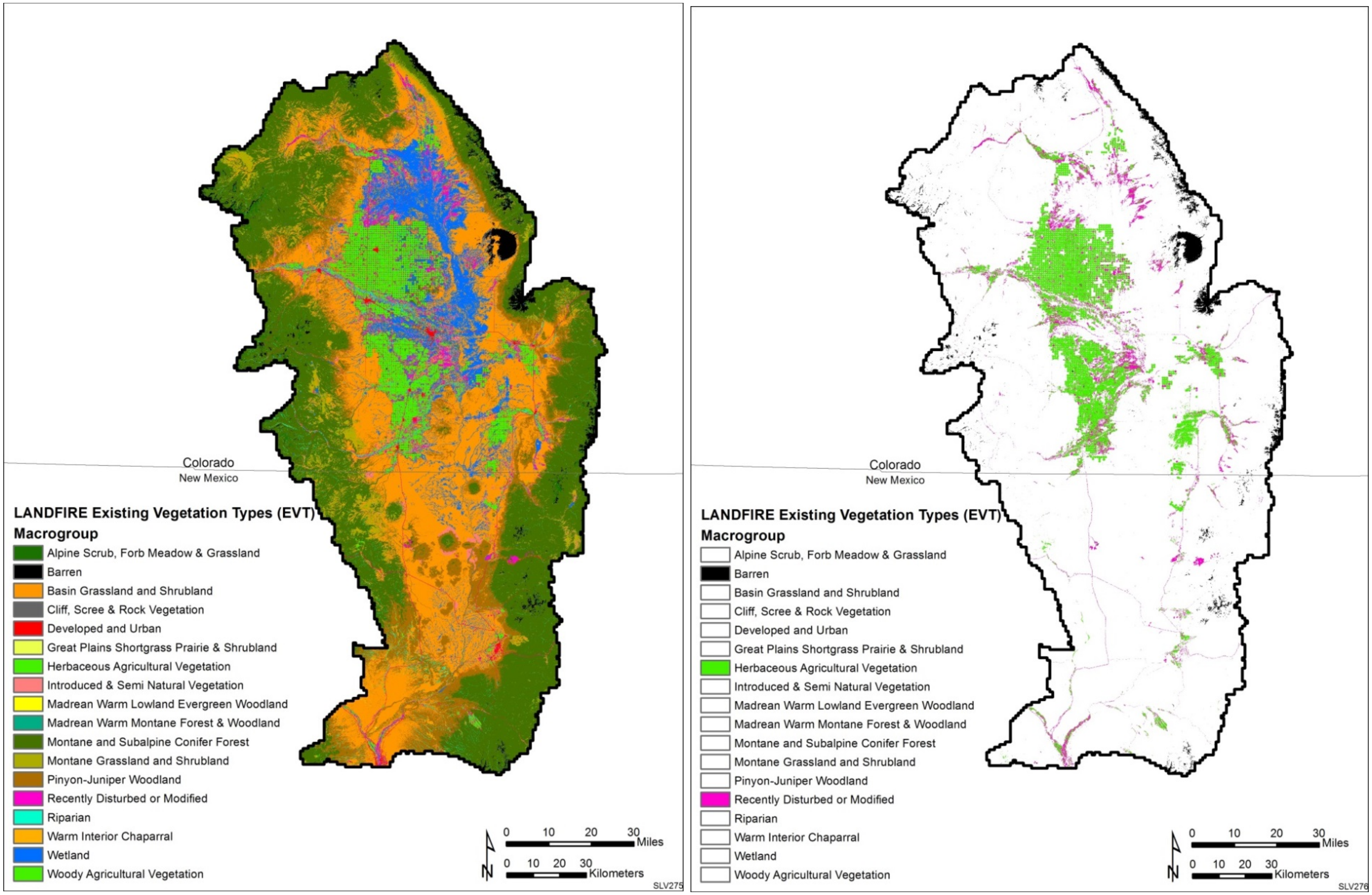


FIGURE 3-4 LANDFIRE Existing Vegetation Types (left panel) and Wind-Erodible Vegetation Types (right panel) in the Study Area (Source: LandFire 2015)

In most cases, once the wind blows the dust away, the surface would need to be redisturbed in order for further dust generation to occur, i.e., operational wind generated emissions would more than likely not continue to occur (at least at the same emissions rates) unless the entire area kept being disturbed. Wind-blown dust emissions would continue but the emission levels would decrease for undisturbed areas over time. However, due to lack of detailed soil property data over a wide area and lack of information on soil disturbance schedules for solar development, an unlimited dust reservoir was assumed, such that assumed dust emission rates would dependent only on the wind speed (not on time since disturbance). These assumptions err on the side of conservatism (that is, they over-estimate the dust emissions).

Erosion Factor Field Generation. The erosion factor field for a given grid cell in the SLV is generated based on WEG and existing vegetation type data as in the following.

Step 1: First, the WEG is transformed into a source function (S). Arbitrarily, source function S is assigned as one for WEG 1 (high emission potential) and as zero for WEG 8 (no emission potential), and then varies linearly for inbetween WEGs as follows:

$$S = 1 - \frac{\text{WEG}-1}{7}$$

where WEG = 1 to 8.

Through the comparison of concentrations between model predictions and observations, source function can be calibrated. For example, predicted concentrations are about twice observed concentrations, and then source function for WEG 1 can be reduced to 0.5 and for other WEG groups proportionally.

Step 2: Calculate area-weighted erosion factor (EROD_tot) for a given grid cell (1.9 mi × 1.9 mi [3 km × 3 km]):

$$\text{EROD\_tot} = \sum_{i=1}^{8} S_i \times (\text{erodible area fraction})$$

where: erodible fraction includes three vegetation types of “barren,” “herbaceous agricultural vegetation,” and “recently disturbed or modified” among 18 vegetation types.

Step 3: Distribute area-weighted erosion factor (EROD_tot) into each soil type:

EROD_sand = (EROD_tot) × (sand fraction)
EROD_silt = (EROD_tot) × (silt fraction)
EROD_clay = (EROD_tot) × (clay fraction)

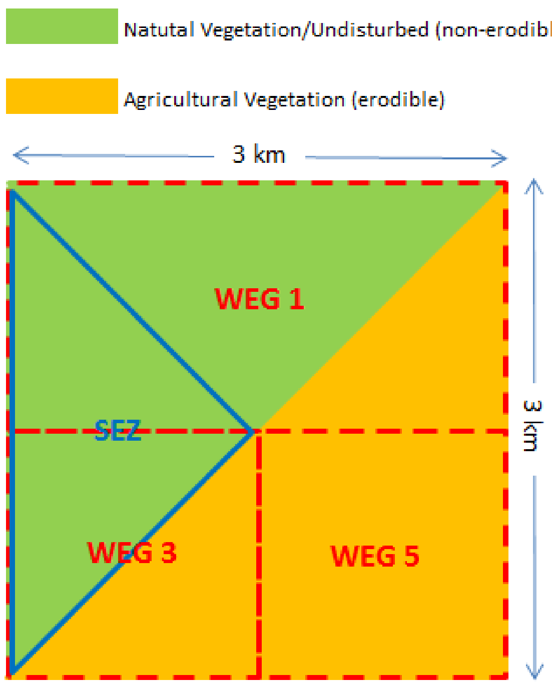
where: (sand fraction) + (silt fraction) + (clay fraction) = 1.

Finally, these three erosion factor fields are fed into the WRF-Chem model. Detailed calculation procedures are exemplified in Figure 3-5 for Base Case (pre-development) and Scenario 1 (100% SEZ vegetative cover removed) to be discussed in Section 4.2.1. For the Base Case, the SEZ (enclosed by thick blue lines) has natural vegetation, which is non-erodible, and thus source functions corresponding to the WEG values (enclosed by thick red dashed lines) are not counted. However, for Scenario 1, the SEZ will be developed, which is now erodible, and thus source functions corresponding to the WEG values are counted. Differences between the two scenarios are colored in red in tables in the right of Figure 3-5 (bottom panel).

Calculations for erosion factors over the SLV domain were made spatially using Geographic Information System (GIS) techniques. A uniform grid of 1.9 mi × 1.9 mi (3 km × 3 km) cells was created across the entire study domain. Those grid cells that intersected the study area were selected and extracted as the working grid cells to calculate the erosion factor. WEG values were combined to the grid cells using the Union tool for ArcGIS. Within each polygon, the source function (S) was calculated to normalize WEG values along a scale from 0 to 1 using the equation in the above Step 1. LANDFIRE Existing Vegetation Types were used to characterize erodible land cover types by selecting three land cover types (“barren,” “herbaceous agricultural vegetation,” and “recently disturbed or modified”) as erodible. All other land cover types were considered to be non-erodible. The area-weighted density of erodible land cover types within each grid cell was calculated as the erodible area fraction (EAF). The final erosion factor for each grid cell was calculated by multiplying S and EAF.

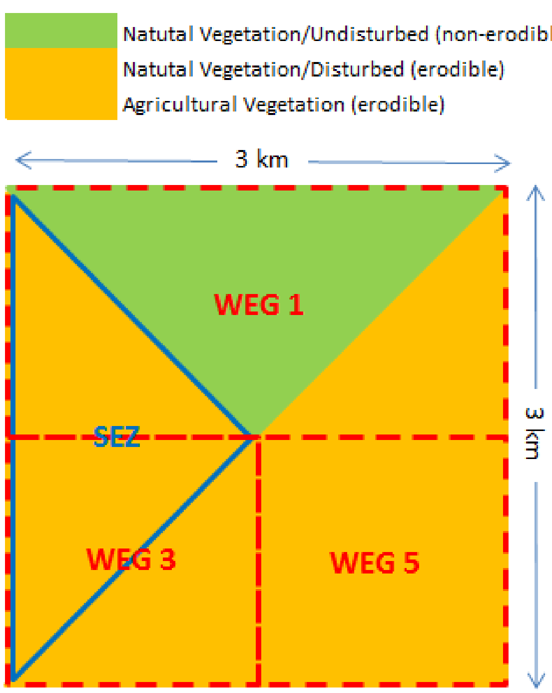
Figure 3-6 shows modeled erosion factor (EROD_tot) distributions within the SLV-Taos Plateau study area. As expected (see the right panel in Figure 3-4), erosion factors on the Colorado side are relatively high, where most erodible vegetation types are located. However, erosion factors on the New Mexico side are mostly near zero. There are no differences in erosion factors between Base Case and Scenario 1 except at the three SEZs, which can be compared in the insets.

Comparison with Other Methods. Another approach for estimating PM concentrations is to derive parametrically fitted equations between vertical PM soil erosion flux and wind speed based on a field study, as was done for the BLM’s Las Vegas Valley Air Quality Modeling Assessment related to federal land disposition actions (Lazaro et al. 2004). In this project, portable wind tunnel field measurements were conducted to quantify the potential for generation of wind-blown dust over a wide variety of soil types and soil conditions, e.g., by WEG group, by stable versus unstable, and by disturbed versus undisturbed. Equations thus derived were coded into the model, which quantified dust generation using the simulated meteorological parameters. However, this approach is effort- and resource-intensive. The approach of using WEG group and land use/vegetation type data used in this study, while not as accurate, likely provides a reasonable estimate of percent increase in PM for the development scenarios, which can be used as a good indicator of impacts during solar facility operations.



WEG	Source Function (S)	Erodible Area Fraction (EAF)	(S) × (EAF)
1	1.00	0.125	0.125
3	0.71	0.125	0.089
5	0.43	0.250	0.107
Area-Weighted Erosion Factor (EROD_tot)			**0.321**

Soil Type	Fraction (assumed)	EROD to WRF-Chem
Sand	0.55	**0.177**
Silt	0.25	**0.080**
Clay	0.20	**0.064**



WEG	Source Function (S)	Erodible Area Fraction (EAF)	(S) × (EAF)
1	1.00	0.250	0.250
3	0.71	0.250	0.179
5	0.43	0.250	0.107
Area-Weighted Erosion Factor (EROD_tot)			**0.536**

Soil Type	Fraction (assumed)	EROD to WRF-Chem
Sand	0.55	**0.295**
Silt	0.25	**0.134**
Clay	0.20	**0.107**

FIGURE 3-5 Examples of Estimation of Erosion Factor (EROD): Base Case - Pre-Development (top panel); and Scenario 1 - 100% Solar Energy Zone Vegetative Cover Removed (bottom panel)

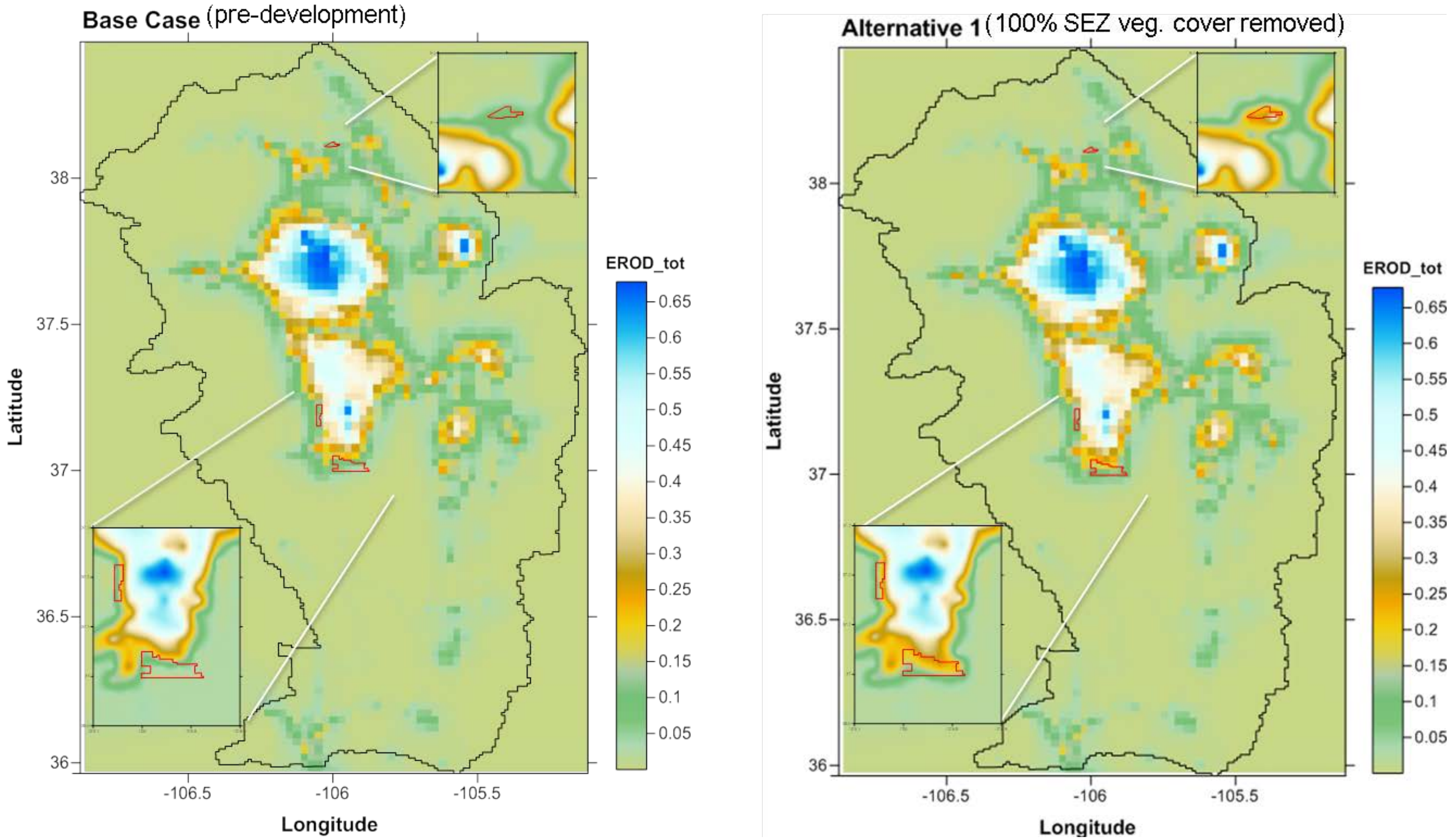


FIGURE 3-6 Erosion Factor Fields in the San Luis Valley-Taos Plateau Study Area along with Three Solar Energy Zones (inset): Base Case – Pre-Development (left panel); and Scenario 1 – 100% Solar Energy Zone Vegetative Cover Removed (right panel)

3.2.1.4 Prediction of PM_{10} and $PM_{2.5}$ Values

As the "Only dust aerosols" option in WRF-Chem modeling does not diagnose PM_{10} and $PM_{2.5}$ concentrations, this was calculated external to the model using the following method. In WRF-Chem dust modeling, five particle size bins were used:

- DUST_1: particles with radius of 0.1 – 1 μm with an effective radius of 0.5 μm,
- DUST_2: particles with radius of 1 – 1.8 μm with an effective radius of 1.4 μm,
- DUST_3: particles with radius of 1.8 – 3 μm with an effective radius of 2.4 μm,
- DUST_4: particles with radius of 3 – 6 μm with an effective radius of 4.5 μm, and
- DUST_5: particles with radius of 6 – 10 μm with an effective radius of 8.0 μm.

The units of DUST_1 through DUST_5 are in μg/kg-dry air. To arrive at PM_{10} and $PM_{2.5}$ concentrations in $\mu g/m^3$, the following formulae were used (available in routine module_gocart_aerosols, subroutine sum_pm_gocart of the WRF-Chem model):

$$PM_{2.5} = \rho_{air} (DUST\_1 + DUST\_2 \times 0.286)$$

$$PM_{10} = \rho_{air} (DUST\_1 + DUST\_2 + DUST\_3 + DUST\_4 \times 0.87).$$

The ρ_{air} in kg/m^3 was calculated using the ideal-gas law with ambient temperature and barometric pressure at the surface level of each grid cell. Due to higher elevations of the SLV (mostly over 7,000 ft), air density is about 75% or lower of that at the sea level. In the WRF-Chem modeling, this process predicted that the ratio of $PM_{2.5}$ to PM_{10} ranged from 0.17 to 0.20, with an average of 0.18.

3.2.2 Modeling Calibration

This section discusses the assessment of air quality impacts for the base case (or baseline) conditions and future scenarios associated with the development of three SEZs in the SLV. First, the model performance was evaluated for the base case and the source function related to erosion factor (see Section 3.2.1.3) was calibrated as necessary. Then, with the calibration, potential dust impacts in the SLV associated with future development of the three SEZs were examined for the future scenarios assuming varied levels of solar development and meteorological conditions similar to previous dust storm episodes. The meteorological conditions from two historic wind-blown dust episodes were selected to support the modeling: April 1-7 in 2011 and April 5-May 1 in 2013.[29] The rationale for selecting these episodes was to provide upper-end but realistic modeling of potential impacts: these episodes represent the highest particulate concentrations for April wind-blown dust episodes over the years for which monitoring data are available. Measurement data are available at several air monitoring sites in the valley to show that wind-blown dust episodes peak in April (see Figure 2-6). There are other dust episodes for which peak concentrations are higher than the selected episodes. However, these episodes either occurred in winter months when the soils are frozen or no agricultural activities exist, or represented sampling data for which observations were made at only one or two sites, or were micro-local episodes, i.e., extremely high concentrations recorded at one Alamosa monitoring site but low concentrations recorded at the other Alamosa site, although the sites are located less than a mile apart.

For the April 2011 episode selected for study, 24-hour PM_{10} concentrations at the Alamosa municipal building monitoring site peaked at 372 $\mu g/m^3$ on April 3, 2011. For the April-May 2013 episode, 24-hour PM_{10} concentrations at the Alamosa municipal building monitoring site peaked at 162, 237, 184, and 246 $\mu g/m^3$ on April 8, 16, 23, and May 1, 2013, respectively (see Table 2-4).

Ideally, to validate the model performance and then simulate future conditions, model predictions should be evaluated with continuous measurements from a dense network of air sampling stations that fully resolve spatial and temporal patterns of the dust plume. In practice this level of data is rarely available except around metropolitan areas. For this study, PM measurements are relatively scarce within the valley, and only a limited number of measurements on a 24-hour basis (not 1-hour basis) were available for each of the episodes evaluated. As a result, comparison of modeling results could only be performed with limited observational data and this adds some uncertainty to the modeling results in this study.

The two key parameters affecting wind-blown dust emissions are soil characteristics and surface wind speed (or friction velocity) that exceeds the threshold wind speed required for saltation[30] to occur. As seen in Section 3.2.1.3, dust flux is roughly proportional to the cube of wind speed. Figure 3-7 shows modeled 1-hr PM_{10} concentrations and 10-m wind speed at Alamosa for the period of April 1-7, 2011, which demonstrates that PM concentrations are closely related to surface wind speed.

Figure 3-8 shows the comparison of modeled and observed 10-m wind speed at the three airports in the SLV-Taos Plateau study area for the period of April 1-7, 2011 (the dust storm occurred on April 3). Predicted wind speeds are lower at Saguache Airport because the airport is located in a narrow valley surrounded by significant terrain elevations. These steep terrain

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[29] For model performance evaluation and calibration purposes, two dust episodes were evaluated. However, the April 2011 episode was used to provide the detailed assessment of potential dust impacts associated with future development of three SEZs, because it was more representative for wind-blown dust with sources in the SLV.

[30] Saltation, the bouncing and leaping action of eroding soil particles near the ground surface, accounts for most of the soil movement by wind. The impact of bouncing particles ejects finer particles into the air, which remain suspended and are carried away by the wind (suspension), while coarser particles are set into a rolling and sliding motion along the ground surface (creep).

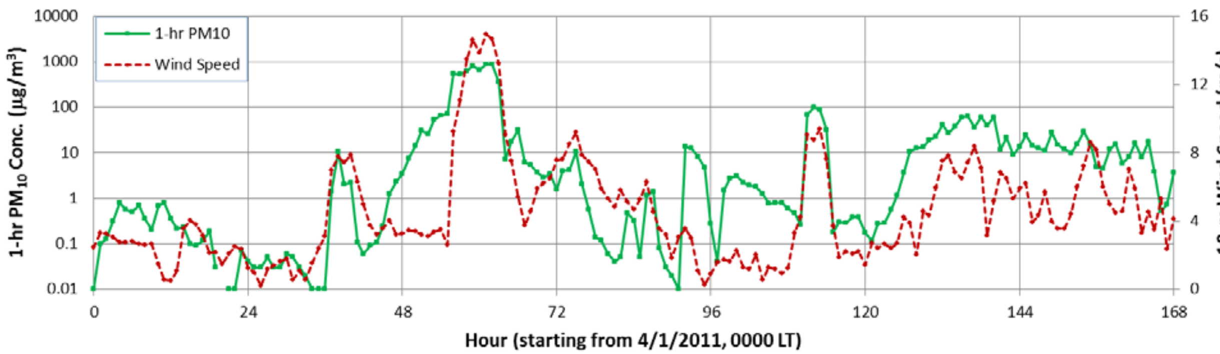

FIGURE 3-7 Modeled 1-Hour PM_{10} Concentrations at Alamosa Air Monitoring Site and Modeled 10-m Wind Speed at San Luis Valley Regional Airport in Alamosa, April 1-7, 2011

changes are not well represented in the modeled grid size of 1.9 mi × 1.9 mi (3 km × 3 km). However, the model predicts wind speeds that are consistent with observations at the Taos Airport. Modeled results generally agree with observations at Alamosa Airport but tend to be lower at very higher wind speeds. For example, the observed wind speed was 51 mph (23 m/s) but the predicted wind speed was 34 mph (15 m/s) around noon on April 3, 2011, which corresponds to a difference in PM_{10} concentrations of about 30-40 µg/m^3 for the 24-hour average value. Figure 3-9 displays modeled versus observed 10-m wind speed at the three airports for the period of April 12-18, 2013 (for this case the dust storm occurred on April 16). As for the April 2011 episode, the model generally captures wind patterns and individual values but with a bias towards lower wind speeds. Given the complex domain, the model prediction are well within the acceptable range when compared to observations in terms of general patterns and values.

Comparison of model predictions for 24-hour PM with air monitoring data was made for the April 2011 and April/May 2013 dust storm episodes. For the April 2011 episode, model runs were made that corresponded to the meteorological conditions for the April 1-7 period. For the April/May 2013 episode, model runs corresponded to the meteorological conditions for the April 5-May 1 period. Air monitoring sites within the valley include two Alamosa locations and Taos along with Great Sand Dunes National Monument and Wheeler Peak Wilderness Area, which are Federal Class I areas (see Section 2.6). Observation data for 24-hour PM_{10} are available at all five sites; for 24-hour $PM_{2.5}$ observation data are available only at the Federal Class I areas.

Calibration based on the April 2011 Meteorological Conditions. Figure 3-10 presents observed and modeled 24-hour PM_{10} and/or $PM_{2.5}$ at five monitoring sites for the period of April 1-7, 2011, for which 24-hour PM_{10} concentrations of 295 and 372 µg/m^3 were observed at two Alamosa monitoring sites on April 3 (see Table 2-4). For 24-hour PM_{10}, the WRF-Chem model calculated values are 16-37% and about 60% lower than observed values for Alamosa and Taos, respectively, but higher than observed values for the two Federal Class I areas. The lower modeled values for the Alamosa and Taos locations could be a result of the lower predicted wind

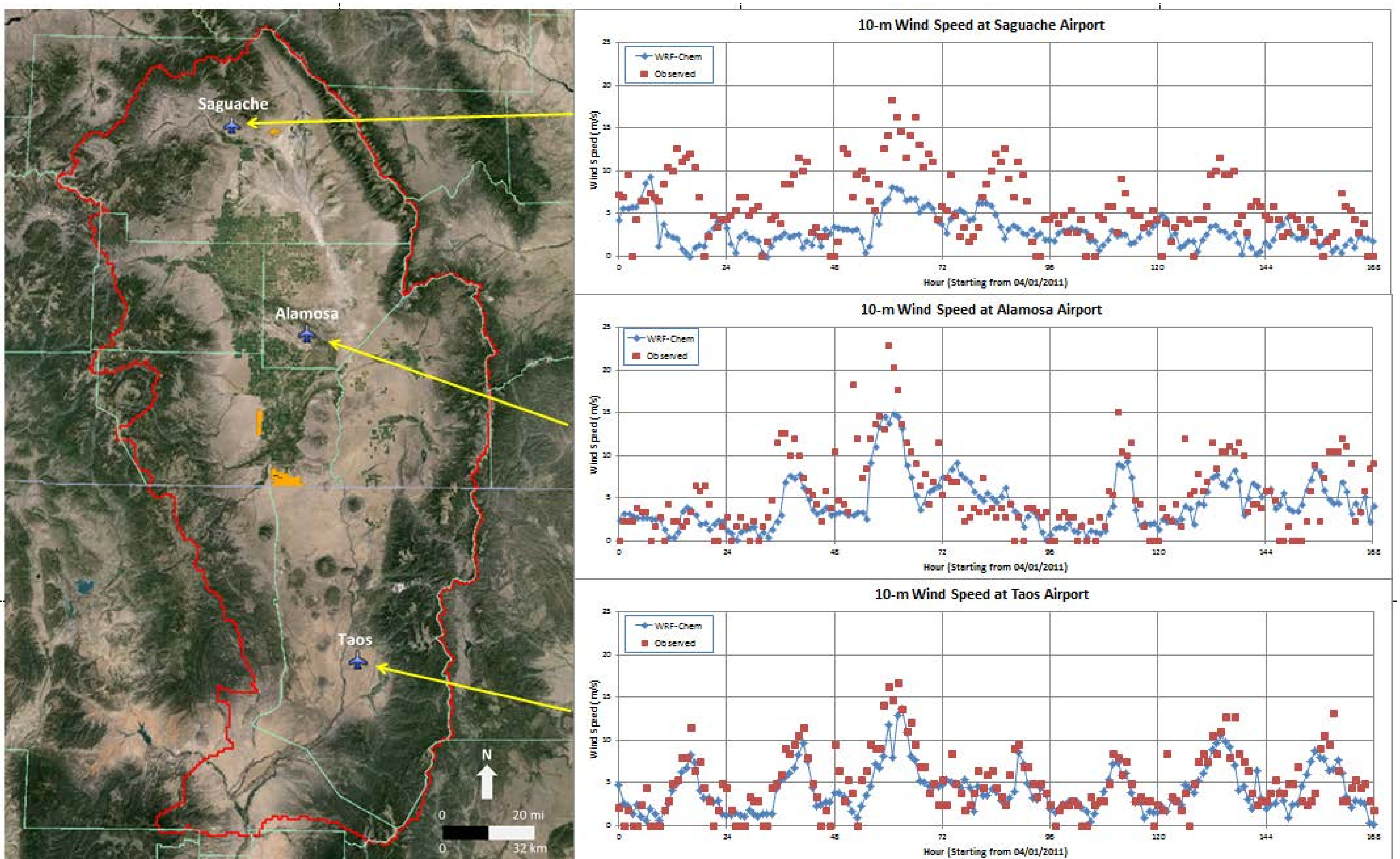

FIGURE 3-8 Comparison of Wind Speeds between WRF-Chem Predictions and Observed Values at Three Airports within the San Luis Valley–Taos Plateau Study Area, April 1-7, 2011

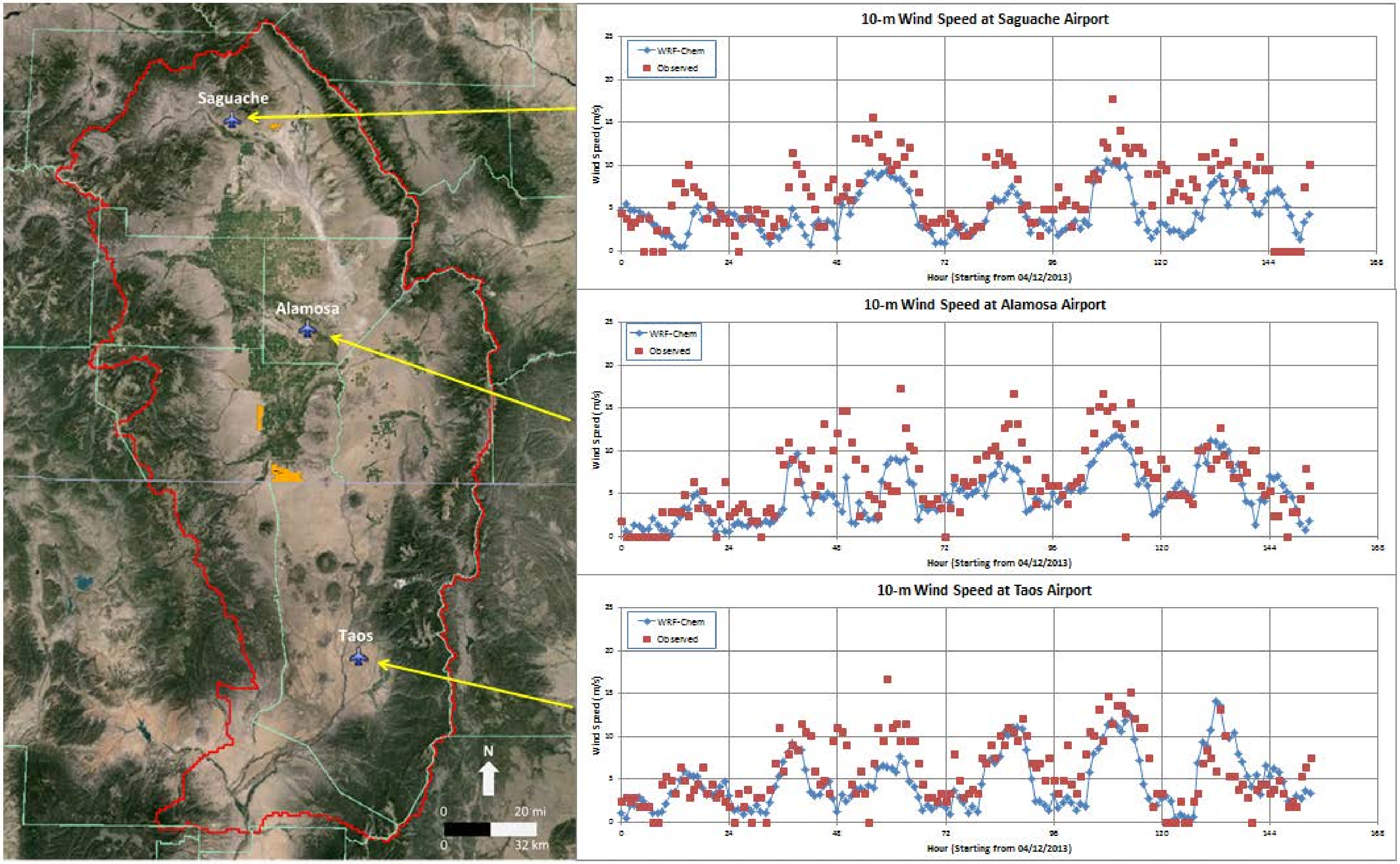

FIGURE 3-9 Comparison of Wind Speeds between WRF-Chem Predictions and Observed Values at Three Airports within the San Luis Valley–Taos Plateau Study Area, April 12-18, 2013

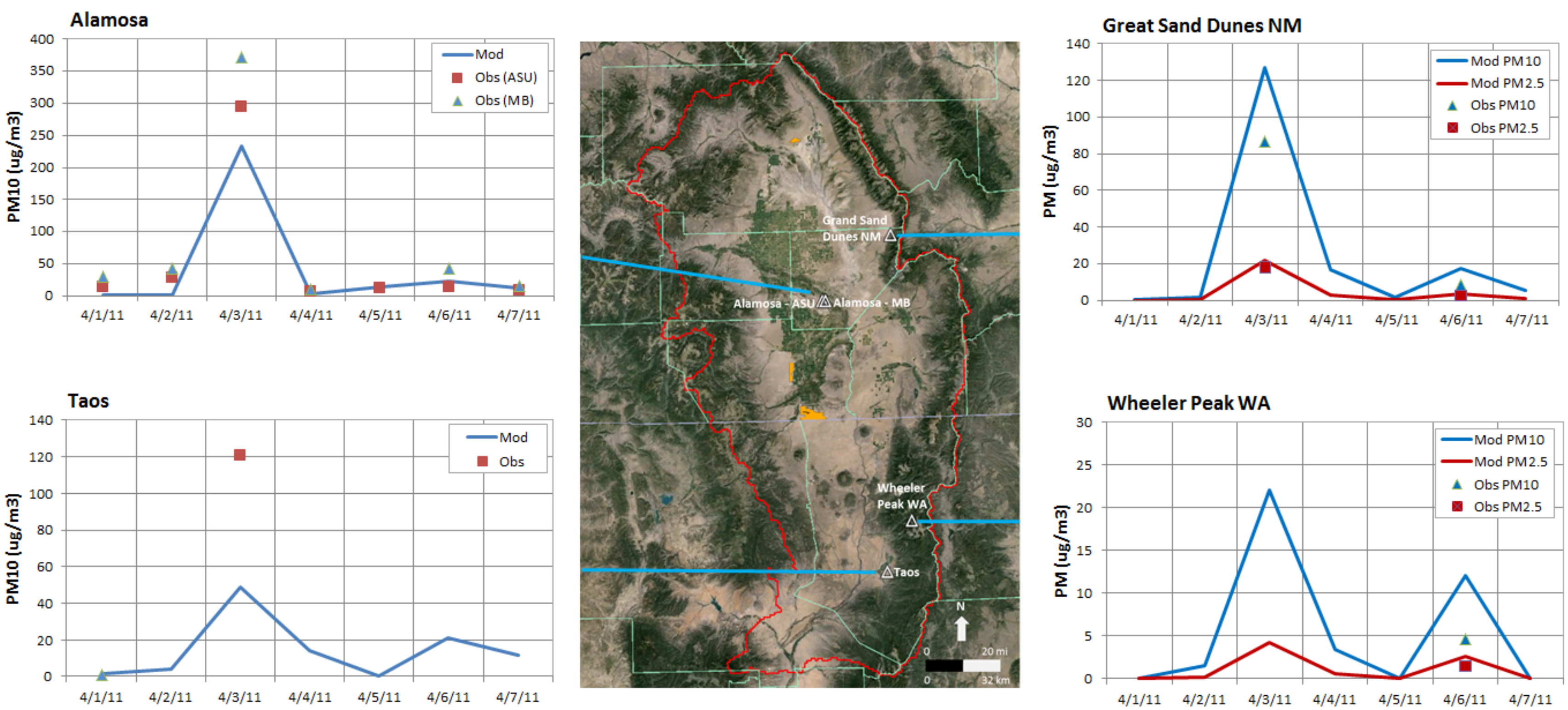

FIGURE 3-10 Comparison of Modeled and Observed 24-Hour PM_{10} at Alamosa and Taos and PM_{10}/$PM_{2.5}$ at Great Sand Dunes National Monument and Wheeler Peak Wilderness Area within the San Luis Valley-Taos Plateau, for Meteorological Conditions Occurring April 1-7, 2011

speeds at the monitoring locations and/or WEG/land use conditions of upwind areas being incorrectly reflected in the data. These upwind areas are classified as non-erodible in the model; however, these areas are may be disturbed from human activities such as agriculture, construction, or off-road vehicle use in small local areas that are not accounted for in the model. Predicted 24-hour $PM_{2.5}$ at the two Federal Class I areas are somewhat higher than but in good agreement with observed data, although the observed data are limited.

As mentioned previously, wind speed plays an important role in dust generation. To examine the relationship between 10-m wind speed and 1-hour PM_{10} concentrations, modeled data at Alamosa were plotted in Figure 3-11, which shows that until wind speed reaches up to 13 mph (6 m/s), 1-hour PM_{10} concentrations remain at a low level. However, 1-hour PM_{10} concentrations increase by about 120 $\mu g/m^3$ per 1 m/s wind speed increase after the threshold wind velocity of 6 m/s is reached, as shown by the slope of the regression line using 1-hour PM_{10} concentration data over 100 $\mu g/m^3$. Considering this relationship, the modeled 24-hour PM_{10} concentrations shown in Figure 3-10 are expected to be within the range of observed data. As is discussed in Section 4.2.2, long-range transport of PM from upwind areas into the valley was relatively small for this episode, and thus this episode is appropriate for examining local effects associated with dust-generating activities in the valley.

Calibration based on the April/May 2013 Meteorological Conditions. Figure 3-12 shows the observed and modeled 24-hour PM_{10} and $PM_{2.5}$ for a time series beginning on April 5, 2013 and ending on May 1, 2013. For Alamosa, the WRF-Chem model reproduced the two peaks observed on April 16 and May 1, but did not reproduce the two other observed peaks on

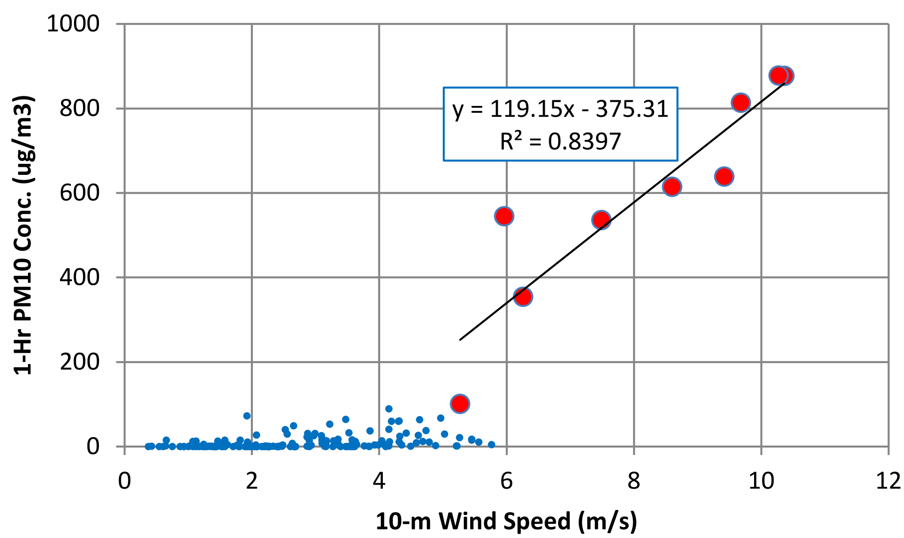

FIGURE 3-11 Modeled 10-m Wind Speed Versus Modeled 1-Hour PM_{10} Concentrations at the Air Monitoring Site in Alamosa, Colorado, April 1-7, 2011

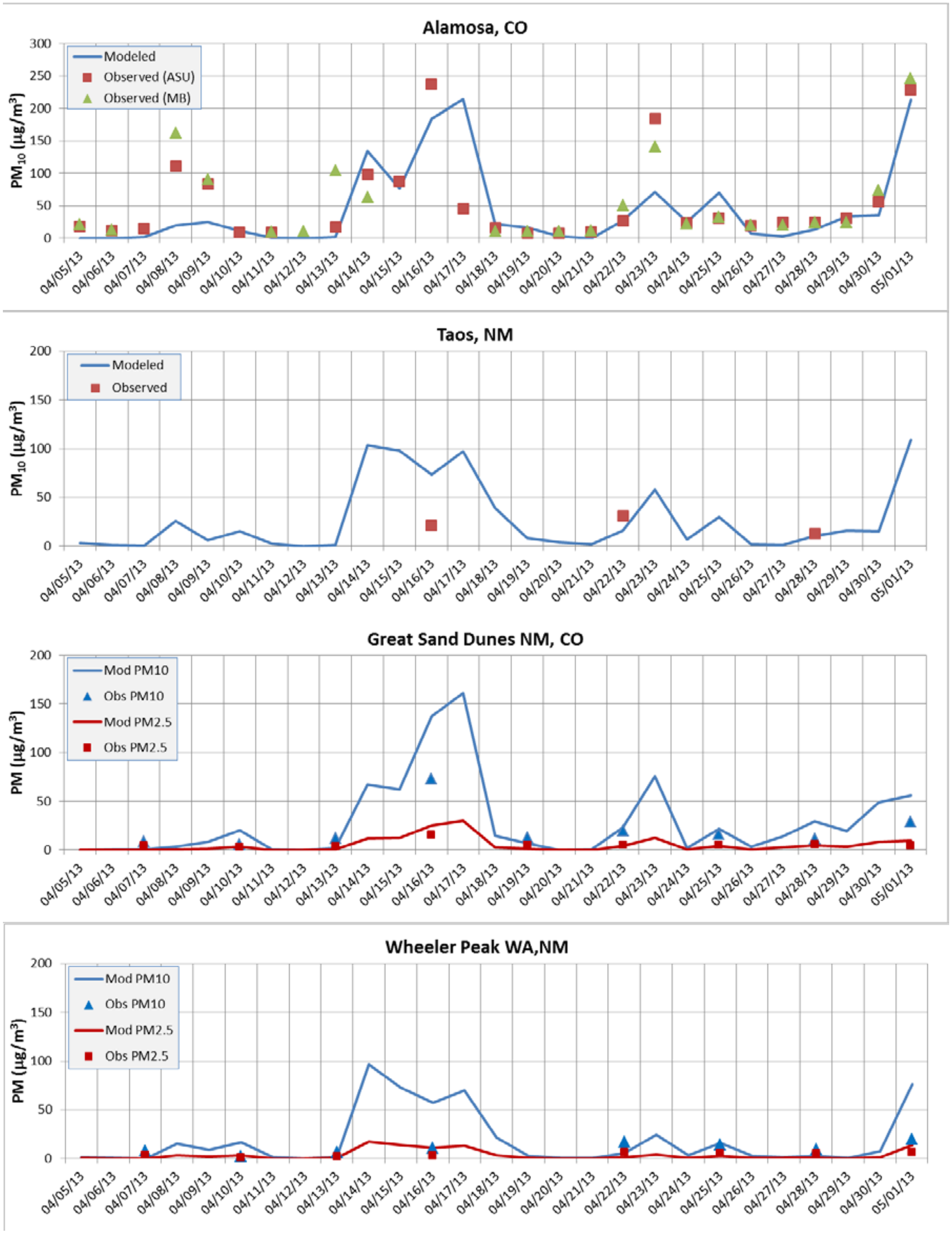

FIGURE 3-12 Comparison of Modeled and Observed 24-Hour PM_{10} at Alamosa and Taos and PM_{10}/$PM_{2.5}$ at Great Sand Dunes National Monument and Wheeler Peak Wilderness Area within the San Luis Valley-Taos Plateau, for Meteorological Conditions Occurring April 5-May 1, 2013

April 8 and April 23. Additionally, the model calculated a high value on April 17, which was not observed. For Taos and Wheeler Peak WA, where dust-generating activities are limited, the assumed long-range transport of dust in the model is primarily responsible for the model's overprediction. For Great Sand Dunes NM, the model captures the general patterns but has higher values than the observed concentrations. This indicates that these meteorological conditions were characterized by long-range transport of dust from upwind areas into the valley, combined with significant local emissions.

The wind-blown dust modeling method used for this study captures general patterns and predicted concentration levels that are in reasonable agreement with observations, considering that the study area is in complex terrain. Reasonable assumptions for dust generation potential were utilized (i.e., WEG and land use for the study area). Since the primary interest of this study is to evaluate the impacts of solar development in the SEZs, this methodology is reasonable for the estimation of expected percent change in the dust levels due to such development. Based on the above comparison of model predictions with observations for two dust storm episodes, potential wind-blown dust impact assessment was performed without adjustment of the model erosion factor field that was discussed in Section 3.2.1.3.

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4 RESULTS FOR THE SAN LUIS VALLEY-TAOS PLATEAU

4.1 CONSTRUCTION IMPACTS ANALYSIS

4.1.1 Modeling Results

4.1.1.1 Antonito Southeast SEZ

The modeling results for both PM_{10} and $PM_{2.5}$ concentration increments and total concentrations (modeled plus background concentrations) that would result from construction-related fugitive dust emissions are summarized in Table 4-1. The modeled maximum 24-hour PM_{10} concentration increment is estimated to be about 569 μg/m^3 at the site boundaries (Figure 4-1), a level which far exceeds the NAAQS level of 150 μg/m^3 (by a factor of almost 4). High PM_{10} concentrations would be limited to the immediate area surrounding the SEZ and would decrease quickly with distance, with concentrations estimated to be about 230 μg/m^{3}at the nearest residence which is about 0.5 mi (0.8 km) north of the SEZ; about 100 μg/m^{3}at the town of Antonito; about 70 μg/m^3 at the town of Conejos; about 60 μg/m^3 at the town of San Antonio; and about 30 μg/m^3 at the towns of Manassa and Romeo.

Total 24-hour $PM_{2.5}$ concentrations are estimated to be 56 μg/m^3 at the SEZ boundary, which is higher than the NAAQS level of 35 μg/m^3; modeled concentrations are more than twice background concentrations. The total annual average $PM_{2.5}$ concentration is estimated to be 14.6 μg/m^3, which is just below the NAAQS level of 15.0 μg/m^3.[31] At the nearest residence, predicted maximum 24-hour and annual $PM_{2.5}$ concentration increments would be about 15 and 1.8 μg/m^3, respectively.

In this analysis, potential impacts were presented based on one 3,000-acre project (which covers about 31% of the developable area of 9,712 acres), and modeled concentration increments at receptors are dependent on the elevation, the distance and direction from the solar development, and the shape of area sources. Albeit unlikely, construction of two or more projects of a similar size could occur simultaneously within the SEZ. If it is assumed that another 3,000-acre project would be simultaneously constructed in the southwest areas of the SEZ, the modeled 24-hour PM_{10} concentration increases by about 20% at the boundary receptor where the highest concentration of 569 μg/m^3 would occur in the case of one project. The modeled concentration would increase by about 40% at the border of the town of Antonito, and would increase by more than 100% at San Antonito, which is located about 1 mi west of the SEZ. Therefore, to minimize potential impacts, it is recommended that the number of concurrent construction projects and soil disturbances should be limited and/or additional mitigation measures should be implemented.

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31 At the time when the Solar PEIS was prepared, both primary and secondary standards for annual-average $PM_{2.5}$ were 15 μg/m^3. However, primary and secondary standards were revised to 12 and 15 μg/m^3, respectively, in 2012.

TABLE 4-1 Maximum Air Quality Impacts from Emissions Associated with Construction Activities for the Antonito Southeast SEZ

				Concentration (µg/m³)				Percentage of NAAQS[c]	
Pollutant[a]	Averaging Time	Rank[b]	Location	Maximum Increment[b]	Back-ground	Total	NAAQS	Increment	Total
PM_{10}	24 hours	H6H	SEZ boundary	569	27	596	150	***380***	***398***
			Nearest residence	230		257		***153***	***171***
			Antonito	100		127		67	85
			San Antonio	60		87		40	58
			Manassa/Romeo	30		57		20	38
$PM_{2.5}$	24 hours	H8H	SEZ Boundary	40	16	56	35	***114***	***160***
			Nearest residence	15		31		43	89
			Antonito	3.5		19.5		10	56
			San Antonio	3.5		19.5		10	56
	Annual	-[d]	SEZ Boundary	10.6	4	14.6	12/15[e]	88/70	***122***/97
			Nearest residence	1.8		5.8		15/12	48/39
			Antonito	0.4		4.4		3/3	37/29
			San Antonio	0.4		4.4		3/3	37/29

[a] $PM_{2.5}$ = particulate matter with an aerodynamic diameter of ≤2.5 µm; PM_{10} = particulate matter with an aerodynamic diameter of ≤10 µm.

[b] Concentrations for attainment demonstration are presented. H6H = highest of the sixth-highest concentrations at each receptor over the 5-year period. H8H = highest of the multiyear average of the eighth-highest concentrations at each receptor over the 5-year period. For the annual average, multiyear averages of annual means over the 5-year period are presented. Maximum concentrations are predicted to occur at the site boundaries.

[c] Values in reds indicate NAAQS exceedances.

[d] A dash indicates not applicable.

[e] A left-hand value denotes primary standard to protect public health, while a right-hand value denotes secondary standard to protect public welfare.

Source: Chick (2009) for background concentration data.

The predicted 24-hour increment at the nearest Class I Area – Wheeler Peak WA, New Mexico – would be about 9.1 µg/m³, or 114% of the PSD increment for Class I Areas (8 µg/m³). When distances, prevailing winds, and topography are considered, concentration increments at the Great Sand Dunes NM would be similar to those at the Wheeler Peak WA but would be much lower at any other nearby Class I areas.

The Pagosa Springs PM_{10} Maintenance Area is located more than 50 mi (80 km) west of the Antonito Southeast and Los Mogotes East SEZs. Pagosa Springs is located upwind of prevailing winds at the SEZs and pollutants from the SEZs would likely be blocked by the San Juan Moutains to the west, more than 3,000 ft (914 m) higher than the SEZs. AERMOD modeling indicated that construction emissions from the SEZs would contribute minimally to PM_{10} concentrations in the maintenance area and thus are not anticipated to affect its attainment status.

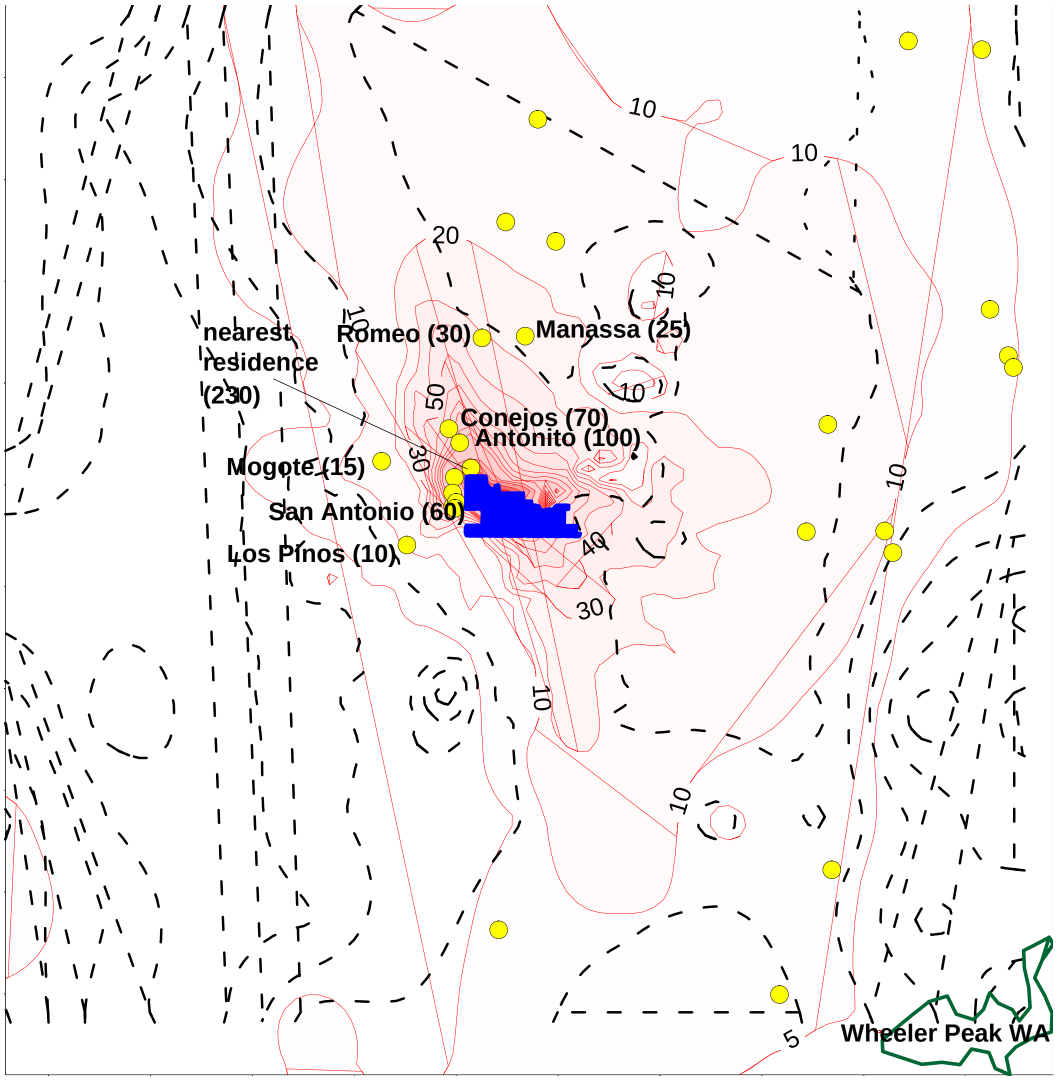

FIGURE 4-1 Predicted Maximum 24-Hour PM_{10} Concentrations Associated with Construction Activities for the Antonito Southeast SEZ, Colorado

4.1.1.2 De Tilla Gulch SEZ

The modeling results for both PM_{10} and $PM_{2.5}$ concentration increments and total concentrations (modeled plus background concentrations) that would result from construction-related fugitive dust emissions are summarized in Table 4-2. The modeled maximum 24-hour PM_{10} concentration increment would be about 430 µg/m^3 at the site boundaries (Figure 4-2), a level which far exceeds the NAAQS level of 150 µg/m^3 (by a factor of almost 3). High PM_{10} concentration increments would be limited to the immediate area surrounding the SEZ and would decrease quickly with distance, with concentrations estimated to be about 81.3 µg/m^{3}at one of the nearest residences which is about 0.45 mi (0.7 km) south of the SEZ; about 13.4 µg/m^{3}at the town of Saguache; about 10.7 µg/m^3 at the town of Moffat; and about 5.2 µg/m^3 at the town of Crestone.

TABLE 4-2 Maximum Air Quality Impacts from Emissions Associated with Construction Activities for the De Tilla Gulch SEZ

				Concentration (µg/m^3)				Percentage of NAAQS[c]	
Pollutant[a]	Averaging Time	Rank[b]	Location	Maximum Increment[b]	Back-ground	Total	NAAQS	Increment	Total
PM_{10}	24 hours	H3H	SEZ boundary	430	27	457	150	***287***	***305***
			Nearest residence	81.3		108		54	72
			Saguache	13.4		40.4		9	27
			Moffat	10.7		37.7		7	25
			Crestone	5.2		32.2		3	21
$PM_{2.5}$	24 hours	H8H	SEZ Boundary	26.3	16	42.3	35	75	***121***
			Nearest residence	3.8		19.8		46	57
			Saguache	0.1		16.1		0.3	46
			Moffat	0.3		16.3		0.9	47
	Annual	-[d]	SEZ Boundary	6.5	4	10.5	12/15[e]	54/43	88/70
			Nearest residence	0.5		4.5		4/3	38/30
			Saguache	0.02		4		0.1/0.1	33/27
			Moffat	0.02		4		0.1/0.1	33/27

[a] $PM_{2.5}$ = particulate matter with an aerodynamic diameter of ≤2.5 µm; PM_{10} = particulate matter with an aerodynamic diameter of ≤10 µm.

[b] Concentrations for attainment demonstration are presented. H3H = highest of the third-highest concentrations at each receptor over the 2-year period. H8H = highest of the multiyear average of the eighth-highest concentrations at each receptor over the 2-year period. For the annual average, multiyear averages of annual means over the 2-year period are presented. Maximum concentrations are predicted to occur at the site boundaries.

[c] Values in reds indicate NAAQS exceedances.

[d] A dash indicates not applicable.

[e] A left-hand value denotes primary standard to protect public health, while a right-hand value denotes secondary standard to protect public welfare.

Source: Chick (2009) for background concentration data.

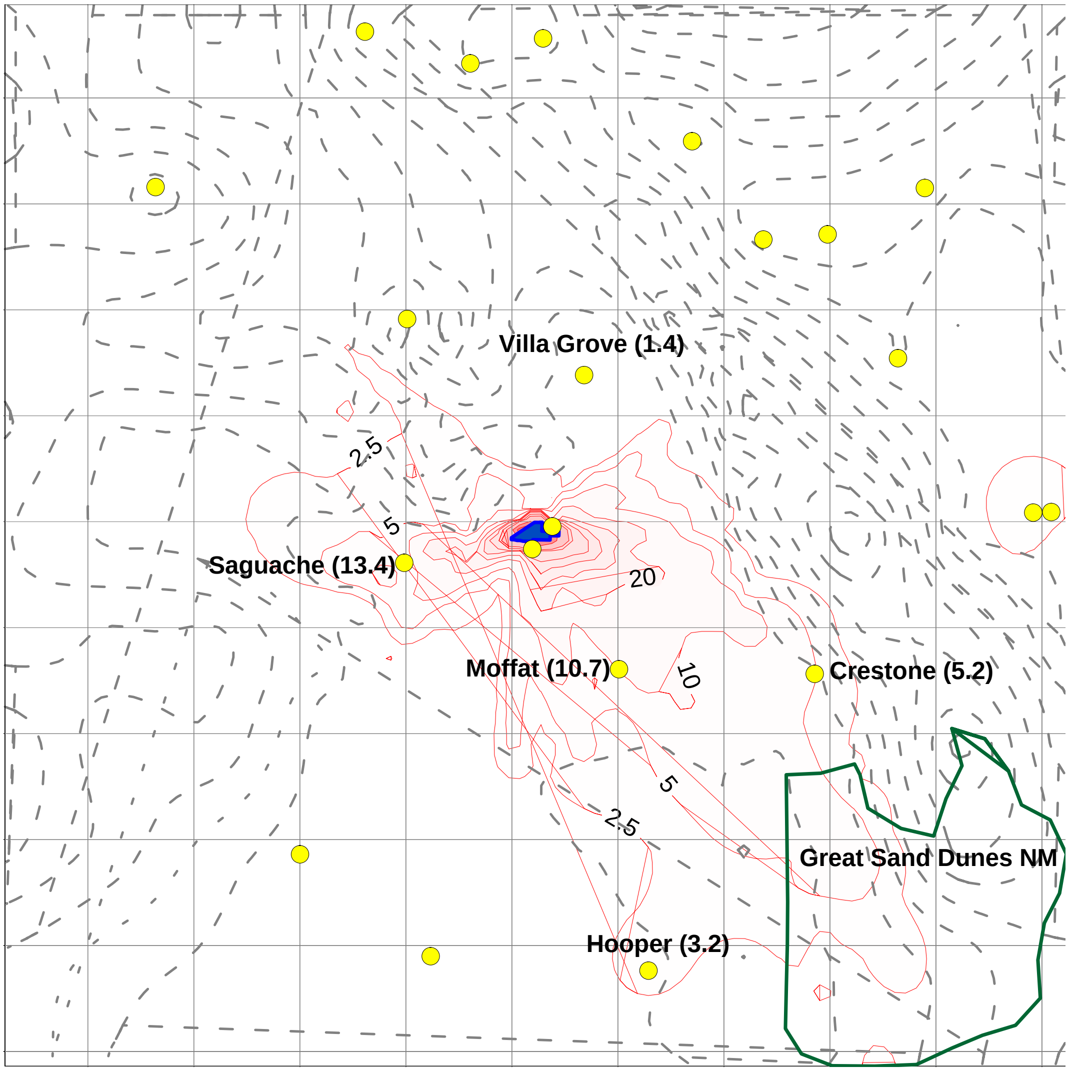

FIGURE 4-2 Predicted Maximum 24-Hour PM_{10} Concentrations Associated with Construction Activities for the De Tilla Gulch SEZ, Colorado

Total 24-hour $PM_{2.5}$ concentrations are estimated to be 42.3 µg/m^3 at the SEZ boundary, which is higher than the NAAQS level of 35 µg/m^3; modeled concentrations are more than 1.5 times background concentrations. The total annual average $PM_{2.5}$ concentration is estimated to be 10.5 µg/m^3, which is just below the NAAQS level of 15.0 µg/m^3. At one of the nearest residences, predicted maximum 24-hour and annual $PM_{2.5}$ concentration increments would be about 3.8 and 0.5 µg/m^3, respectively.

The predicted 24-hour increment at the nearest Class I Area – Great Sand Dunes NM, Colorado – would be about 9 µg/m^3, or 112% of the PSD increment (8 µg/m^3) for Class I Areas. When distances, prevailing winds, and topography are considered, concentration increments at other nearby Class I areas would be much lower than those at the Great Sand Dunes NM.

The Canon City PM_{10} Maintenance Area is about 45 mi (72 km) east-northeast of the De Tilla Gulch SEZ. Canon City is not located downwind of prevailing winds at the site and pollutants from the SEZ would likely be blocked by the Sangre de Cristo Mountain Range to the east, more than 3,000 ft (914 m) or more higher than the SEZ. AERMOD modeling indicated that construction emissions from the SEZ would contribute minimally to PM_{10} concentrations in the maintenance area and thus are not anticipated to affect its attainment status.

4.1.1.3 Los Mogotes East SEZ

The modeling results for both PM_{10} and $PM_{2.5}$ concentration increments and total concentrations (modeled plus background concentrations) that would result from construction-related fugitive dust emissions are summarized in Table 4-3. The modeled maximum 24-hour PM_{10} concentration increment is estimated to be about 374 µg/m^3 at the site boundaries (Figure 4-3), a level which far exceeds the NAAQS level of 150 µg/m^3 (by a factor of about 2). High PM_{10} concentrations would be limited to the immediate area surrounding the SEZ and would decrease quickly with distance, with concentrations estimated to be about 141 µg/m^{3}at one of the nearest residences which is about 0.6 mi (1 km) north of the SEZ's northeastern corner; about 30 µg/m^3 at the towns of Antonito, Conejos, and Romeo; about 20 µg/m^3 at the towns of La Jara and Manassa, respectively; and about 15 µg/m^3 at the towns of Estrella, Sanford, and San Antonio.

Total 24-hour $PM_{2.5}$ concentrations are estimated to be 42.0 µg/m^3 at the SEZ boundary, which is higher than the NAAQS level of 35 µg/m^3; modeled concentrations are more than 1.5 times background concentrations. The total annual average $PM_{2.5}$ concentration is estimated to be 10.3 µg/m^3, which is just below the NAAQS level of 15.0 µg/m^3. At the nearest residence, predicted maximum 24-hour and annual $PM_{2.5}$ concentration increments are about 6.8 and 0.7 µg/m^3, respectively.

The predicted 24-hour increment at the nearest Class I Area – Great Sand Dunes NM, Colorado– would be about 6.9 µg/m^3, or 87% of the PSD increment (8 µg/m^3) for Class I Areas. When distances, prevailing winds, and topography are considered, concentration increments at any other nearby Class I areas would be much lower than those at the Great Sand Dunes NM.

TABLE 4-3 Maximum Air Quality Impacts from Emissions Associated with Construction Activities for the Los Mogotes East SEZ

				Concentration ($\mu g/m^3$)				Percentage of NAAQS[c]	
Pollutant[a]	Averaging Time	Rank[b]	Location	Maximum Increment[b]	Back-ground	Total	NAAQS	Increment	Total
PM_{10}	24 hours	H6H	SEZ Boundary	374	27	401	150	***249***	***267***
			Nearest residence	141		168		94	***112***
			Conejos	33.3		60.3		22	40
			Romeo	31.1		58.1		21	39
			Antonito	29.1		56.1		19	37
			La Jara	20.6		47.6		13	32
			Sanford	14.7		41.7		10	28
$PM_{2.5}$	24 hours	H8H	SEZ Boundary	26.0	16	42.0	35	74	***120***
			Nearest residence	6.8		22.8		46	65
			Conejos	0.7		16.7		2	48
			Romeo	1.9		17.9		5	51
	Annual	-[d]	SEZ Boundary	6.3	4	10.3	12/15[e]	53/42	86/68
			Nearest residence	0.7		4.7		6/5	39/31
			Conejos	0.1		4.1		1/1	34/27
			Romeo	0.2		4.2		2/1	35/28

[a] $PM_{2.5}$ = particulate matter with an aerodynamic diameter of ≤2.5 μm; PM_{10} = particulate matter with an aerodynamic diameter of ≤10 μm.

[b] Concentrations for attainment demonstration are presented. H6H = highest of the sixth-highest concentrations at each receptor over the 5-year period. H8H = highest of the multiyear average of the eighth-highest concentrations at each receptor over the 5-year period. For the annual average, multiyear averages of annual means over the 5-year period are presented. Maximum concentrations are predicted to occur at the site boundaries.

[c] Values in reds indicate NAAQS exceedances.

[d] A dash indicates not applicable.

[e] A left-hand value denotes primary standard to protect public health, while a right-hand value denotes secondary standard to protect public welfare.

Source: Chick (2009) for background concentration data.

4.1.2 Cumulative Impacts

While solar energy generates minimal emissions compared with fossil fuels, the site preparation and construction activities associated with solar energy facilities would generate PM[32]. Dust generation from construction activities in the SEZs would be controlled by implementing dust control measures (such as increased watering frequency, using dust suppressing agents, and/or paving road surfaces). However, when particulate emissions from construction in the SEZs are combined with those from other projects in the region or when they

[32] Construction vehicles exhaust is also a source of some criteria pollutants; these emissions were evaluated in the Solar PEIS as causing only short-term impacts.

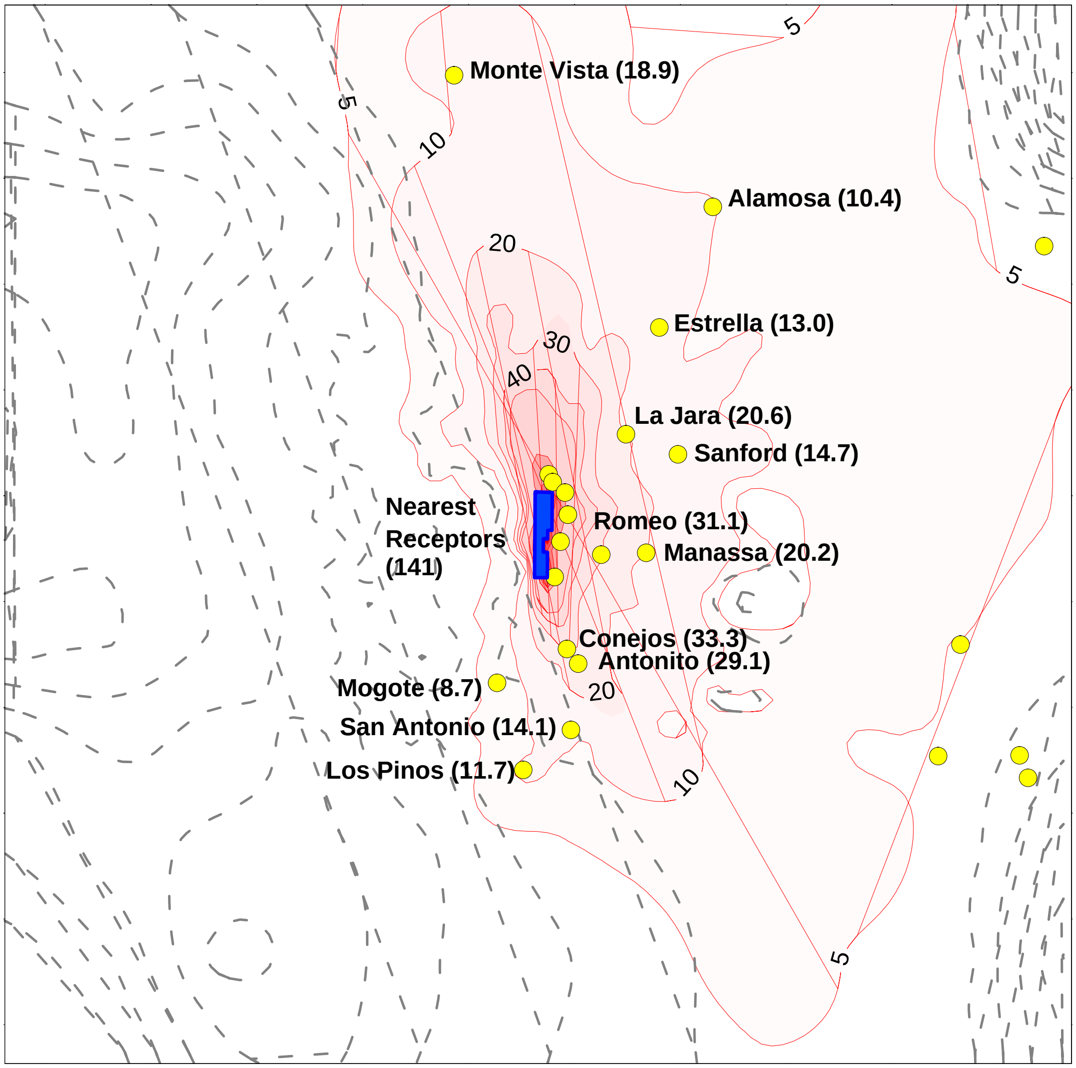

FIGURE 4-3 Predicted Maximum 24-Hour PM_{10} Concentrations Associated with Construction Activities for the Los Mogotes East SEZ, Colorado

are added to natural dust generation from winds and windstorms, the air quality in the general vicinity of a solar facility could be temporarily degraded. Also, since the Los Mogotes East and Antonito Southeast SEZs are within about 12 mi (19 km) of each other, construction of solar facilities at the two SEZs could have cumulative impacts. Because of the limited duration of construction activities and the likelihood that those activities would occur at different times, adverse cumulative air quality impacts are not expected from concurrent construction in the two SEZs. Also, if two solar facilities were being constructed at approximately the same time at the two SEZs, specific schedules could be managed to reduce air quality impacts. Cumulative impacts associated with dust generation from construction activities along with wind-blown dust could theoretically be best controlled by limiting SEZ disturbances of surface soils, especially by retention of existing shrubland-grassland vegetation to the greatest extent possible, but also retaining desert pavement or other stony surfaces. In addition to lessening of the potential for wind-blown dust, this can also preserve wildlife habitat to the greatest extent. Disadvantages of this option include obstacles during the construction phase, fire hazard, and difficulties in maintenance and concomitant incremental expenses (e.g., access to mirrors or conducting weed control activities).

Over the long term and across the region, the development of solar energy may have beneficial cumulative impacts on air quality by offsetting the need for energy production that results in higher levels of emissions, such as from coal, oil, and natural gas. During operations of solar energy facilities, only a few sources of air emissions exist, and their emissions would typically be relatively small (see Chapter 4.2). However, the amount of criteria and other air pollutant emissions that would be avoided if the solar facilities were to displace the energy that otherwise would have been generated from fossil fuels could be relative large. For example, if the Antonito Southeast SEZ were fully developed with solar facilities, the quantity of pollutants avoided could be as large as 5.7% of all emissions from the electric power systems in Colorado (BLM and DOE 2010).

4.2 OPERATIONS IMPACT ANALYSIS

4.2.1 Scenarios Analyzed

For dust impacts modeling, a base case condition (without SEZ development) and the following six scenarios were evaluated:

- Base Case (or Baseline) – pre-development (current);
- Scenario 1: Assumes 100% of SEZ vegetative cover is removed for all three SEZs;
- Scenario 2: Assumes 80% (corresponds to PEIS full build out) of vegetative cover is removed for all three SEZs;
- Scenario 3: Assumes 50% of vegetative cover is removed for all three SEZs;

- Scenario 4: Assumes 20% of vegetative cover is removed for all three SEZs;
- Scenario 5: Assumes 100% of SEZ vegetative cover is removed (as for Scenario 1), but dust suppressant is applied over 20% of SEZ area (assume suppressant decreases dust emissions by 50%); and
- Scenario 6: Assumes 100% of SEZ vegetative cover is removed (as for Scenario 1), but dust suppressant is applied over 80% of SEZ area (assume suppressant decreases dust emissions by 50%).

The base case (baseline or current pre-development conditions) serves as a benchmark to assess future impacts in the SLV. For this scenario, erodible lands in the valley, such as agricultural lands or disturbed lands, are assumed to be subject to wind erosion. Currently, the soils of the three SEZs have a natural vegetation and thus are assumed to be non-erodible.

For Scenario 1, it is assumed that 100% of vegetative cover is removed for all three SEZs. Note that, although the Solar PEIS assumed a maximum of 80% vegetative cover removal at full build out, for this study 100% was modeled as a worst-case. For Scenarios 2 through 4, 80%, 50%, and 20% of vegetative cover are assumed to be removed for all three SEZs.

For Scenarios 5 and 6, it is assumed that 100% of SEZ vegetative cover is removed (as was assumed for Scenario 1), and dust suppressant is applied over 20% and 80% of SEZ area, respectively. It is conservatively assumed that dust suppressant would decrease dust emissions by 50%, although a control efficiency of 80% or higher is common. Dust suppressants can have variable effectiveness and also can result in some adverse environmental impacts (Patton et al. 2014). A summary of the effectiveness and potential environmental impacts of various classes of dust suppressants is provided in Patton et al. (2014), including some specific dust suppression products that the BLM considers for use on BLM-administered lands.

4.2.2 Modeling Results For Development Scenarios

To examine how wind-blown dust storm episodes evolve, modeled 24-hour PM_{10} concentration contours are presented over the inner modeling domain for the meteorological conditions of April 2-4, 2011 as shown in Figure 4-4. Peak PM_{10} concentrations of 295 and 372 $\mu g/m^3$ at two Alamosa sites were observed on April 3. For April 2, 2011, the model calculated low dust generation and thus modeled 24-hour PM_{10} concentrations are relatively low over the domain. For April 3, a low-level dust plume originating from the lower left corner of the domain (i.e., Sonoran Desert) advances into the SLV, and simultaneously a higher concentration plume is generated on the Colorado side of the valley where agricultural activities prevail. For this episode, the contribution to high PM_{10} concentrations from outside of the valley is relatively small, between 30-60 $\mu g/m^3$ in Colorado and less than 30 $\mu g/m^3$ in New Mexico. Locally generated dust emissions are the major contributors to modeled higher concentrations in the lower part of the valley in Colorado, where 24-hour PM_{10} concentrations of more than 300 $\mu g/m^3$ are predicted. On April 4, the model predicted no wind-blown dust and PM_{10} levels declined to background levels over most of the domain. In this episode, PM_{10} contribution from outside

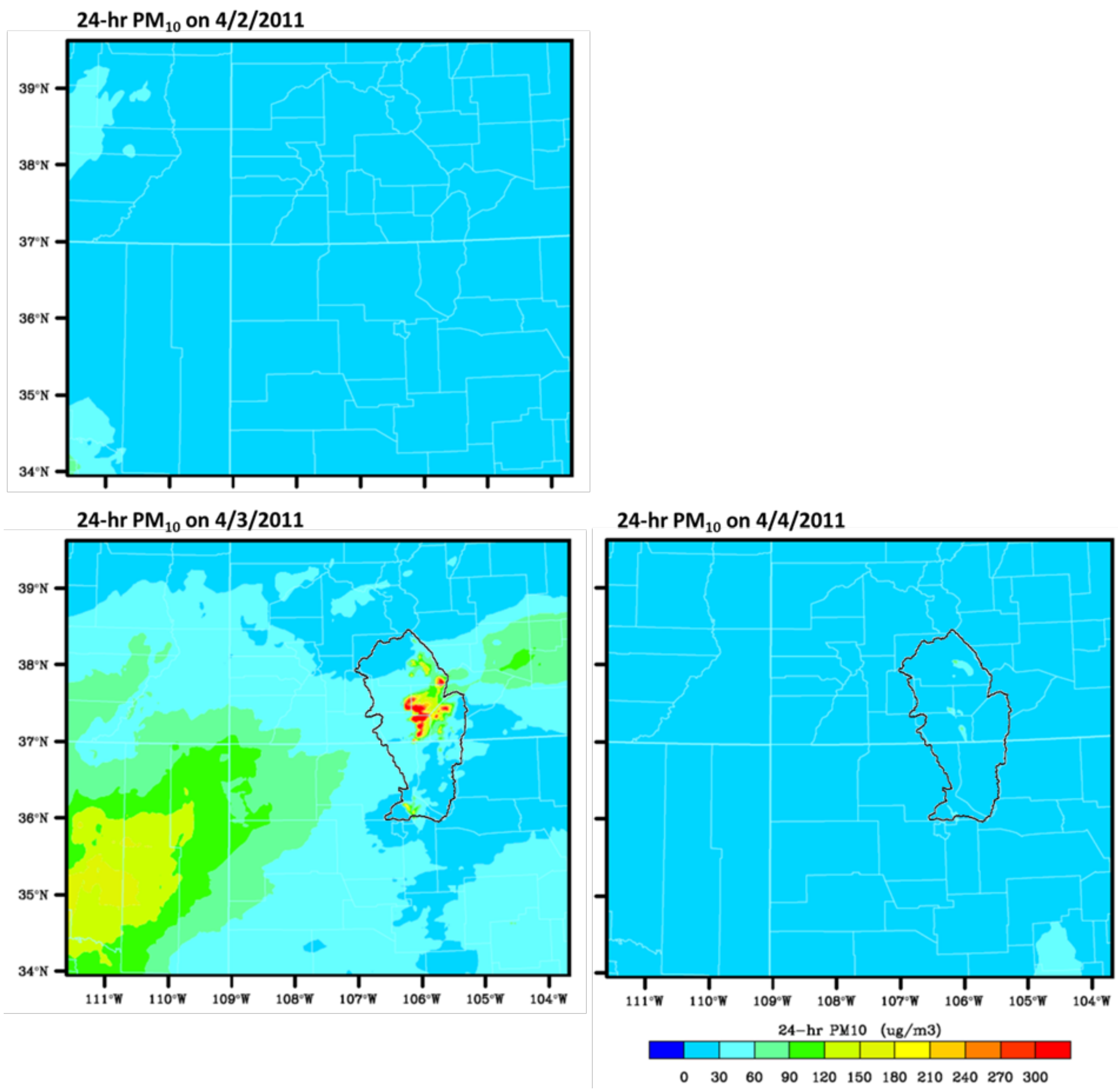

FIGURE 4-4 Temporal Evolution of Modeled 24-Hour PM_{10} Concentrations over the Inner Domain, April 2-4, 2011

sources into the valley is relatively small and thus this episode is ideal to investigate the behavior of dust plumes within the valley associated with future development of the SEZs.

Figure 4-5 shows the modeled temporal evolution of the episode over a 4-hour period on April 3, 2011, starting at midnight, i.e., 00:00 local time (LT). The shows 1-hour PM_{10} concentrations at six different hours of the day and the corresponding wind fields for those hours.

In general, strong wind fields (over 10 m/s) were computed by the model during the daytime hours. At 00:00 LT, large dust plumes originate at the western boundary of the modeling domain (Sonoran, Mohave, and Great Basin Deserts). These plumes move in the northeast direction and bring PM_{10} of up to about 300 $\mu g/m^3$ into the valley until noon. However, as the wind direction change from west to northwest, contribution of these plumes into the valley are weakened. Within the valley, the model calculated that dust generation started at 4 a.m. LT and peaked around noon when westerly winds became stronger. Later, dust generation gradually reduced and disappeared by early evening of that day. Within the Taos Plateau in New Mexico, dust generation was minimal even at higher wind speeds due to limited erodible areas, and PM levels were mostly influenced by dust transport from the outside.

The modeled 24-hour PM_{10} results around the SEZs (using April 3, 2011 meteorological conditions as representative for a dust generation episode) are displayed in Figure 4-6, along with concentration changes between the base case scenario and Scenario 1.[33] For the base case, it is assumed that the SEZs have natural vegetation, which is assigned as non-erodible and thus the SEZs are not a source of wind-blown dust generation, and 24-hour PM_{10} concentrations are higher on agricultural lands and their immediate downwind areas (left panels of Figure 4-6). Westerly winds prevailed during daytime hours when dust generation is most active around the Antonito Southeast and Los Mogotes East SEZs (top left panel). Around the De Tilla Gulch SEZ, winds predominantly would blow from the northwest (bottom left panel), because prevailing westerly winds aloft are steered by the valley near Saguache which runs in the northwest-southeast direction.

Under the 100% development scenario (Scenario 1), higher concentration contours are shown immediately downwind of the SEZs (center panels). The difference between 24-hour PM_{10} concentrations for the base case and Scenario 1 are displayed in the right panels of Figure 4-6. At the boundaries of Antonito Southeast and Los Mogotes SEZs, PM_{10} concentrations are predicted to increase by about 260 and 50 $\mu g/m^3$, respectively, with 100% development, but concentrations would tend to decrease rapidly with distance. The Antonito Southeast SEZ contains soils with higher (less erodible) WEG groups (see Figure 3-3) and most of the towns near the Antonito Southeast SEZ (denoted by green dots) are located upwind of the SEZ, and thus would be minimally affected by large-scale soil disturbance at the SEZ. Conversely, several towns are located downwind of the Los Mogotes East SEZ. However, in general increases in PM_{10} concentrations due to wind-blown dust from development of the

[33] The study was based on modeling a hypothetical future event assuming weather conditions identical to those that occurred on April 3, 2011. To assess the impact of land use/land cover changes, the same meteorological conditions were used with the added land disturbance.

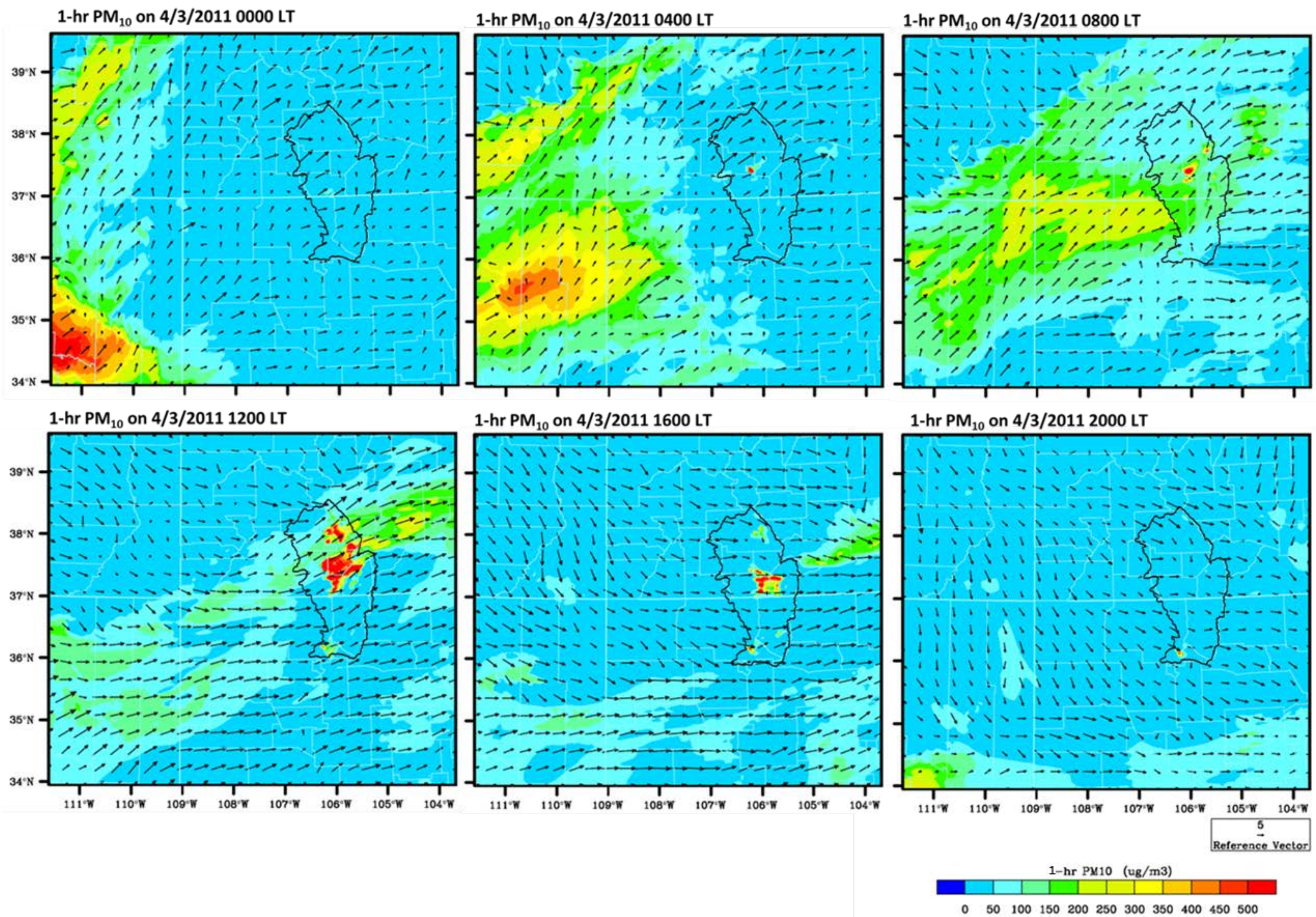

FIGURE 4-5 Temporal Evolution of Modeled 1-Hour PM_{10} Concentrations and Wind Patterns over the Inner Domain at 4-Hour Interval, for Meteorological Conditions Occurring April 3, 2011

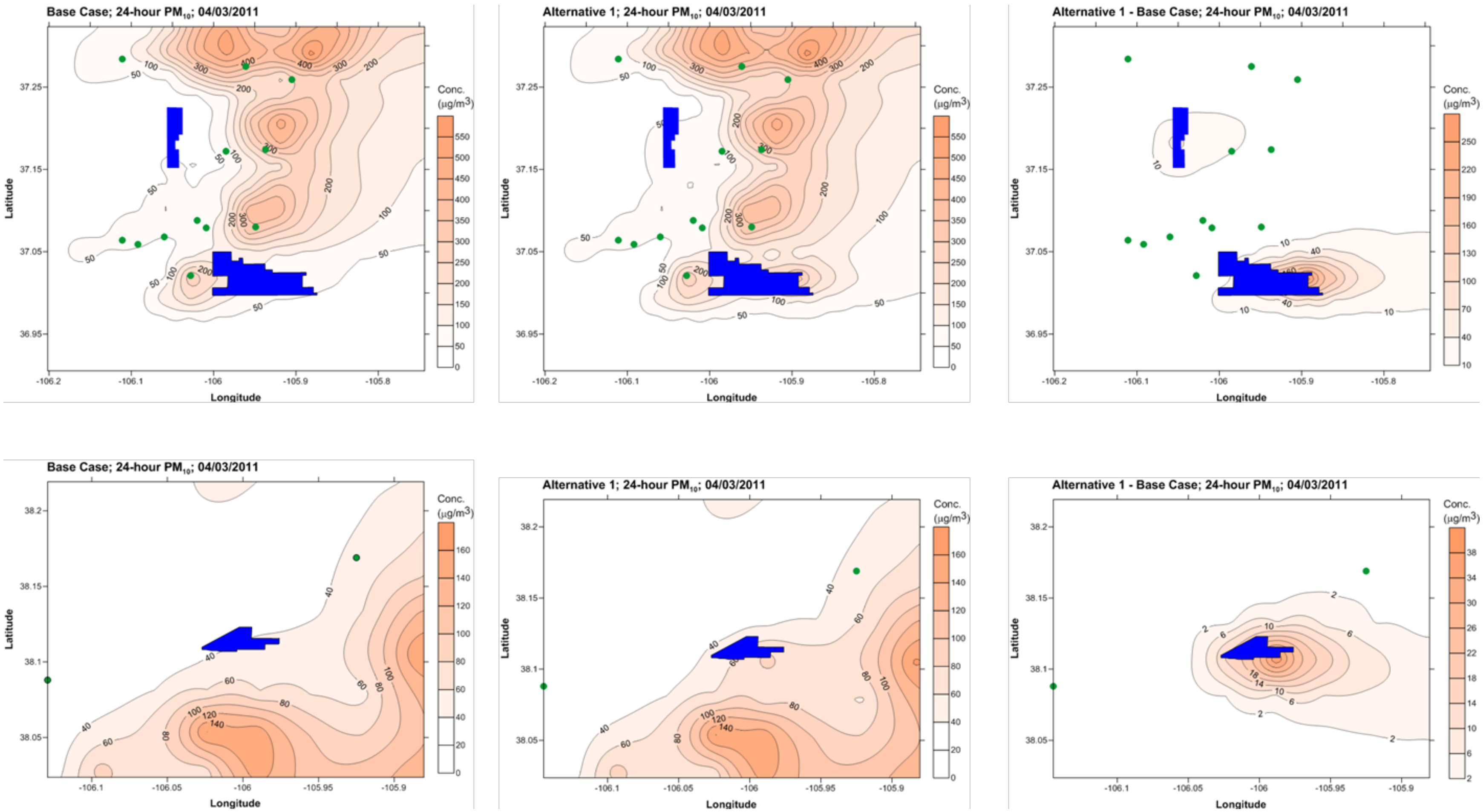

FIGURE 4-6 Modeled 24-Hour PM_{10} Concentrations for the Base Case and Scenario 1, and Difference of Scenario 1 from Base Case around the Antonito Southeast and Lost Mogotes East SEZs (upper panels), and De Tilla Gulch SEZ (lower panels). Note – Uses meteorological conditions of April 3, 2011 as representative for a dust generation episode

Los Mogotes SEZ would be minimal because the SEZ also contains soils with higher (less erodible) WEG groups, and only a narrow region of the SEZ is exposed to the prevailing wind direction. However, PM_{10} concentrations at Romeo, which is located about 3 mi (5 km) east of the Los Mogotes East SEZ, would increase considerably in comparison with increases at other towns near SEZs (i.e., concentrations are predicted to increase by up to 20% under Scenario 1).

At the boundary of De Tilla Gulch SEZ, modeled PM_{10} concentrations are predicted to increase by about 40 $\mu g/m^3$ with 100% development. A portion of the De Tilla Gulch SEZ (about 225 acres or 21% of the SEZ) has soils with WEG group of 1 or 2 (indicating a higher erosion or dust generation potential). However, most towns are not downwind of and/or are far from the SEZ, and thus potential dust impacts related to development of the SEZ would be minor.

To examine more closely potential impacts among the six scenarios as described in Section 4.2.1, PM concentrations associated with varying levels of development of the three SEZs were calculated. Table 4-4 along with Figure 4-7 presents modeled PM_{10} concentrations at towns around the SEZs along with the five air monitoring stations within the valley, and projected changes in PM_{10} concentrations. For the base case (no development), 24-hour PM_{10} concentrations at towns that are located downwind of agricultural lands and in the direction where the highest level of agricultural dusts will blow[34] are predicted to exceed the NAAQS of 150 $\mu g/m^3$ during dust episodes in the SLV. These towns are Alamosa, La Jara, Lobatos, Manassa, San Antonito, and Sanford. In contrast, lower PM_{10} concentrations are predicted for towns upwind of agricultural activities or with a short fetch distance. Scenario 1 has the largest impact on ambient air quality because the scenario assumes that 100% of SEZ vegetative cover is removed for solar development of the three SEZs. Under Scenario 1, projected 24-hour PM_{10} concentrations at the nearest towns remain almost the same as under the non-development base case or have a relatively small increase (a few percent at most). This is because most towns are located far from and/or upwind of the SEZs. For example, most towns around the Antonito Southeast SEZ (denoted by green dots in Figure 4-6) are located upwind of prevailing westerly/southwesterly winds. An exception is the town of Romeo, which is located immediately downwind of the Los Mogotes East SEZ; there the 24-hour PM_{10} concentration under Scenario 1 is predicted to increase by about 20% (from 81 to 97 $\mu g/m^3$) compared with the base case. At Joyful Journey Hot Spring Spa about 5 mi (8 km) northeast of the De Tilla Gulch SEZ, the 24-hour PM_{10} concentration is predicted to increase by about 4% (from 54 to 56 $\mu g/m^3$) compared with the base case. At the five air monitoring sites within the valley (which are quite distant from the SEZs), the model results indicate that the development of SEZs would increase 24-hour PM concentrations resulting from wind-blown dust by 0.3% at most. Modeling indicates that 24-hour PM_{10} concentrations would increase by about 0.2% at Great Sand Dunes NM directly downwind of the De Tilla Gulch SEZ. Therefore, dust impacts associated with development of the three SEZs on other Class I PSD areas around the valley (as in Figure 1-1) would be much lower.

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34 Direction of highest dust concentration is determined by the “fetch distance”, defined as the distance downwind from the leading edge across the erodible material. The shape of the agricultural field determines the fetch distance (e.g., fetch distance would be the longest if winds are blowing diagonally across a rectangular agricultural field.

TABLE 4-4 Modeled 24-Hour PM_{10} Concentrations for Base Case and Scenarios 1-6 and Their Changes from Base Case at Towns/Locations around the Solar Energy Zones and at Air Monitoring Sites. Note – Uses meteorological conditions of April 3, 2011 as representative for a dust generation episode.

	Base Case (current)	Scenario 1 (100% vegetative cover removed)		Scenario 2 (80% vegetative cover removed)		Scenario 3 (50% vegetative cover removed)		Scenario 4 (20% vegetative cover removed)		Scenario 5 (dust suppressant applied 20% SEZ)		Scenario 6 (dust suppressant applied 80% SEZ)	
Town/Location Name	(µg/m³)	(µg/m³)	Change[a]	(µg/m³)	Change[a]	(µg/m³)	Change[a]	(µg/m³)	Change[a]	(µg/m³)	Change[a]	(µg/m³)	Change[a]
Around Antonito Southeast and Los Mogotes East Solar Energy Zones													
Antonito	57.8	58.0	0.3%	58.0	0.2%	57.9	0.2%	57.9	0.1%	58.0	0.3%	57.9	0.2%
Capulin	78.9	78.8	0.0%	78.8	0.0%	78.9	0.0%	78.9	0.0%	78.8	0.0%	78.9	0.0%
Conejos	57.8	58.0	0.3%	58.0	0.2%	57.9	0.2%	57.9	0.1%	58.0	0.3%	57.9	0.2%
La Jara	246.6	250.6	1.7%	249.7	1.3%	248.3	0.7%	247.2	0.3%	250.2	1.5%	248.7	0.9%
Las Mesitas	87.7	87.7	0.1%	87.7	0.1%	87.7	0.0%	87.7	0.0%	87.7	0.1%	87.7	0.0%
Lobatos	317.4	316.8	-0.2%	316.9	-0.2%	317.1	-0.1%	317.3	0.0%	316.9	-0.2%	317.1	-0.1%
Manassa	251.2	257.5	2.5%	256.0	1.9%	253.9	1.1%	252.2	0.4%	256.7	2.2%	254.5	1.3%
Mogote	43.4	43.5	0.3%	43.5	0.2%	43.5	0.1%	43.4	0.1%	43.5	0.3%	43.5	0.2%
Paisaje	59.2	59.1	-0.2%	59.2	-0.2%	59.2	-0.1%	59.2	0.0%	59.1	-0.2%	59.2	-0.1%
Romeo	80.8	96.7	19.8%	93.2	15.4%	87.9	8.9%	83.4	3.3%	94.9	17.6%	89.6	11.0%
San Antonito	292.0	294.9	1.0%	294.3	0.8%	293.5	0.5%	292.6	0.2%	294.6	0.9%	293.8	0.6%
Sanford	191.4	195.6	2.2%	194.7	1.7%	193.4	1.1%	192.2	0.4%	195.1	2.0%	193.8	1.3%
Around De Tilla Gulch Solar Energy Zone													
Crestone	102.0	103.3	1.2%	103.0	1.0%	102.6	0.6%	102.2	0.2%	103.1	1.1%	102.7	0.7%
Joyful Journey Hot Springs Spa	53.6	55.5	3.7%	55.1	2.9%	54.6	1.8%	54.0	0.7%	55.3	3.3%	54.7	2.2%
Moffat	92.3	92.6	0.3%	92.5	0.2%	92.4	0.1%	92.4	0.0%	92.5	0.2%	92.5	0.2%
Saguache	21.7	21.7	-0.3%	21.7	-0.2%	21.7	-0.2%	21.7	0.0%	21.7	-0.3%	21.7	-0.2%
Air Monitoring Sites													
Alamosa (Adams St Univ)[b]	233.6	234.3	0.3%	234.2	0.2%	233.9	0.1%	233.7	0.1%	234.3	0.3%	234.0	0.2%
Alamosa (Municipal Bldg)[b]	233.6	234.3	0.3%	234.2	0.2%	233.9	0.1%	233.7	0.1%	234.3	0.3%	234.0	0.2%
Taos (Fire Station)	48.5	48.5	0.0%	48.5	0.0%	48.5	0.0%	48.5	0.0%	48.5	0.0%	48.5	0.0%
Great Sand Dunes NM	127.1	127.4	0.2%	127.3	0.1%	127.5	0.3%	127.4	0.2%	127.4	0.2%	127.4	0.2%
Wheeler Peak WA	22.0	22.0	0.0%	22.0	0.0%	22.0	0.0%	22.0	0.0%	22.0	0.0%	22.0	0.0%

[a] Percent change from modeled concentrations for the base case (or baseline).

[b] Two air monitoring sites at Alamosa are about 0.85 mi (1.4 km) apart but two sites fall onto the same 1.9 mi by1.9 mi (3 km by 3 km) modeling grid cell.

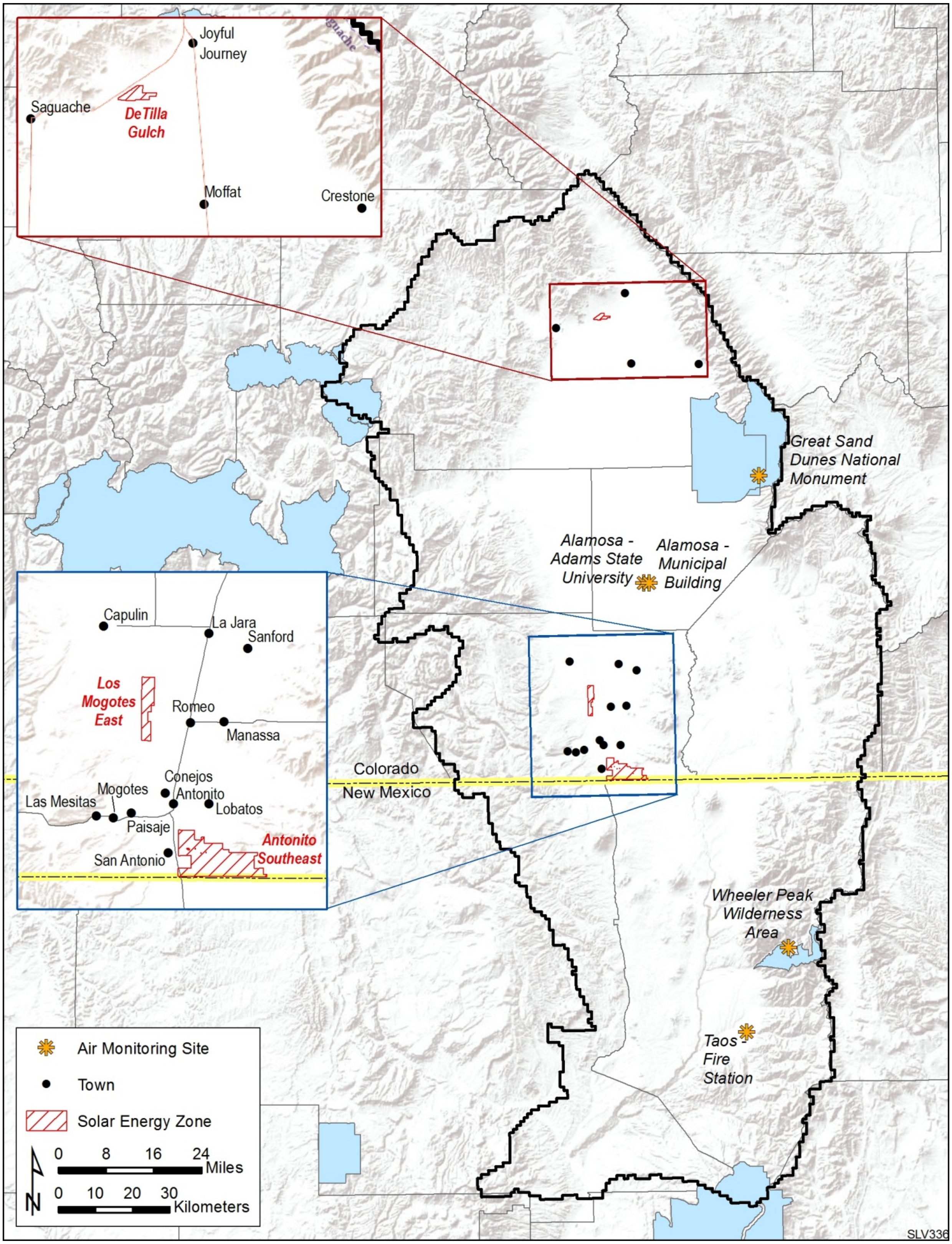

FIGURE 4-7 Locations of Air Monitoring Sites and Towns around the Solar Energy Zones within the San Luis Valley

In conclusion, the WRF-Chem modeling indicates that potential dust impacts on ambient air quality associated with development of three SEZs would be relatively small because: (1) the Antonito Southeast and Los Mogotes East SEZs have a large combined area but contain soils with less dust emission potential (i.e., higher WEG groups); and (2) the De Tilla Gulch SEZ contains soils with a higher dust emission potential (i.e., WEG groups 1 and 2) but these soils extend over a small area (225 acres, about 21% of the SEZ). An additional factor that leads to low predicted impacts is that most towns are upwind of and/or relatively far from the SEZs.

As a sensitivity analysis, the WRF-Chem model was run for the period of April 12-18, 2013, based on the April 16, 2013 episode when 24-hour PM_{10} concentrations rose to 237 $\mu g/m^3$ at the Alamosa-Adams State University monitoring site. During this episode, surface winds were generally weaker than those for the April 3, 2011 episode, and the contribution to the dust plume from outside sources into the valley was comparable to the contribution from locally generated dust in the valley. Therefore, if the meteorological conditions from this episode were used to model potential impacts under Scenario 1, the maximum increases in 24-hour PM_{10} concentrations would be less than 2% in comparison with the base case, which is far less than the modeled increase of about 20% using the April 3, 2011 episode meteorological conditions.

Another local concern is whether dust storm events in the SLV are caused by dust storms originating in the western deserts. As discussed in Section 2.6.3, monitoring data over the region indicates that elevated PM levels were associated with local conditions for the sites of interest (e.g., towns near SEZs), even when meteorological and soil conditions were favorable for wind-blown dust from outside of the SEZ to impact PM levels. As a result, monitoring showed many low concentrations in the study area, even during regional dust storm events. For example, Taos is located far downwind of many dust-prone areas but nearer downwind of relatively low dust potentials. No 24-hour PM_{10} exceedances have been measured at Taos, although peak winds are comparable to those at Alamosa during dust storm events. These data seem to indicate that during dust storm events, outside dust sources may contribute to high PM concentrations in the valley to some extent, but not considerably.

4.2.3 Cumulative Impacts

In Section 4.2.2, cumulative changes in 24-hour PM_{10} concentrations are presented assuming that development of all three SEZs in the valley occurs at the same time. The De Tilla Gulch SEZ is located more than 60 mi (96 km) north of the Antonito Southeast and Los Mogotes East SEZs. On average, winds blowing from the southwest quadrant prevail in the valley floor as in Figure 2-1 and dust storm episodes occur more frequently when strong winds blow from the southwest quadrant. Potential impacts presented in Table 4-4 are cumulative impacts from all three SEZs combined. Cumulative contributions would not be much different than contributions from individual SEZs upwind of any given location. For the April 3, 2011 representative meteorological conditions shown in the right panels of Figure 4-6, dust plumes showing the differences between base case and Scenario 1 stretch out eastward around the Antonito Southeast and Los Mogotes East SEZs and east-southeastward around the De Tilla Gulch SEZ with relatively short contours. As shown, the dust plume originating from each SEZ may merge with that of another SEZ at a long distance from either, but at those locations the PM_{10} concentrations would be low, and thus cumulative contributions from all three SEZs combined would be low in most dust storm episodes that could impact sensitive receptors in the valley.

4.2.4 Effectiveness of Dust Suppressants to Control Dust

Potential dust impacts among scenarios depend on the level of disturbance (i.e. how much of SEZ vegetative cover is removed) and/or control options (e.g, percent of disturbed area treated with a dust suppressant and the effectiveness of the dust suppressant). As mentioned, Scenario 1 (100% vegetative cover removed) has highest impacts and Scenario 4 (20% of SEZ vegetative cover is removed for all three SEZs) has the lowest impacts. As discussed in Section 4.2.1, for Scenarios 5 and 6, it is assumed that 100% of the SEZ vegetative covers are removed (same as Scenario 1) but dust suppressant is applied over 20% and 80% of the SEZ area, respectively. Typically, dust suppressants have a control efficiency of 80% or higher, but for this modeling exercise a control efficiency of 50% was conservatively assumed. Thus, dust emissions for Scenarios 5 and 6 are calculated as 90% (=[0.8][1-0]+[0.2][1-0.5]) and 60% (=[0.2][1-0]+[0.8][1-0.5]) of those for Scenario 1, respectively. Potential impacts under Scenario 5 would be between those of Scenario 1 (100% vegetative cover removed) and Scenario 2 (80% vegetative cover removed), while impacts under Scenario 6 would be between those of Scenario 2 and Scenario 3 (50% vegetative cover removed). Compared with a 19.8% increase in 24-hour PM_{10} concentrations at Romeo under Scenario 1, the increases would be 17.6% and 11.0% under Scenarios 5 and 6, respectively, roughly proportional to the ratios of estimated emissions stated above. At other locations, percent changes would be similarly proportional. As mentioned, a control efficiency of higher than the assumed 50% is readily achievable and thus in practice potential dust impacts under Scenarios 5 and 6 may be lower than those discussed above.

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5 POTENTIAL HEALTH IMPACTS

5.1 HEALTH IMPACTS ASSOCIATED WITH PARTICULATE MATTER

5.1.1 Types of Effects

PM, as previously defined in Section 2.3, is a mixture of solid particles and liquid droplets suspended in air. PM_{10} is used worldwide as a standard measure of air pollution. The EPA groups PM_{10} into the following two categories (EPA 2013a):

- "Inhalable coarse particles," such as those found near roadways and dusty industries, are larger than 2.5 μm and smaller than or equal to10 μm in diameter (also referred to as $PM_{10\text{-}2.5}$)

- "Fine particles," such as those found in smoke and haze, are 2.5 μm in diameter and smaller (referred to as $PM_{2.5}$). These particles can be directly emitted from sources such as forest fires, or they can form when gases emitted from power plants, industries and automobiles react in the air.

The size of particles affects their ability to cause health problems. Particles comprising PM_{10} can reach the lower regions of the respiratory tract after being inhaled, and there can cause respiratory damage and other health effects. $PM_{10\text{-}2.5}$ can reach the bronchiolar portion of the lungs, while $PM_{2.5}$ is small enough to reach the alveoli, where gas exchange takes place. The EPA recently updated its review of studies on $PM_{10\text{-}2.5}$ and $PM_{2.5}$ toxicity (EPA 2009b; Table 5-1). The review concluded that both short-term and long-term exposures to $PM_{2.5}$ cause or contribute to cardiovascular damage such as heart attack and thickening of the artery walls, adverse respiratory effects such as asthma, coughing, and difficulty breathing (often observed through increases in hospitalizations), and increased mortality. The review also found that many studies presented suggestive (but not conclusive) evidence that even the coarse particle fraction of PM_{10} (that is, $PM_{10\text{-}2.5}$) could cause these effects. Thus, all components of PM_{10} are of concern with respect to adverse respiratory and cardiovascular effects, and elevated exposures ultimately lead to premature mortalities in some individuals. The elderly, children, and people with chronic lung disease or asthma are especially sensitive to the effects of PM_{10}. Additionally, the types of particles in PM_{10} may include substances with individual toxic effects, such as metals, and hydrocarbons.

There is also some suggestive evidence that long-term exposure to $PM_{2.5}$ could cause reproductive or developmental effects, and possibly cancer (EPA 2009b). Research is ongoing to answer these questions.

TABLE 5-1 Summary of PM Causal Determinations by Exposure Duration and Health Outcome

Size Fraction	Exposure	Outcome	Causality Determination
$PM_{2.5}$	Short-term	Cardiovascular Effects	Causal
		Respiratory Effects	Likely to be causal
		Central Nervous System	Inadequate
		Mortality	Causal
	Long-term	Cardiovascular Effects	Causal
		Respiratory Effects	Likely to be Causal
		Mortality	Causal
		Reproductive and Developmental	Suggestive
		Cancer, Mutagenicity, Genotoxicity	Suggestive
$PM_{10-2.5}$	Short-term	Cardiovascular Effects	Suggestive
		Respiratory Effects	Suggestive
		Central Nervous System	Inadequate
		Mortality	Suggestive
	Long-term	Cardiovascular Effects	Inadequate
		Respiratory Effects	Inadequate
		Mortality	Inadequate
		Reproductive and Developmental	Inadequate
		Cancer, Mutagenicity, Genotoxicity	Inadequate

Source: EPA (2009b).

Based on an EPA history of the NAAQS for PM (EPA 2009b), the EPA first created NAAQS for PM_{10} in 1987 to protect the public against the above health effects. The maximum allowable 24-hour average PM_{10} concentration was set at 150 $\mu g/m^3$ not to be exceeded more than once per year on average over a 3 year period; the maximum annual arithmetic mean was not to exceed 50 $\mu g/m^3$. The first standard for $PM_{2.5}$ was set in 1997 at 65 $\mu g/m^3$ 24-hour average and 15 $\mu g/m^3$ annual mean. In 2006 the standards were revised: the NAAQS for 24-hour $PM_{2.5}$ was lowered to 35 $\mu g/m^3$ on the basis of increasing evidence for short-term health effects at lower concentrations. Additionally, the annual-average NAAQS for PM_{10} of 50 $\mu g/m^3$ was revoked because available evidence generally did not support a link between long-term exposure and health or welfare effects (EPA 2009b). In 2012 the primary NAAQS for annual $PM_{2.5}$ was reduced to 12 $\mu g/m^3$ and the secondary NAAQS was retained at 15 $\mu g/m^3$ (EPA 2013b).

5.1.2 Comparison of PM Levels in the Study Area with Health-Based Standards

Data and Assumptions on* $PM_{2.5}$ *and* $PM_{10\text{-}2.5}$ *Levels. Of the 5 monitoring stations in the SLV, only two collect both PM_{10} and $PM_{2.5}$ data; the others collect only PM_{10} data. In order to compare the PM data to levels correlated with adverse health effects for both PM_{10} and $PM_{2.5}$, this assessment assumes that PM_{10} is distributed as 62% $PM_{10-2.5}$ and 38% $PM_{2.5}$ (ratio typical for the Southwest U.S.; EPA 2004).

Additionally, this assessment assumes that the average annual mean PM concentrations at the Alamosa municipal building (MB) monitoring location are representative of higher end long-term exposures in the SLV. Annual-average PM_{10} concentrations at the three monitoring locations[35] are presented in Table 5-2. Between 2004 and 2013 the annual-average PM_{10} values at the MB location have ranged from 23.6 $\mu g/m^3$ in 2004 to 37.9 $\mu g/m^3$ in 2011, with an average of 28 $\mu g/m^3$ over those years. The annual averages were about 20% higher at the MB location than at the other Alamosa monitoring location, and about 50% higher than at the Taos monitoring location. Therefore the MB location was considered representative of higher end exposures in the SLV.

Some limited 24-hour average PM_{10} data were obtained in Spring 2013 at a location near Antonito. The 10 samples were obtained between February and June 2013; 24-hour average PM_{10} concentrations ranged from 6.2 to 51.9 $\mu g/m^3$, with an average of 22 $\mu g/m^3$ (Guajardo 2014). These samples all fell well below the NAAQS of 150 $\mu g/m^3$ for 24-hour average PM_{10}, and were within the range of values measured at the Alamosa monitoring locations.

TABLE 5-2 Summary of Annual-Average PM_{10} Concentrations at Three Monitoring Locations in the San Luis Valley

	Annual-Average PM_{10} Concentration ($\mu g/m^3$)		
Year	Alamosa (Adams State Univ.)	Alamosa (Municipal Building)	Taos (Fire Station)
2004	21.1	23.6	17.6
2005	20.4	23.8	21.8
2006	21.4	26.7	19.4
2007	22.2	29.0	18.9
2008	20.3	27.2	23.0
2009	20.9	24.5	16.0
2010	23.5	26.5	16.1
2011	25.5	37.9	20.7
2012	26.9	32.3	17.4
2013	23.3	25.0	15.2
Average 2004-2013	22.5	27.7	18.6

Source: EPA (2014b).

[35] Two other monitoring sites are located within the Federal Class I areas, which are far from human dwellings and/or at much higher elevations than the other three monitoring stations, and thus are excluded from the health impacts analysis.

PM_{10} Short-term and Long-Term Exposures and Potential Health Effects in the San Luis Valley. Section 2.6 of this document describes the PM_{10} and $PM_{2.5}$ monitoring occurring in the SLV. Three of the five monitoring locations only measure PM_{10} levels. For the Alamosa locations, a total of 52 exceedances of the 24-hour NAAQS of 150 $\mu g/m^3$ were recorded between 1989 and 2013 (see Table 2-4). There appears to be a trend of increasing number of exceedances when comparing average number of exceedances per year over 5-year intervals. For the Alamosa monitoring locations (data collected since 1989 at one location and since 2002 at the other), the average values were less than one exceedance per year prior to 1998, then increased to an average of 1.6 exceedances per year between 1999 and 2008, and then almost doubled to nearly 4 exceedances per year for the period 2009-2013 (see Figure 5-1). These exceedances would result in short-term exposures to elevated PM_{10} levels. As presented in Section 5.1.1, there is suggestive evidence that short-term exposures to elevated PM_{10} can cause cardiovascular and respiratory effects.

If it is assumed that measured PM_{10} consists of 38% $PM_{2.5}$ (EPA 2004), then a 24-hour average above 150 $\mu g/m^3$ would contain 57 $\mu g/m^3$ $PM_{2.5}$, about 1.5 times the NAAQS for 24-hour $PM_{2.5}$. As discussed in Section 5.1.1, short-term exposures to $PM_{2.5}$ levels above the 24-hour NAAQS level can cause cardiovascular damage and adverse respiratory effects. Such events occurring about 4 times per year on average in the Alamosa area (see Figure 5-1)

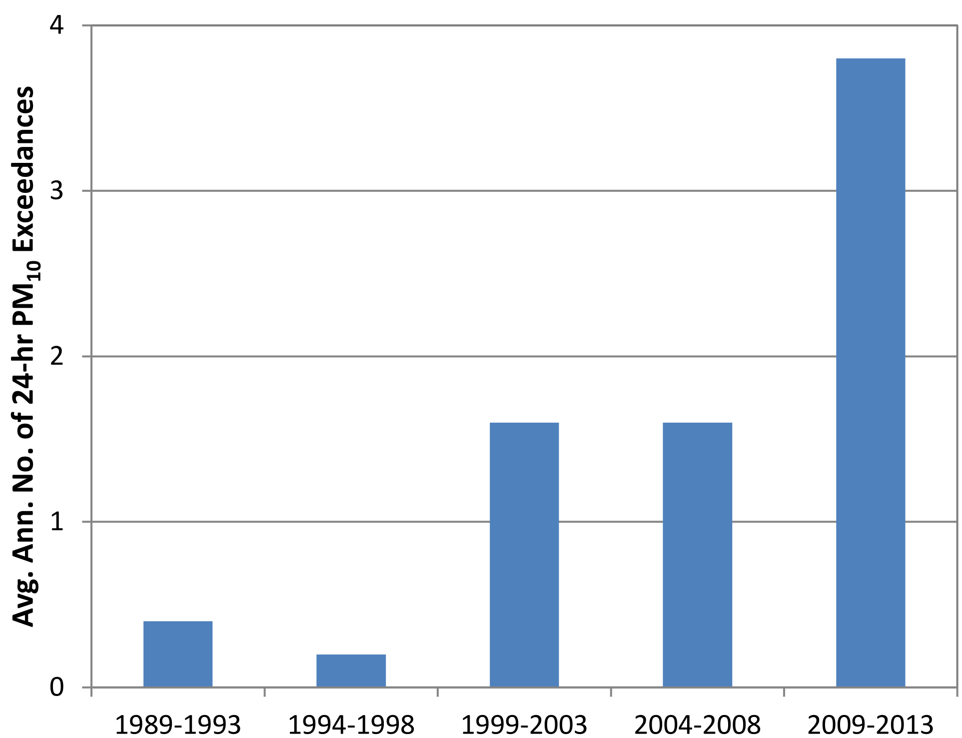

FIGURE 5-1 Average Annual Number of 24-Hour PM_{10} Exceedances of the 150 $\mu g/m^3$ Standard at the Alamosa Monitoring Locations, 5-Year Intervals

represent a public health concern, particularly for sensitive populations including the elderly and individuals with existing respiratory health issues.

Long-term exposures to $PM_{2.5}$ at levels above the annual NAAQS of 12 μg/m^3 also can cause cardiovascular damage and adverse respiratory effects. Assuming $PM_{2.5}$ is 38% of the annual-average PM_{10} value of 28 μg/m^3, the annual-average $PM_{2.5}$ concentration at the Alamosa location would be about 11 μg/m^3, very close to the NAAQS level.[36] Thus, long term exposures to $PM_{2.5}$ in the Alamosa area may also be causing health effects there.

Although monitoring locations are not adequate to identify other locations in the SLV where elevated short-term and long-term PM concentrations are of concern, the modeling of exceedance events conducted for this study indicates that several other towns might exceed 24-hour PM_{10} NAAQS levels at times when dust events (i.e., days when PM_{10} levels exceed the 24-hour standard) are occurring in the SLV. These towns are La Jara, Lobatos, Manassa, San Antonito, and Sanford (see Table 4-4).

Potential Solar Development-Associated Health Impacts During Construction. Tables 4-1 and 4-3 and Figures 4-1 and 4-3 show predicted 24-hour PM_{10} concentration increases that would be associated with construction at the Antonito Southeast and Los Mogotes East SEZs, respectively. The 24-hour average PM_{10} and $PM_{2.5}$ concentration increments of 569 and 40 μg/m^3 respectively (concentrations including background would be 596 and 56 μg/m^3, respectively) at the boundary of the Antonito Southeast SEZ would exceed the NAAQS. Similarly, the 24-hour average PM_{10} and $PM_{2.5}$ concentration increments of 374 and 26 μg/m^3 respectively (concentrations including background would be 401 and 42 μg/m^3, respectively), at the boundary of the Los Mogotes East SEZ would exceed the NAAQS. The increase at the nearest residences would be 230 μg/m^3 for Antonito Southeast SEZ and 141 μg/m^3 for the Los Mogotes East SEZ. These concentrations exceed or are close to the NAAQS level of 150 μg/m^3.

The increase at the town of Antonito would be 100 μg/m^3 due to construction at Antonito Southeast SEZ and 29 μg/m^3 due to construction at Los Mogotes East SEZ. The increase at the town of Romeo would be 30 μg/m^3 due to construction at Antonito Southeast SEZ and 31 μg/m^3 due to construction at Los Mogotes East SEZ. An increase of 100 μg/m^3 due to construction at the Antonito Southeast SEZ at the town of Antonito would not likely result in exceedance of the 150 μg/m^3 NAAQS during dust events. This is because the highest concentrations from construction would occur when wind speeds are low, whereas the highest background concentrations in Antonito would occur when wind speeds are high. The highest estimated concentrations in Antonito during high wind speed dust events are about 58 μg/m^3 (see Table 4-4) Since these high background levels are very unlikely to coincide with high levels during construction and typically construction activities are temporarily suspended under high wind conditions, it is not expected that NAAQS would be exceeded at Antonito during either construction or operation of solar facilities. Therefore associated health effects are also unlikely.

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[36] These concentrations are somewhat higher than official concentrations to determine NAAQS compliance because they contain exceptional events, which are not included in NAAQS compliance.

For the town of Romeo, the modeled 30 $\mu g/m^3$ increase would also not be likely to cause NAAQS exceedances; the modeled level during dust events is 81 $\mu g/m^3$ (see Table 4-4).

In general, these data indicate that respiratory and cardiovascular health effects at nearby residences and in the town of Antonito could be caused by PM generated from construction activities. However, the method used to estimate construction emissions would tend to overestimate the actual emissions (e.g., it was assumed that an entire 3,000 acre area would be disturbed each day during construction). Based on required design features presented in the Solar PEIS Record of Decision (BLM 2012), during actual construction activities PM emissions would be minimized through disturbing smaller areas each day, wetting construction areas, using low-disturbance construction methods, or other means. Monitoring of the construction activities to confirm that emissions were within the specified limits would also be required.

As shown in Table 4-2 and Figure 4-2, 24-hour average PM_{10} and $PM_{2.5}$ concentration increments were predicted to be 430 and 26 $\mu g/m^3$, respectively (concentrations including background would be 457 and 42 $\mu g/m^3$, respectively), at the boundary of the De Tilla Gulch SEZ. The 24-hour average $PM_{2.5}$ increment would not exceed the NAAQS, although the concentrations with background would exceed the NAAQS levels. Concentration increases would drop to less than 15 $\mu g/m^3$ at the nearest town of Saguache. The 24-hour PM_{10} PSD increment of 8 $\mu g/m^3$ could be slightly exceeded at Great Sand Dunes National Monument. The PSD increment is not based on health effects, and construction activity emissions would be monitored and required to stay below the PSD increment at the National Monument.

Potential Solar Development-Associated Health Impacts During Operations. Table 4-4 shows the modeled changes in 24-hour average PM_{10} levels that would occur at nearby towns during wind-blown dust events if solar development occurred in the SEZs at various levels. For the scenario representing maximum ground disturbance at the SEZ (Scenario 1), the percent change is less than 2% at most locations, generally because these locations are upwind of and/or distant from the SEZs. Exceptions are the towns of Manassa (2.5% increase), Romeo (20% increase), and Sanford (2.2% increase), and the Joyful Journey Hot Springs Spa (3.7% increase). For the towns where modeling indicates NAAQS exceedances (and associated health effects) could occur, solar development would not contribute significantly to dust levels (less than 3% increase). For the town of Romeo, although the 20% percent increase of PM_{10} is significant because the town is close to and downwind of the Los Mogotes East SEZ, the modeling results do not indicate that the NAAQS would be exceeded even with contributions from solar development. However, monitoring data in the town of Romeo would be useful to confirm the actual PM concentrations.

5.2 HEALTH IMPACTS ASSOCIATED WITH ARSENIC-CONTAMINATED PARTICULATE MATTER

Stakeholders living near the SEZs in the SLV have expressed concern regarding the potential health hazards from inhalation of arsenic that is naturally occurring in soil in the area. The concern is that large-scale disturbance of soil in the SEZs would result in high inhalation exposures because of increased concentrations of arsenic in wind-blown dust. Long-term exposure to elevated levels of arsenic can cause adverse health effects including anemia, liver damage, kidney damage, and increased risk of cancer (ATSDR 2007a,b; EPA 2012). Other studies cited in these documents indicate that for children there is some evidence that long-term exposure to inorganic arsenic may result in lower intelligence quotient (IQ) scores, and that pre-birth and early childhood exposures may increase mortality in young adults. The main research question for this study is whether inhalation exposures due to increased dust levels would be high enough to cause health effects in residents near the SEZs. Secondarily, potential worker health effects due to inhalation and ingestion exposures are estimated.

Concentrations of arsenic in soil in the SLV range from about 4.9 to 26 mg/kg, with an average level of 5.2 mg/kg, as compared with an average of 5.5 mg/kg overall in soils in the Western U.S. (Tidball 1996). The average concentration can be used to calculate a risk of cancer and non-cancer health effects from both long-term inhalation and incidental ingestion using soil screening equations available from the EPA.

To estimate health risks, a value for longer-term average concentrations of soil entrained in the air during either construction or operations of solar facilities is also needed. The modeling conducted for this study estimated increased PM concentrations during construction (Section 4.1) and during elevated dust incidents occurring during operations (Section 4.2), in order to evaluate health impacts with respect to exceedance of air quality standards (related to PM health effects). However, the amount of long-term elevation of average PM levels was not estimated; these long-term average levels are required for estimation of health effects due to exposure to arsenic in wind-blown dusts. An estimate of the long-term average PM_{10} levels at the residences nearest to the SEZs during construction was provided in the Draft Solar PEIS (BLM and DOE 2010). The maximum was for the Antonito Southeast SEZ, at approximately 30 $\mu g/m^3$ annual-average PM_{10}. For the purpose of this screening level health risk evaluation for residents at towns near the SEZ, the PM_{10} exposure concentration was assumed to correspond to this level (i.e., 30 $\mu g/m^3$).

Additionally, it was conservatively assumed that the average dust level that construction workers would be exposed to was 119 $\mu g/m^3$. This was an estimate of the annual-average PM_{10} level at the Antonito Southeast SEZ boundary during construction, as reported in the Draft Solar PEIS (BLM and DOE 2010). This level was the maximum boundary concentrations for the three SEZs.

The default exposure parameters and factors for residential and worker exposures represent Reasonable Maximum Exposure (RME) conditions for long-term/chronic exposures and are based on the methods outlined in EPA's Risk Assessment Guidance for Superfund, Part B Manual (EPA 1991) and Soil Screening Guidance documents (EPA 1996; EPA 2002). Table 5-3 provides a summary of the parameters used in the calculation of risks that would correspond to long-term (chronic) exposure of residents from inhaling arsenic contained in soil-derived airborne PM near the SEZ. Additionally, parameters used to calculate risks for outdoor workers that would be present at the SEZs, both from inhalation and incidental ingestion, are presented. Table 5-4 summarizes the potential non-cancer and cancer risks for these receptors.

TABLE 5-3 Residential and Outdoor Worker Soil Screening Parameter Values

Parameter	Description	Value
General		
AT	Averaging time (days/year)	365
BW	Body Weight (kg)	Adult: 80 Child:15
ED	Exposure Duration – Adult (years)	Resident: 26 Worker: 25
EF	Exposure Frequency (days/year)	Resident: 350 Worker: 250
ET	Soil Exposure Time (hours/day)	Resident: 24 Worker: 8
IFS_{adj}	Age-adjusted Soil Ingestion Factor – Resident (mg/kg)	36,750
IRS	Soil Ingestion Rate - Adult (mg/day)	100
LT	Lifetime (years)	70
PEF_w	Wind Driven Particulate Emission Factor – Default (Minneapolis) (m^3/kg)	1.36×10^9
THQ	Target Hazard Quotient – Single Contaminant Assessment	1
TR	Target Risk	1×10^{-6}
Contaminant-specific: Arsenic		
CSF_o	Chronic Oral Slope Factor $(mg/kg\text{-}day)^{-1}$	1.5
IUR	Chronic Inhalation Unit Risk $(\mu g/m^3)^{-1}$	4.3×10^{-3}
RBA [a]	Relative Bioavailability Factor	0.6
RfC [b]	Chronic Inhalation Reference Concentration (mg/m^3)	1.5×10^{-5}
RfD	Chronic Oral Reference Dose (mg/kg-day)	3×10^{-4}

[a] In 2012, the RBA was added to the arsenic calculation for ingestion of soil. Relative bioavailability accounts for differences in the bioavailability of a contaminant between the medium of exposure (e.g., soil) and the media associated with the toxicity value (e.g., the arsenic RfD and CSF are derived from drinking water studies).

[b] EPA has not established a RfC for inorganic arsenic (EPA 1998). The value reported is the chronic reference level (REL) established by the California Environmental Protection Agency (CalEPA), which is based on a study indicating decreased intellectual function in 10 year old children exposed to elevated arsenic in drinking water (CalEPA 2014).

TABLE 5-4 Potential Risk from Arsenic Contaminated Soil Originating from Solar Energy Zones in the San Luis Valley

Route of Exposure	Potential Risk: Residential[a]	Potential Risk: Outdoor Worker[b]
Non-cancer – Hazard Quotient		
Incidental Ingestion	not assessed	0.007
Inhalation	0.009	0.008
Cancer – Target Risk		
Incidental Ingestion	not assessed	1.1×10^{-6}
Inhalation	2.1×10^{-7}	1.7×10^{-7}

[a] Residents were assumed to be exposed to dust at PM levels of 30 μg/m^3 (corresponding to the estimated annual-average level at the residence nearest to the Antonito Southeast SEZ during construction, as presented in the Draft Solar PEIS). Incidental ingestion exposure for residents was not assessed because this study addresses exposures for residents located at towns near the SEZs, and assumes long-term (greater than 30 years) operation of the SEZs (and therefore no residential use of the SEZ areas). Furthermore, arsenic is not a contaminant associated with solar development; the risk assessment is addressing exposures for residents from naturally-occurring arsenic in wind-blown dust.

[b] Construction workers were assumed to be exposed to annual-average PM_{10} levels of 119 μg/m^3 (corresponding to the maximum estimated annual-average level at the Antonito Southeast SEZ boundary during construction, as presented in the Draft Solar PEIS).

For non-cancer risk, the hazard quotient (HQ) represents the ratio between the potential exposure and the reference dose (a dose below which adverse health effects would not be expected). For inhalation exposures due to solar development in the SEZs, HQs for both residential and outdoor worker exposures are calculated to be much less than 1, which indicates no adverse non-cancer health effects are expected as a result of exposure to arsenic in soil particulates.

For carcinogenic effects, risk is expressed as excess probability of contracting cancer over a lifetime (i.e., 70 years). For inhalation exposures of nearby residents due to solar development in the SEZs, the estimated cancer risk associated with the inhalation of particulates is 2.1×10^{-7} (i.e., 0.21 excess cancer cases in a population of 1 million). One excess cancer case per million population is a cancer risk benchmark often used by the EPA as the lower end of the range of acceptable risk (1×10^{-4} is used as the upper end of the range) (EPA 1997), so this risk can be considered to be of minimal concern.

The cancer risk calculations for SEZ outdoor worker inhalation and incidental ingestion of arsenic in the soil indicate small increased lifetime cancer risks. The value for inhalation exposures is 1.7×10^{-7}, which is of minimal concern. The value for incidental ingestion is approximately equal to the lower end of the 1×10^{-6} target risk value. However, this risk does not assume use of exposure controls such as personal protective equipment by workers (e.g., dust-filtering masks that would also cover the mouth to reduce the potential for incidental ingestion). As explained above, worker protection would be required.

It should be noted that the risk levels presented here correspond to the risks associated with background concentrations of arsenic in soils. Solar development would not increase those concentrations, but it could lead to higher exposures for both nearby residents and workers at the solar facilities by producing elevated levels of PM in air.

6 SUMMARY AND CONCLUSIONS

6.1 CONSTRUCTION

Fugitive dust emissions from soil disturbances during the entire construction phase would be a major concern, because of the large areas that would be disturbed in a region that experiences wind-blown dust problems.

Predicted 24-hour PM_{10} and 24-hour $PM_{2.5}$ concentration levels could exceed the NAAQS used for comparison at the boundaries of all three of the SEZs and within the areas immediately surrounding them during the construction phase of a solar development. To reduce potential impacts on ambient air quality, aggressive dust control measures would be needed. Total (modeled plus background) concentrations for annual $PM_{2.5}$ would be below the NAAQS level at the site boundary for all the SEZs. Additionally, potential air quality impacts on neighboring communities would be much lower. Modeling indicates that construction activities are anticipated to exceed Class I PSD PM_{10} increments at the nearest Class I areas (Great Sand Dunes NM and Wheeler Peak WA). This comparison is made simply to gauge the magnitude of potential impacts (as construction activities are not subject to the PSD program). Accordingly, it is anticipated that impacts of construction activities on ambient air quality would be moderate, but temporary.

AERMOD modeling indicated that construction emissions from the De Tilla Gulch SEZ would contribute only minimally to PM_{10} concentrations in the Canon City PM_{10} Maintenance Area due to the distance (located about 45 mi [72 km] east-northeast of the SEZ) and intervening elevations (more than 3,000 ft [914 m]), and thus would not likely affect its attainment status. Similarly, PM_{10} concentrations in the Pagosa Springs PM_{10} Maintenance Area, which is located more than 50 mi (80 km) west (upwind) of Antonito Southeast and Los Mogotes East SEZs, would be minimally affected.

6.2 OPERATION

Wind-blown dust impacts on ambient air quality from future development of three solar energy zones within the SLV-Taos Plateau were assessed using the WRF-Chem model, a state-of-the-art air quality model. To date, most wind-blown dust model applications have been targeted to large geographical areas, such as the Saharan Desert or Middle East Desert. In this study, the modeling activity focused on a smaller area. For the modeling, erosion factors to determine wind-blown dust emissions over the domain were needed. For larger geographical areas, these erosion factors can be derived from a built-in database in WRF-Chem, and are based on topographic differences between adjacent grid cells under the assumption that loose sediment accumulates in topographic depressions (i.e., that Holocene lake beds are the primary sources of dust). However, the erosion factor fields derived from the WRF-Chem database did not represent the actual dust generation potential of the SLV. Thus, erosion factors were parameterized using the WEG and land use for the SLV-Taos Plateau. Built-in erosion factors based on topographic differences were used outside the SLV-Taos Plateau. The model was used to evaluate six scenarios in addition to the baseline (or base case), which represents current, pre-development conditions of the solar energy zones.

Modeled wind patterns generally matched with observations at the three airports in the study area but the model often underestimated the peak winds which are important in wind-blown dust generation. Due to the lower calculated wind speeds, modeled PM_{10} concentrations were lower than the observed values at some locations but nevertheless were reasonably well within the range of observation data, which are not resolved temporally or spatially. Considering that the study area is in complex terrain, a reasonable but rough surrogate for erosion factor is introduced, and limited soil data are used, and there are large uncertainties inherent in dust generation algorithm, the model prediction in this study can be acceptable.

Potential air quality impacts would be highest under Scenario 1 (100% of SEZ vegetative cover removed) and lowest under Scenario 4 (20% of SEZ vegetative cover removed). Under all scenarios and at nearly all towns around the SEZs, PM_{10} concentrations would remain almost the same or increase by a few percent. One exception is that, under Scenario 1, modeled 24-hour PM_{10} concentrations would increase up to 20% (from 81 to 97 $\mu g/m^3$) at the town of Romeo, which is located immediately downwind of the Los Mogotes East SEZ.

In conclusion, potential ambient air quality impacts associated with SEZ development in the SLV are predicted to be relatively small because: (1) De Tilla Gulch SEZ includes only a small area (about 21% of SEZ or 225 acres) with erodible soils (WEG 1 and 2 groups), which have highest dust potential; and (2) Los Mogotes East and Antonito Southeast SEZs have a larger area but with the soils are classified as higher WEG groups (low dust potential). As demonstrated in this study, use of WEG/land use to parameterize erosion factors can be a good surrogate method if no detailed soil data are available or erosion factors are not reasonable. This study does not present precise PM concentrations and their changes among scenarios from the base case (baseline) for various reasons, such as complex terrain, limited soil data, etc. Rather, it presents both general trends and ranges of concentration changes, which can be used by stakeholders to inform their considerations and decisions.

6.3 CONCLUDING REMARKS

This study was designed to answer several questions regarding possible air quality impacts from dust generated during construction and operation of solar facilities in the SLV SEZs. The questions and brief answers based on the modeling and calculations conducted are given below.

- *Will dust levels be increased during the construction and operational phases of solar facilities, and if yes, what will be the area of impact?*

  Dust levels will be increased during both construction and operational phases of solar facilities. PM would be most increased during construction, which would last from about one to five years. During construction, the highest increases in dust levels would be near the SEZ boundaries and at nearby residences.

- *Would wind-blown dust generation be decreased if solar development avoided areas of highly-erodible soils? How would the use of dust suppressants impact the amount of dust generated?*

  Yes, dust generation would be decreased either through avoiding areas of highly-erodible soils or through the use of dust suppressants over portions of the SEZs. The use of these methods to limit dust generation may be included in plans for solar projects within the SEZs.

- *If there are increased dust levels during operations, what would be the cumulative impacts of operations in SEZs?*

  Estimates of cumulative impacts assumed that development of all three SEZs could occur at the same time. The De Tilla Gulch SEZ is located more than 60 mi (96 km) north of the Antonito Southeast and Los Mogotes East SEZs and thus cumulative impacts associated with the De Tilla Gulch SEZ would be minimal. Because the Los Mogotes East and Antonito Southeast SEZs are located closer together, there is some potential for dust-related cumulative impacts. However, the two SEZs are not aligned with the prevailing southwesterly wind direction and thus their impacts are only minimally additive. Nevertheless, for construction impacts, work schedules could be coordinated to ensure that dust impacts in the vicinity of the two SEZs would remain low, even if construction activities were ongoing at the same time at both SEZs. For impacts during operations, modeling for this report showed that during periodic high dust episodes the estimated dust contours around these SEZs would only overlap far away from the SEZs at areas of lower PM concentrations. With appropriate management cumulative adverse air quality impacts are not expected.

- *If there are increased dust levels during construction and operations, would there be associated adverse health impacts for residents of nearby communities? Would arsenic-contaminated dust be a health concern?*

  The modeling in this report indicated that construction of solar facilities could contribute significantly to episodes of high dust levels that could occur several times per year during the construction period at locations near the SEZ boundaries and at some nearby residences. These elevated exposures could contribute to respiratory health effects in exposed people (for example, solar facility workers or residents of the nearby homes). However, during actual construction solar facility operators would be required to maintain dust levels at the site boundaries lower than permit-required levels, through altering construction practices and/or schedules and using dust control measures. For example, these include limiting surface disturbing activities on windy days and installing wind fences to control dust transport upwind of sensitive receptors (residences) and to induce particle deposition before PM arrives at the areas where the model predicted maximum impacts.

The analyses in this report did not indicate that the operation of solar facilities would result in adverse health effects from exposure to wind-blown dust from the developed areas of the SEZs. Additionally, exposure levels for arsenic contained in wind-blown dust were estimated to be lower than levels associated with cancer and non-cancer health effects from arsenic. Future monitoring of dust levels at solar facility boundaries during construction and operations should be employed to verify that dust levels are maintained at levels lower than the health-based guidelines.

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